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LAND-GRANT COLLEGE EDUCATION

1910-1920

PART IV

ENGINEERING AND MECHANIC ARTS

Edited by

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FOREWORD

The subject of this bulletin, or Part IV of the survey of land-grant college education, is Engineering and Mechanic Arts in Land-Grant Colleges.

The other sections, published separately, are as follows:

Part I. History and Educational Objectives of Land-Grant College Education.

Part II. The Liberal Arts and Sciences and Miscellaneous Subjects in Land-Grant Colleges.

Part III. Agricultural Education in Land-Grant Colleges.

Part V. Home Economics in Land-Grant Colleges.

The subject of agricultural engineering has not been included in this section, but is found in the section on Agricultural Education, or Part III.

LAND GRANT COLLEGE EDUCATION 1910-1920

PART IV.—ENGINEERING AND MECHANIC ARTS

Chapter I

SURVEY OF ENGINEERING EDUCATION IN THE LAND-GRANT COLLEGES

By A. A. POTTER

Dean of Engineering and Director of the Engineering Experiment Station, Purdue University.

All educational institutions went through a severe strain during the war, but notwithstanding this fact the smaller institutions of the South and of the West made notable progress during the period from 1910 to 1920 by, advancing their requirements for admission and for graduation, by improving their standards of teaching, by adding to their material equipment, and by greatly increasing their enrollment.

The following figures show the growth of the engineering divisions of 42 of the most prominent land-grant institutions during the years 1910-1920:

1. Enrollment, regular collegiate engineering students at 42 land-grant institutions:

1910-11.....	14,374
1920-21.....	23,686
Increase from 1910 to 1920.....per cent..	65.1
2. Gross enrollment, including regular collegiate, graduate, special, and non-collegiate engineering students:

1910-11.....	15,368
1920-21.....	26,972
Increase from 1910 to 1920.....per cent..	75.5
3. Teachers giving instruction in engineering subjects at 42 land-grant institutions:

1910-11.....	1,131
1920-21.....	1,670
Increase from 1910 to 1920.....per cent..	47.5

These figures show that while the gross enrollment in 42 land-grant institutions has increased from 1910 to 1920 about 75.8 per

cent, the number of teachers giving engineering instruction has increased only about 47.5 per cent. Also, large numbers of engineering teachers left the educational field on account of low salaries, and in many cases their places had to be filled with less capable men. The large number of inexperienced teachers, the increased teaching load, and the fact that the additions to buildings and equipment have not kept pace with the growth of the enrollment have influenced the quality of instruction.

Much progress, however, has been made in engineering education since 1910. One of the most important factors in improving engineering education has been the stimulus to self-analysis on the part of institutions and teachers, which came as the result of the "Study of Engineering Education" by Dr. C. R. Mann, of the Carnegie Foundation for the Advancement of Teaching. This study of engineering education was made at the request of a joint committee on engineering education representing the principal engineering societies. Much credit should also be given to the Society for the Promotion of Engineering Education for bringing about in the engineering schools of the country greater interest in good teaching.

The engineering curricula of 1920 in the land-grant institutions, as compared with those of 1910, show the following important changes:

1. More uniform entrance requirements. Practically all engineering colleges now require 15 entrance units, including 3 units of mathematics and 3 units of English.
2. Greater attention to English. The demand for better training in English is being met by including in engineering curricula, in most cases, two years of required work in English. In some institutions the instruction in English is carried on throughout the entire four years. The attitude of engineering students toward the study of English has also improved.
3. Elimination of the required foreign language. Very few institutions require a foreign language for entrance. Nearly all of the engineering colleges have either eliminated the required foreign language from the curriculum or made it elective. Engineering educators favor greater attention to foreign language study before the student enters the engineering college, but feel that the time devoted in the engineering college to the study of a foreign language may be more profitably spent in broadening the student's training by required or elective courses in English, history, psychology, economics, and similar subjects.
4. More attention is given to economics and business administration. Nearly all institutions require for graduation at least a three-hour basic course in economics. Required or elective courses are

offered to an increasing extent in business administration, including corporate organization and finance, business law, patent law, accounting and cost keeping, banking, and salesmanship.

5. Courses in highway engineering, automotive engineering, heat treatment of steel, radio, and industrial engineering have been added to the curricula of many institutions. The increased attention to highway and automotive engineering instruction and research is most marked.

6. Decrease in specialization. The tendency has been to broaden the training by liberalizing the curriculum, by decreasing specialization, making the first year or even the first two years common to all engineering students, and by giving more attention to the thorough training in the fundamental subjects.

7. Increase in electives. In order to broaden the student's training, several of the larger institutions allow a limited choice of technical and nontechnical electives during the junior and senior years.

8. Congestion in curricula reduced. Some progress has been made in reducing the congestion in engineering curricula. There seems to be a general tendency to keep down the required credit hours per semester below 18.

9. Shop practice instruction changed in character. The amount of required shop practice has been decreased in most institutions, but the character of such instruction has been improved by paying less attention to manual skill and by devoting more time to modern production problems.

10. Greater attention to freshmen. Much attention has been given during the past 10 years to the orientation of freshmen. In most institutions freshmen orientation lectures are offered. In several land-grant institutions the engineering student is introduced during his freshman year to concrete engineering problems. This also gives him an opportunity to come in contact with the best trained and most experienced engineering teachers during the early part of his course.

11. Greater attention to objective tests. The success of the Army intelligence tests has resulted in much interest on the part of engineering educators in objective tests. Nearly all land-grant institutions are rating their students not only on academic performance but also objectively. Several institutions have developed fairly successful personality rating systems. All such rating systems are an aid in discovering the students' talents.

12. Greater interest in advanced training for engineers. A dean of an engineering school, at one of the most prominent land-grant colleges, makes the following statement concerning this subject: "I believe that the time has now arrived when the engineering

schools of the country should seriously consider some real advance in engineering education, such as can be secured only by increasing the length of time provided for the college training of engineers. An increasing number of engineering graduates are pursuing graduate study leading to advanced degrees.

13. Cooperative system extended. The cooperative system formulated by Dean Schneider, of the University of Cincinnati, has been introduced, with slight changes, at the Massachusetts Institute of Technology in connection with the courses in electrical and chemical engineering.

14. Increased facilities for training chemical engineers. The increased demand, on account of the war, for technically trained chemical engineers has resulted in increased facilities for such training in a large number of engineering colleges. At least eight land-grant institutions have added curricula in chemical engineering since 1910.

15. More attention to architecture and architectural engineering. Several land-grant institutions have added curricula in architecture and in architectural engineering.

16. Training of vocational teachers. Several institutions developed courses for the training of teachers for trades and industries to meet the needs of the Smith-Hughes Act. These courses attract very few students.

17. Interest in agricultural engineering. The increased use of mechanical power and of machinery on American farms has resulted in greater attention on the part of land-grant colleges to the engineering problems of the farm. In all land-grant institutions this branch of instruction has been greatly strengthened during the past decade. In several cases courses leading to degrees in agricultural engineering are offered. In most cases such instruction has been under the direction of the agricultural division of the land-grant college. The tendency is now to place such courses of study under the engineering divisions of the institutions.

That engineering education has made marked progress during the past decade is evidenced by the fact that technically trained engineers are not only welcome in industry but are being sought. Men of affairs realize that technically trained engineers are particularly well fitted for positions of responsibility in connection with the solution of problems which are related to the broader questions affecting industry and public life. The technically trained engineer is now an indispensable factor in every important industry and the appreciation of his value to the community is increasing.

Besides training engineers the land-grant institutions have also given greater attention during the past decade to research and extension activities in engineering.

In 1910 only the University of Illinois and the Iowa State College maintained engineering experiment stations supported by State funds. In 1920-21,¹ 19 land-grant institutions were reported as having engineering experiment stations. The staffs of these stations included 53 full-time and over 300 part-time research workers. These experiment stations have available about one-third of a million dollars per year for engineering research and are giving valuable service to the industries of the country.

18. More attention to engineering extension. In 1910 only the University of Wisconsin gave much attention to engineering extension activities. In 1920 more than half of the land-grant institutions were carrying on some form of extension service of benefit to their States. This extension service has been in the form of short courses, technical institutes, correspondence study courses, evening classes in industrial centers, package library service, technical lectures and conferences, visual instruction service, and engineering publications.

The engineering divisions of the land-grant institutions have made marked progress during the past decade by improving their courses of study and teaching methods, by carrying on more research work of value to the Nation, and by bringing the benefits of their teaching and research work to the people and industries of their States.

Chapter II

CIVIL ENGINEERING

By F. E. TURNEAURE

Dean, College of Engineering, University of Wisconsin.

Systematic training for civil engineers was the earliest organized branch of engineering education in this country. The need for this training was emphasized by the development of canal and railroad construction in the early part of the nineteenth century, and the value of school training for men engaged in this work was recognized from the very outset. Prior to the organization of the land-grant colleges systematic courses in civil engineering had been organized in several institutions—notably Rensselaer Polytechnic Institute (1835), Union College (1845), and the University of Michigan (1852). A chair in civil engineering was established, on paper, at the University of Wisconsin in 1850, but for lack of funds no instruc-

¹ Twenty-eight institutions reported engineering experiment stations on January 1, 1925.

tion was offered until five or six years later. These early courses in civil engineering were established as distinct professional courses to prepare young men for the well-recognized work of the civil engineer.

The land-grant act in 1862 gave a great impetus to the growth of engineering schools, as well as to the establishment of instruction in branches more closely related to the manufacturing industries, and many of the most notable schools of engineering were established as a result of that legislation. In many of these early land-grant colleges, the civil engineering course of study was for some time the only course of study in engineering—largely for the reason that instructional material in this branch was already well organized and the avenue of employment well marked. In fact, if one turns back to the catalogues of the better schools of 30 or 40 years ago, a program of studies will be found, four years in length, which does not differ materially from that of to-day. Fundamental studies of applied mechanics, materials of construction, and methods of field investigations underlying the work of the civil engineer were very thoroughly taught at that time and to-day still constitute the backbone of the curriculum for the engineer of construction—the civil engineer.

While the course of study for the civil engineer has not greatly changed in the fundamentals of applied science, there have been notable improvements and modifications, reflecting the advances in scientific knowledge and the changes in the character of employment for which the young engineer is trained. In many respects the developments have been continuous since the organization of the early schools, but to a large degree they are the result of the researches and the industrial growth of the past 10 or 15 years.

From the standpoint of civil engineering instruction, the increased technical information may be considered in two categories: That relating to collateral subjects, and that relating to this particular field. As an illustration of the former may be mentioned the important subject of electrical power transmission. The wide development of hydroelectric power requires the cooperation of the civil and the electrical engineer, and such cooperation is most effective when each has at least a good general understanding of the work of the other. The civil engineer must also have a wider knowledge of the use of various types of machinery with which he has to deal in his construction problems. Such requirements lead to a more extended study of electric, steam, and gas machinery than was formerly the case.

In his own particular field the civil engineer is confronted with a vast amount of valuable material developed in recent years.

Progress in the knowledge of materials of construction is especially noteworthy, and the results of the research of the chemist and metallurgist have a very important bearing upon his designs. He must know about alloy steels for bridges and rails, bitumens for road construction, preservative processes for wood and metals, the durability of cement and clay products, and the properties of sands and gravels significant in their use in concrete. The work of the chemist and bacteriologist in sewage and water purification has modified practice in this field very greatly in the past few years. The development of this information is due, in part, to the research of scientists, and in part to the engineering teacher and investigator, supplemented by study and application of the man in practice. A very great acceleration has been given to work of this kind within the last 10 years by the establishment of engineering experiment stations in land-grant institutions. These have been of great value, not only in their research work, but also in providing better instructional work in these schools. Such investigative work has also brought together in cooperative effort the teacher and the practical engineer, which is well indicated by the vast amount of work accomplished by the various committees of the national engineering societies. On most of these committees will be found, working together, the engineer and the teacher or investigator, and their viewpoints are so similar that it is difficult to recognize by the discussion who is the practical engineer and who the investigator. Such cooperation has been greatly promoted by the land-grant colleges, and several important committees have recently been headed by men from these schools.

Besides such investigations as the foregoing, considerable progress has been made, both theoretical and experimental, in various lines of applied mechanics, particularly in reinforced concrete design, in the study of bridge stresses, stresses in railroad track, the theoretical analyses of flat slabs and plates and other complex structures, secondary stresses in frames, strength of columns, and many problems in hydraulics. All of this work is not only of great assistance to the engineer, but furnishes a basis for better instruction of the student; in fact, the mass of scientific information now available is far greater than can possibly be taught in the four-year course of study, even if organized in the best possible way, and a large part of such information is more scientific and fundamental than most of the technical material which was available 30 or 40 years ago.

In another direction, also, has there been a great development of teaching material with which the engineering school is concerned. This is in the field of economics and sociology—"human engineering," as it is sometimes called. To these branches may be added

such subjects as business law, business administration, and the more ancient studies of ethics, logic, and psychology, to which a new emphasis is being given. Broadly speaking, the work of the modern engineer has come to be more and more the work of management, not merely of the materials and forces of nature, as defined by Tredgold, but management of men, of industries, and even of cities. This development has been particularly rapid in the past decade, and engineering teachers are much concerned with finding the best solution. The problem of the engineering teacher at present is: What subjects should be taught, how should they be taught, and what should be the length of the course so that the best results will be secured in the various lines of activity?

From the standpoint of demand the technical requirements of the civil engineering graduate have also changed very considerably in recent years, and this change is reflected in the curriculum. The great field of railroad engineering, which employed so many civil engineers 20 or 30 years ago, has lost its relative importance. It has been replaced, to a large extent, by requirements in new fields of construction, such as reinforced concrete, and, more recently, by an enormous expansion of highway building. In fact, it is probable that not less than half of the civil engineering graduates throughout a large portion of the country are entering the highway field. While this change has not modified the fundamentals of the course of study, it has changed the emphasis, and substituted, to a large extent, highway options for railway options. In some schools highway engineering is highly developed, including special courses in highway bridges, in chemistry and geology of special materials, and economics of highway transportation. Other special studies include hydroelectric engineering, advanced structural engineering, sanitary engineering, and engineering geology. The development of additional instruction of this kind has led to the arrangement of various optional groups, as many as five or six different options in civil engineering being offered in various institutions.

In spite of these developments the civil engineering course remains substantially a course in static structures, and beginning positions in almost any field of civil engineering are freely open to graduates in any of the special options now offered. Specialization in this respect is looked upon by many as a valuable pedagogical expedient of employing such illustrations in engineering practice as may be of greatest interest to the student, and dividing up large numbers of students into smaller groups, rather than as an attempt to make highly trained specialists in schools. It is still true that a school can not make engineers, and can only prepare young men in an economical and efficient manner eventually to become engineers.

What to do with the studies of a more general character is a more difficult and indeed a more important problem. Studies of this character have become of increasing importance, by reason of the general economic development of the country and the enlargement of the field of employment for the civil engineer. The inclusion of more work of this kind in the course leads, not so much to optional groups, as to a consideration of longer courses of study, since most of these subjects are quite as applicable to one phase of engineering practice as another. In fact, the discussion of engineering education during recent years has centered very largely around the best method of handling this material of a general or cultural nature, which constitutes not to exceed 20 or 25 per cent of the curriculum. One solution of this problem has been to establish special courses in engineering administration in the several lines of engineering practice: Civil, mechanical, electrical, etc. These courses are intended for those preparing themselves for positions involving the business element more largely than the technical. This is one method of avoiding the congestion of studies involved in a more general four-year course or the question of a five-year course.

The broad problem of content of curriculum and length of course is at present undergoing a great deal of discussion, not only on the part of educators, but by engineers and committees of engineering societies. A large amount of cooperative effort is being exerted along this line, and it would seem likely that opinion and practice will begin to crystallize in the near future. The problem has been made difficult, not only by reason of the increase in scientific and technical information, but also and largely because of the greatly enlarged scope of the engineer's activity. The range of this activity now lies between positions in which a high degree of technical skill and ability is required, with little or no business contact, and those in which the technical features are reduced to a minimum, and business and administrative duties constitute 80 or 90 per cent of the activities of the individual. That engineers are sought to occupy positions covering such a wide range of talent is proof of the value of an engineering training, even though such training may be far short of the ideal. However that may be, this fact makes the problem of the engineering college of great importance, and at the same time more difficult than was formerly the case. The importance of this question and many of the difficulties involved have been set forth in many contributions of engineers and teachers in recent years, and particularly in the report of Dr. Charles R. Mann, of the Carnegie Foundation, made in cooperation with committees of engineering societies.

Methods of teaching have received their share of discussion, and many phases of this subject have been freshly considered by reason

of the various special educational activities of the war period. The above-mentioned report of Doctor Mann has also brought about much discussion of this subject. The cooperative system has received much attention, and under favorable conditions has been very successful. It has not been widely adopted, however, as the difficulties involved in most cases are very great. Early introduction of the student to the engineering world has been given a great deal of attention, and in several schools simple technical problems are now given to freshman students. It would appear that such a scheme may be more readily adapted to civil engineers than to students of other courses of study, and this is exemplified in the freshman work in surveying, which has long been a part of the curriculum of many schools. Broad educational problems are receiving a great deal of discussion in the meetings of the Society for the Promotion of Engineering Education and of the engineering division of the Land-Grant College Association. To anyone attending these meetings for a number of years, it is obvious that there has been a very considerable improvement in teaching staff and in material equipment during the past 10 years in practically all of the land-grant colleges, and more particularly in the smaller institutions of the less populous States. Standards have become fairly well equalized, and do not differ greatly in the various institutions in different parts of the country. Salaries of teachers were notably low for a time after the sharp rise in prices during the war, but in most institutions have recently been very considerably increased, so that they are now on a fairly comfortable basis. In some institutions, however, they are still lamentably low, and the best results can not be secured under these conditions.

The future of engineering education is an interesting speculation. While the technical and scientific aspects do not warrant expectation of radical changes, the rapidly increasing complexity of industrial development brings with it a constantly widening demand for men with more or less technical training and at the same time men with breadth of understanding who will interest themselves to a greater extent in the social, economic, and political problems of the country. The extent to which the school is able to contribute toward this requirement will be, to a large degree, the measure of its future success.

Chapter III

MECHANICAL ENGINEERING

By R. A. SEATON

Dean, Division of Engineering, and Director, Engineering Experiment Station, Kansas State Agricultural College

Mechanical engineering education in the United States dates practically from the close of the Civil War. Before this time the Rensselaer Polytechnic Institute and the West Point Military Academy had done valuable pioneer work in engineering education, and a few other schools had made a start in such work, but comparatively little had been accomplished specifically in education for mechanical engineering. Undoubtedly the passage by Congress of the Morrill Act in 1862 did much to promote this as well as other lines of engineering education. Within a few years after the close of the Civil War most of the States had established colleges of "agriculture and the mechanic arts," and in numerous other colleges departments of engineering were established.

The great growth in the manufacturing industries of this country in the last 50 years has greatly stimulated interest in mechanical engineering education and caused it to grow rapidly. In 1870 the total value of the manufactured products in the United States was only about \$4,000,000,000; in 1919 it was \$63,000,000,000. This increase in manufacturing made necessary a greatly increased number of mechanical engineers. Further, while in the earlier development of the manufacturing industries most of the mechanical engineers acquired their training through practical experience, in more recent years a much larger percentage of the total number of engineers have been trained in engineering colleges. In 1870 there were in college only about 1,400 students in all branches of engineering, while in 1910 there were about 6,400 mechanical engineering students alone, and in 1922 about 12,000 mechanical engineering students in the colleges of this country.

From its inception, education for mechanical engineering has been very closely connected with that for the other branches of engineering. The fundamental principles underlying all branches of engineering are the same; the differences are chiefly in the applications of these principles. Naturally, therefore, many of the recent developments in mechanical engineering education have occurred also in the other branches of engineering education, or are paralleled by similar developments. Hence, many of the statements in this

paper would doubtless apply equally well to other branches of engineering education.

Since there had been approximately half a century of growth and development in mechanical engineering education before the beginning of the last decade, the curriculum, the courses, and the methods of instruction had become fairly well standardized. Recent developments have not been sweeping and fundamental in character but have generally been minor, though perhaps important, modifications of established practice at the beginning of the decade. Probably the most important developments have been brought about by developments in mechanical engineering practice, and extensions of the mechanical engineering field.

The constant increase in mechanical engineering knowledge, and in the extent and character of the applications of this knowledge, has made necessary the inclusion of much new material in the curriculum, and the revision of courses to include the new applications, with sometimes a relocation of emphasis on matter already included. The development and general utilization of the internal combustion engine, the steam turbine, and the uniflow steam engine; the great increase in the consumption of mechanical and electrical power; the general adoption of electrical distribution of power; and the development of great central power stations have made it necessary to modify the courses in power engineering and to enlarge their scope. The introduction of improved tool steel and of high-power machine tools, and the demand for greater shop production and for the elimination of waste in industry have called for additional attention to these matters in courses dealing with shop work. The extension of the field of the mechanical engineer to include management and sales work—industrial and commercial engineering—has called for additional attention to economics, business law, factory organization and management, psychology, labor problems, and similar subjects.

Engineering curricula were already overcrowded, and one of the effects of the pressure for the introduction of this new material has been to force the elimination from the curriculum of material not strictly essential. Doubtless this is at least one of the reasons for the recent tendency to eliminate foreign language from among the required subjects. The thesis, which was formerly required of all students, is also being eliminated, doubtless in part, at least, for the same reason. Less time than formerly is being devoted to shop work, drawing, and in some cases the humanities, to help make room for this material.

Dr. C. R. Mann states in his *Study of Engineering Education*:

There is almost unanimous agreement among schools, parents, and practicing engineers that at present the engineering curriculum, whatever its organization, is congested beyond endurance. It is obviously absurd to require from the

student more hours of intense mental labor than would be permitted him by law at the simplest manual labor. Yet on all sides the pressure of topics and subjects that have become important because of the extraordinary growth of science and industry is constantly increasing.

Notwithstanding this crowded condition of the curricula, it is well recognized that an inadequate allowance of time is given to a number of important subjects, and others must be omitted entirely because of lack of time. As a result there is a growing feeling that the engineering curricula should be extended to five or six years, at least for those who are to become leaders in the profession.

At a conference of the deans or other representatives of 14 mid-western engineering schools, held in Chicago in the spring of 1922, the following resolutions were adopted:

The undersigned engineering deans, directors, and representatives, in conference assembled, hereby resolve that—

In order to meet the constantly enlarging responsibilities of the engineering profession, we favor an advance in engineering education at this time that shall provide five years of collegiate training for those engineering students whose aim is to become qualified to take positions among the creative leaders in the profession, and that such advance shall be made in substantial accordance with the following plan:

1. Remodel the present four-year engineering curricula by substituting a substantial proportion of humanistic and fundamental subjects in place of an equivalent amount of advanced technical work. It is desirable that, so far as possible, the curricula in the different branches of engineering shall be sufficiently uniform to permit students to defer their final choice of a specialty at least to the end of the second year.
2. Add a fifth year of advanced work, mostly or wholly technical, and specialized to such an extent as desired.
3. The first four years of work shall lead to a bachelor's degree and the fifth year to an advanced degree in engineering.

It is too early yet to determine what the final outcome of the movement toward a longer curriculum will be, but it is hoped that it will give some relief from the present crowded curriculum, and at the same time permit the inclusion of some work for which time can not be found in four years.

The great increase in the number of engineering students in recent years has made feasible a greater degree of specialization by teachers and by students than formerly. Special courses in industrial history, English, physics, and the like have to a considerable extent replaced the more general courses formerly given to all college students. Similarly, the larger number of mechanical engineering students has made possible the introduction of more options in the senior year, without reducing the number of students in each section to too small a number for economical instruction. Curricula in industrial engineering, heating and ventilating, power engineering, railway mechanical engineering, and the like have also been

introduced in a number of colleges. The larger number of mechanical engineering teachers required for the larger number of students has made possible the specialization of the teachers in those subjects they are best qualified to handle, and has doubtless improved the quality of instruction. The growth of the physical plants and the increased laboratory facilities have also been factors in permitting greater specialization and raising standards of instruction.

The purposes to be accomplished and the methods of instruction used in teaching shop work have never been so fully standardized as have most phases of mechanical engineering education. The Worcester Polytechnic Institute has for many years maintained upon its campus a shop for the manufacture and sale of commercial articles by paid mechanics. Students work in the shop with these mechanics and thus acquire experience similar to that which might be obtained in the usual commercial shop. In recent years much of the students' time in the shop has been devoted to the study of shop organization and management and shop methods, with less emphasis on the acquirement of manual skill than formerly. At the University of Illinois the methods used in shop instruction were reorganized a few years ago. No paid mechanics are employed, but all of the work in the manufacture of a two-cylinder gas engine is done by students. The shop work is handled much like that in a commercial shop, all the different positions in the operation and management being filled by different sections of the classes in rotation. Emphasis is laid upon the organization and management and the shop processes used, rather than upon the acquiring of manual skill. The work is intended to give mechanical engineering training, rather than training for mechanics. A number of other schools in recent years have adopted methods of shop instruction similar to those used at the University of Illinois, and the general tendency seems to be toward the conversion of the college shops into shop laboratories for illustrating modern methods of shop production, and of factory organization and management.

A development which has helped to make possible the large amount of work now done in four years is the production of a large number of excellent textbooks covering most phases of mechanical engineering. There has been unusual activity in this field in the last decade, and many of the standard texts which had long been used have been replaced by others which contain a clearer presentation of fundamental principles, and in which recent developments in the engineering field are discussed. Such books have made it possible to replace a considerable amount of lecture and notebook work by the more efficient home study and recitation method, and have been a great aid to both teacher and student. They have helped also to stand-

ardize the content of courses, and probably to raise the standard of quality of work done.

Among the more important recent developments in education for mechanical engineering, then, are: (1) Greatly increased enrollments, keeping pace with the growth of the manufacturing industries; (2) the revision of curricula and courses to correspond with developments in mechanical engineering practice and extensions of the mechanical engineering field, with more attention to specialized engineering courses and to economic and business problems and less to foreign languages, thesis, shop work, drawing and the humanities; (3) renewed agitation for a five-year curriculum; (4) greater degree of specialization by students and teachers; (5) the introduction of freshman engineering courses; (6) change of emphasis in shop work by acquiring manual skill to study of shop methods, organization, and management; and (7) the production of excellent textbooks covering most phases of mechanical engineering.

While several of these developments are not common to all schools teaching engineering, and some are found only in a few schools, it is believed that they fairly represent the general tendency in mechanical engineering education.

Chapter IV

ELECTRICAL ENGINEERING

W. N. GLADSON

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Electrical engineering education in the United States may be considered to have had its beginning in the Morrill Act of 1862, which provided for more general industrial education than had previously been possible; and emphasized the importance of scientific study. This act laid the foundation of a new type of industrial education to be fostered jointly by the State and the United States Governments. However, electrical engineering instruction as distinct from mechanical engineering did not take place in the United States until about 1885.

Faraday had discovered the principle of electro-magnetic rotation in 1821, and 10 years later the principle of electro-magnetic induction. The fundamental laws underlying the future applied science of electrical engineering were, therefore, known when the Morrill Act provided means for promoting more extended study and research.

Electrical engineering, as a separate department of education, resulted from the development of electricity and magnetism as taught in physics, and at first was often associated with the study of this science. As early as 1870 special courses in physics for electricians were offered. Ten years later, due to improvements in the series and shunt dynamos and their application to arc and incandescent lighting, as well as to small power, there was a call from the industries for men with special knowledge of applied electricity, and a few colleges responded by creating departments or courses of study in electrical engineering.

In 1881 interest in alternating current machines was revived. Long-distance transmission of electric energy was made practicable, and with the introduction of polyphase alternators in 1891 the electric motor became a worthy rival of the steam engine and other forms of prime movers in the field of mechanical power. Electrical industries multiplied rapidly. Large sums of money were invested, and there was an ever increasing call for engineers with electrical training.

The Chicago Exposition in 1893, with its splendid display of electrical machines and appliances, undoubtedly stimulated interest in electrical invention, manufacture, and education. During the period from 1890 to 1900 many educational institutions of higher learning added a department of electrical engineering. In the next decade these departments of learning were enlarged and extended until many colleges had physical equipment and teaching staffs in electrical engineering that compared favorably with the teaching equipment of the older departments of engineering. Professional and graduate courses were introduced, and by 1910 electrical engineering education was firmly established as an integral part of the curricula of more than 100 schools of collegiate grade in the United States, of which more than 40 were land-grant colleges.

The annual enrollment of students in electrical engineering has gradually and consistently increased, except for the years of 1917-18 and 1918-19, which were abnormal years, 1917-18 witnessing a decrease in enrollment, caused by large numbers of students enlisting or being drafted into the Army, while in 1918-19 there was apparently an abnormal growth, due to the Students Army Training Corps. While exact figures are difficult to obtain, information compiled by the Electrical World, the Engineering News-Record, and other current engineering publications indicates the approximate registration of electrical engineering students in institutions of collegiate grade in the United States, as compared with the total registration of students in all engineering courses in these institutions since 1906, to be as follows:

Registration of engineering students

	1905-6	1910-11	1914-15	1919-20
Electrical engineering.....	5,096	6,128	6,637	12,856
Per cent of increase during the period.....	7.5	8.3	93.7	
All engineering students.....	27,722	31,499	32,843	
Per cent of increase during the period.....	10	4.8	1.75	

¹ Estimated.

The increase in enrollment in the latter part of the period from 1915 to 1920 is undoubtedly due to unsettled conditions in the country following the war, when a large number of young men, discharged from the Army, found difficulty in obtaining employment. As business conditions become more stable and manufacturing industries resume a more normal pre-war status, the number of students entering college will likely decrease to such an extent that the attendance curve will show only a normal growth when carried on to include 1925.

As electrical engineering is a branch of mechanical engineering, early curricula were modeled after the parent course. The first two years of the four years' course were usually devoted to chemistry, physics, the languages, mathematics, and primary courses in mechanic arts, such as shop work and drawing. The last two years of the course were given over to more or less technical subjects, largely in the mechanical engineering field, although such subjects as ethics, history of civilization, and business law were found in some early courses. The general tendency in the late eighties and early nineties was toward specialization.

Among practicing engineers the remark was often heard that "an electrical engineer should be nine-tenths mechanical," and this belief was reflected in the courses of study for electrical engineers. Among the first technical electrical engineering subjects which appeared were advanced courses in physics, electricity and magnetism, electrical measurements, and dynamo machinery.

As the field of electrical engineering was developed, there sprang up specialties in such lines as illumination, long distance transmission of power, electric railways, and electric refining of metals, etc., which colleges interpreted to be a call for specialization along such lines in electrical engineering. The result was the crowding out of general information subjects from the last two years of the course and the invasion of the sophomore and freshman years by technical subjects in many college courses.

By 1910 engineering firms and business houses that employed engineering college graduates began to complain that the men they received, although well trained technically, were deficient in general and business education, and about this time the educational pendu-

lum began to swing back toward the side of business and commercial training for engineers. Educational institutions seem to have been feeling their way deliberately in an attempt to develop the best subject-matter for courses of study suited to the needs of their people, and, although frequently discussed, no serious attempt had been made to standardize curricula, thus leaving individual institutions free to develop.

There were at this time in the United States 5,500 central stations, representing an investment of \$1,500,000,000. Of these stations, 154 did a purely transmission business, while 300 operated electric street railways. Some 70,000 families were reached by electric service, the old open arc lamps were rapidly being superseded by metallic electrode flaming arcs or metal filament incandescent lamps, and ornamental street and park lighting was coming into vogue; while in the household electricity was being used for heating, cooking, and small power, as well as for light. Hydroelectric developments had reached a total of 1,900,000 horsepower, and consolidation of small isolated plants was begun.

In the field of telephony and telegraphy wireless telegraphic communication was established between the United States and England. The Berliner telephone patents having expired in 1904, many firms began the manufacture and sale of telephone apparatus, the direct result being the widespread use of the telephone. By 1910 there were 7,000,000 telephones in use in the United States, many of them serving rural communities, and the telephone was accepted by railways for train dispatching.

In 1920 central stations were developing more than 13,000,000 horsepower, of which 6,500,000 horsepower was from hydroelectric stations. There was a total of 49,000,000 horsepower developed by stationary prime movers, and of this 9,500,000 was from water horsepower, which indicates that hydroelectric power is playing an important part as a primary source. A total of 2,500 miles of standard trunk-line railways had been electrified, power being generated chiefly from water. Electric locomotives having a 1-hour rating of 4,000 horsepower have been built, and the electrification of standard steam railways has proven practical.

According to the United States Geological Survey, it is estimated there is yet 60,000,000 horsepower of undeveloped water power in the United States; and, as there is still 25,000,000 horsepower of steam locomotives in use, which require the burning of 150,000,000 tons of coal annually, it seems logical to predict that the future development in this line will result in harnessing this latent water power, tying hydro stations together with high tension transmission lines, and substituting electric locomotives for the old inefficient steam

machines, thus releasing a large part of the present railway coal consumption for other industrial purposes.

In long distance transmissions a potential of 150,000 volts has been reached, and 250,000 is being seriously considered. These voltages make practical much longer lines and reduce the copper investment.

In the field of transmission of intelligence the telephone circuits were improved by the device of phantom lines for multiplex telephony and high frequency carrying currents for extending distances of clear articulation. There were some 13,000,000 telephones in use in the United States. Automatic exchanges were improved, and marked advances were made in perfecting and extending the practical range of the wireless telephone.

The preference of the United States Navy for electrical propulsion was shown by the electrical equipment of the battleships *New Mexico*, *California*, and *Texas*, and new battle cruisers of 180,000 horsepower propelled by electric motors.

The demand for larger and more rapid production just prior to and during the war, together with the Government's restriction on fuel, caused steel mills, chemical industries, and manufacturing shops in general to discard old equipment and install electrical appliances. These changes to electrical equipment taxed the central stations to supply power, and the emergency was met by tying stations together to equalize the load. This demand for electric power seems to continue after peace has come to the country and indicates a still more universal use of electricity for industrial and domestic purposes. More than 5 per cent of the farms in the United States now have electric light and power, according to information published in the last census report.

Engineering education must parallel industrial development. The apprenticeship method of acquiring engineering knowledge is obsolete. The college course of study offers a shorter and surer road to a knowledge of the fundamental principles on which the profession is based.

Electrical engineering is constantly extending and acquiring more dignity and responsibility. It offers inducements to men of the highest intellectual attainments. In the industrial field there is not an important division in which electrical equipment is not an important factor. Transmitted electricity is more economical and more easily directed and controlled than any other source of power known to-day. The vast accomplishment of this great applied science in the past 50 years is unprecedented, and each new application uncovers more territory, until the field for future development is almost limitless. The phenomenal developments in electrical engineering in the past decade have been reflected in the

colleges by a correspondingly increased enrollment. In 1910 there was about \$1,500,000,000 invested in electrical industries and there were 6,000 students enrolled in electrical engineering courses. By 1920 the investment had grown to \$15,000,000,000 and the enrollment to 12,856 students. From the best available data on the subject, it appears that approximately 30 per cent of the freshmen engineering students graduate and that 20 per cent of these graduates do not follow the profession; therefore we are now sending into the electrical industries, which employ 1,500,000 people, approximately 3,000 graduate electrical engineers annually. The above-mentioned developments in electrical engineering from 1910 to 1920 have had a marked effect on the enrollment of students and on the curricula in electrical engineering.

During the period from 1910 to 1920 college courses of study including electrical engineering underwent many changes, in general for their betterment. As late as 1910 most of the State universities admitted students who had not completed four years of high-school work and many of them maintained preparatory schools or departments. In 1920 nearly all required 15 units of high-school work for college entrance, a unit being defined as one-fourth of a high-school year. Experimental work was being done along the line of psychological tests, with the object of directing into engineering courses only those high-school graduates who possessed the quality of mind essential to the mastery of engineering problems, as well as of weeding out from the lower classes all those not likely to succeed as engineers. Should such psychological tests prove a reliable guide in selecting young men for engineering courses of study, it will undoubtedly increase the percentage of engineering students who successfully complete their college course and should give to the industry better qualified embryo engineers.

Electrical engineering curricula in the past decade have been enlarged by adding new specialties in an attempt to keep pace with the growing applications of the science, yet the length of time allotted to the course of study remains four years in the great majority of colleges. These students have for some time been called upon to carry a much heavier load than is required of students in arts and science colleges, and it has become a grave question whether the average student is getting a satisfactory grounding in fundamental principles. However, electrical engineering has had the benefit in recent years of educational studies, such as were initiated by the Society for the Promotion of Engineering Education.

Since the war there is a demand for engineers with broader training in business and commercial subjects, and engineering colleges are responding by adding such courses as general economics, business law, contracts and specifications, business management, accounting,

salesmanship, business psychology, labor and employment, transportation, etc. In other words, the present-day tendency of electrical engineering education is toward a broader and more general course at the expense of technical subject matter, and unless an extension of time beyond four years can be effected, colleges will soon be turning out graduates with a general education but very little actual engineering knowledge. Institutions are anxious to meet these new demands for the courses mentioned above, but on the whole they are not convinced that the time given to the basic mathematical, scientific, and engineering subjects should be materially lessened.

Chapter V

CHEMICAL ENGINEERING

By W. K. LEWIS

Professor of Chemical Engineering, Massachusetts Institute of Technology

In the industrial growth of a new country, chemical industries other than metallurgical are the last to develop, because the existence of these industries is possible only where a strong transportation system is available to supply raw materials and distribute products, where mechanical industries can be relied upon for equipment, and where electrical developments exist to furnish and distribute power and the like. In consequence, the rapid expansion of chemical industry in this country did not begin until the eighties. Prior to that there was no demand for men with chemical engineering training, but when the demand developed it was met primarily by the initiative of land-grant institutions. Thus, the Massachusetts Institute of Technology established a course in chemical engineering in 1898, the University of Illinois in 1895, the University of Michigan in 1898, Ohio State University in 1902, and the University of Wisconsin in 1905. Available data indicate that prior to the last date only one institution outside the land-grant group established such a course.

Since those early days the concept of the chemical engineer has radically changed. Thus, in the announcement of the first course offered in this country it was stated that "the chemical engineer is not primarily a chemist, but a mechanical engineer." His function was the construction of chemical plants and equipment but did not include the development and operation of chemical processes. In all cases the courses offered were undigested mixtures of chemical and engineering subjects, the relative proportions varying with the judgment of those responsible for individual curricula. In no case did the instruction include the subject of chemical engineering as

such, except in name. Thus, one school described the subject of chemical engineering, instruction in which was given during the third and fourth years of the course, as consisting of "surveying, machine design, elementary steam engineering, electrical measurements, direct-current machinery, and building construction." During the past 10 years the outstanding development in chemical engineering education has been the elimination of this chaos and the crystallization of definite concepts as to the fundamentals needed in preparation for the work of the profession.

The first important forward step in the reorganization of the subject matter of the curriculum was taken in 1907, upon the initiative of Prof. W. H. Walker, at the Massachusetts Institute of Technology. Walker realized that the chemical engineer must be primarily a chemist, though thoroughly trained in the fundamentals of engineering. Furthermore, he recognized the necessity of restricting undergraduate instruction to a grounding in principles, with elimination of specialization. The general distribution of instructional emphasis adopted by him is becoming more and more widely accepted as sound.

The next important development was the establishment, in 1910, by Prof. M. C. Whitaker, of the course of study in chemical engineering at Columbia University. Professor Whitaker deserves especial credit for the development of instruction in the subject of chemical engineering itself as a separate entity. He emphasized the universality of its underlying principles and utilized and developed laboratory instruction for the purpose of teaching those principles, rather than for instruction in the details of a specific industry. In terms of a phrase coined at a later date, he recognized that the field of chemical engineering covers a limited number of basic unit operations, and that instruction should develop mastery of these operations rather than the details of various chemical industries.

Professor Whitaker further recognized that the breadth of the profession, requiring, as it does, a thorough foundation in both chemistry and engineering, makes it impossible to provide in undergraduate courses adequate training for professional leadership. In 1915 the course of study at Columbia was made exclusively postgraduate; and while none of the land-grant colleges have followed this precedent, because of the undesirability of excluding from the profession men unable to spend so many years in university training, most of them are emphasizing postgraduate work. The demands of the industries for men trained in these postgraduate courses are yielding unusually conclusive evidence of their value.

A contribution of especial importance is the work of the committee on chemical engineering education of the American Institute of Chemical Engineers, under the chairmanship of the past president

of that organization, Dr. A. D. Little. This committee made a survey intended to include all professional courses in chemical engineering given in the country. The committee report is an admirable analysis of the character of the courses at present offered. The most valuable result of the work of the committee was the general agreement it was able to secure between the educators who train our students and the leaders in chemical industry who employ them as to the fundamentals which should be included in undergraduate instruction, namely, that "any course in chemical engineering should provide, as the background for specific instruction in chemical engineering as such, strong courses in chemistry, physics, mathematics, and mechanical engineering." This report should result in greater uniformity in curricula and marked improvement in instructional method through the focusing of attention upon essential points without danger of loss of initiative on the part of the individual institutions.

In no other branch of engineering is research of more importance, and the land-grant colleges have maintained the leadership in training men for research work in chemical industries. During the past decade it has become clearly recognized that work of this sort can be more advantageously prosecuted through cooperation with the industries themselves. While one such cooperative method in the training of men has functioned successfully since 1907, there is as yet no general agreement as to the best methods of organization. Cooperation of this sort has been initiated in the institutions in Massachusetts, Illinois, Michigan, and Wisconsin, and from the results of these various efforts agreement as to the best general method of operation should be reached during the coming decade.

In 1900 Dean Schneider organized at the University of Cincinnati his cooperative scheme of engineering instruction by which the student spends part of his time in industrial plants, thereby securing a practical experience of great professional value. This particular scheme has not been widely adopted by land-grant institutions, but the proposal of Doctor Little, in which the student goes out, not as an undergraduate, but only upon completion of four years of theoretical training to enable him to appreciate the technical significance of the experience, not as an employee, but as a student whose activities are directed wholly from the educational point of view, and not as a workman, but as a young engineer securing technical experience under the direction and guidance of members of the university faculty, has been adopted at the Massachusetts Institute of Technology and offers great promise of success, not only in chemical engineering, but in other engineering fields as well.

There are in engineering education two schools of thinkers—those who believe that the sciences should be taught as abstract entities

unrelated to practical things, and those who would teach them by means of their applications only. According to the first school, the best possible mechanical or electrical engineer, for example, is a well-trained physicist; according to the second, such a man is unfit to practice the profession. It must be admitted that the first method of instruction has not been successful in developing the large number of engineers which modern industry demands. In turn, one must also confess that the second method of instruction has been reasonably successful in the more highly standardized branches of engineering. Chemical engineering, however, is by no means standardized, but offers unusual diversity of character in a single field. To meet the exacting requirements of this broad demand upon the profession, our institutions are developing a new standard of engineering education, consisting of a saner balance between theory and practice. Thorough grounding in the fundamental sciences affords the best development of the scientific imagination and of versatility in the attack of industrial problems. However, it will be admitted that during the last century and a half of industrial growth, broad, general methods of attack in the application of scientific principles to the solution of the problems of industry have been developed and tested. The young engineer who goes out unacquainted with these general methods of attack is obviously handicapped in his professional work. The last decade has seen the introduction, in the field of chemical engineering, of a sounder balance between the emphasis to be laid upon fundamental science and upon general methods of solution of industrial problems. The next decade should witness a consequent reaction upon instruction in other branches of engineering which will result in improvement in the whole field of engineering education.

Chapter VI

Mining Engineering¹

By G. M. BUTLER

Dean, College of Mines and Engineering, Director, Arizona Bureau of Mines, University of Arizona

Three noteworthy things have exerted a more or less pronounced influence upon mining engineering education since 1910, namely, (1) the World War, (2) the Mann report, and (3) the conference on

¹ The percentages given and most of the facts and opinions herewith expressed were obtained by means of a questionnaire sent to the more prominent mining engineering educators of the country. Thirty-four replies were received, and it is believed that the data thus obtained are sufficiently numerous and reliable to make it possible to generalize with confidence.

commercial training for engineers, fostered by the United States Bureau of Education, which was held in Washington in June, 1919.

All engineering courses have, of course, been affected by the three things just mentioned, but mining engineering curricula are in general so crowded and inflexible that they are particularly difficult to modify, and the fact that they *have* been changed is proof of the compelling force of the factors mentioned. It is but fair to admit, however, that some significant modifications can not be attributed to these three causes, but are, instead, to be regarded as natural developments arising from the sincere desire of educators to improve courses and to meet better the needs of the mineral industries.

The three outstanding things that have affected engineering education will be considered briefly in the order mentioned:

The war first threatened to leave the mining schools without students and minus many of their most capable teachers; then it brought about a hectic few months during which cherished traditions were thrown in the scrap heap and methods intended solely to meet the needs of a great Nation at war were substituted therefor.

With the very welcome, but unexpectedly early, cessation of hostilities many educators returned with relief and thanksgiving to long-established customs, but found it impossible entirely to escape serious consideration of the educational problems arising from the conflict. Engineering was never so well advertised, its value and fundamental importance to human happiness were never so strongly demonstrated, its possibilities and opportunities were never so plainly shown as by the "Engineers' war," and thousands of young men who otherwise might never have thought of studying engineering resolved to equip themselves for the practice of that profession. Their ranks were swelled through the rehabilitation work of the Government, and many engineering colleges found it extremely difficult to care adequately for their suddenly augmented classes.

The relatively low prices at which metals were quoted, and the resulting slump in the mineral industries tended to decrease the number who might otherwise have chosen to study mining engineering; nevertheless nearly all the better mining colleges reported increases in registration which were in some instances so great as to tax severely the resources of such schools. Then, too, for several years the students were affected by a strange restlessness, an apparent inability to concentrate upon serious study, and an intolerance of discipline and long-established modes of doing things that proved decidedly perplexing and trying. Fortunately these conditions, the natural consequences of a catastrophe that threatened to obliterate our civilization, no longer prevail, but they form an ineradicable feature of the decade.

Numerically, the direct effect of the war is shown by the fact that the total registration in mining in 1915 was approximately 55 per cent of what it was in 1910. However, the total enrollment in 1922 was about 105 per cent greater than in 1915, and 15 per cent greater than in 1910. From the standpoint of enrollment, then, the mining schools barely held their own during the decade following 1910, although the curve was ascending very rapidly in 1920.

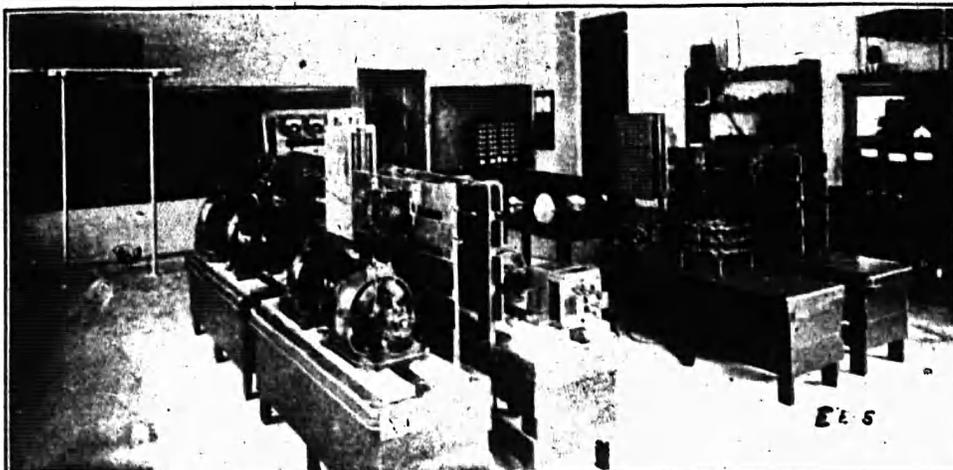
Although the average increase from 1910 to 1922 was only 15 per cent, several institutions experienced much higher increases, in some instances amounting to 100 per cent or more. Of course, these schools were the ones that found the period following the war a rather severe strain upon their resources. To counterbalance the growth of such institutions and keep the average increase only 15 per cent, it is found that 30 per cent of the mining schools actually had smaller registrations in 1922 than in 1910, and that 10 per cent actually had fewer students in 1922 than in 1915.

The second of the notable features of the decade, Doctor Mann's report, is filled with extremely interesting data and suggestions which deserve and have generally received the careful consideration of engineering educators.

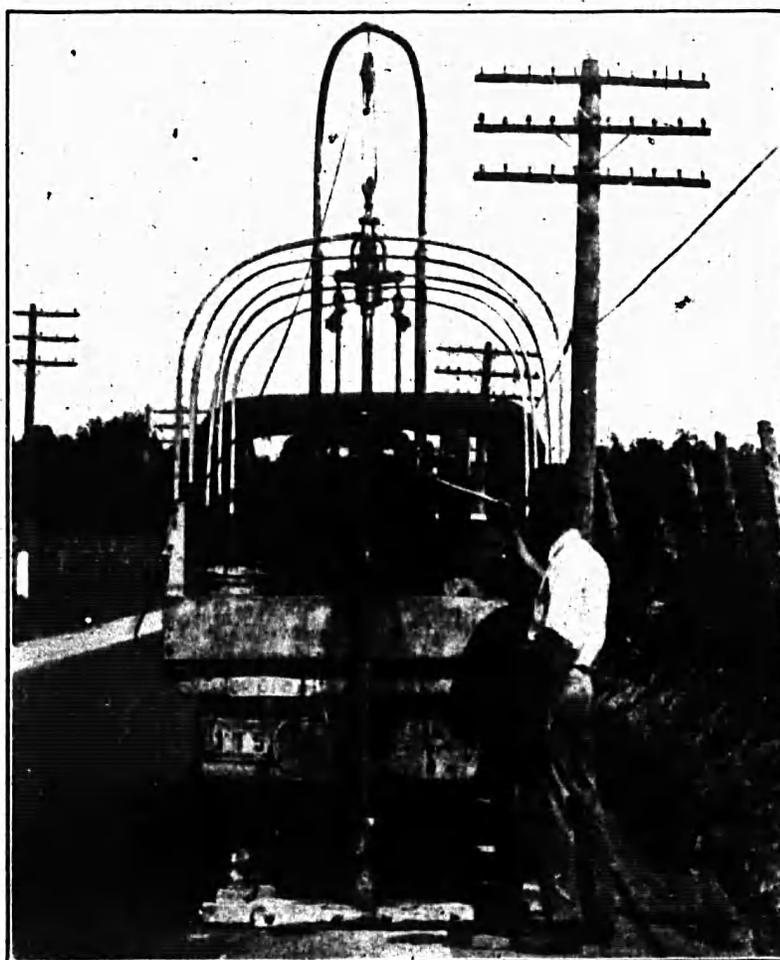
Doctor Mann urged, among other things, however, that (a) curricula should be constructed in such a way that the number of required credit hours per week should be less than 18—preferably 16; (b) that the number of simultaneous courses carried should not be more than four or five at the outside; (c) that all engineering curricula should be identical through (by inference) at least two years; (d) that "practical" courses should be introduced as early as the freshman year and a determined effort made more closely to link theory and practice; and (e) that "considerable attention should be paid to humanistic studies like English, economics, sociology, and history," and that the study of English be planned so as to develop skill in expression, appreciation of literature, and a philosophy of values and cost; such a course to cover "several years."

Mining engineering educators have generally found themselves unable to harmonize all or even most of these suggestions, with the necessarily varied and extremely comprehensive four-year course that they feel obligated to offer. Indeed, it is doubtful if Doctor Mann would have made such recommendations if he had studied especially the problems of the mining schools and had attempted to formulate solutions therefor. Some of his ideas have been or are being adopted, however; and his report has certainly awakened mining engineering educators to the desirability of modifying curricula, courses, and practices to meet present-day conditions.

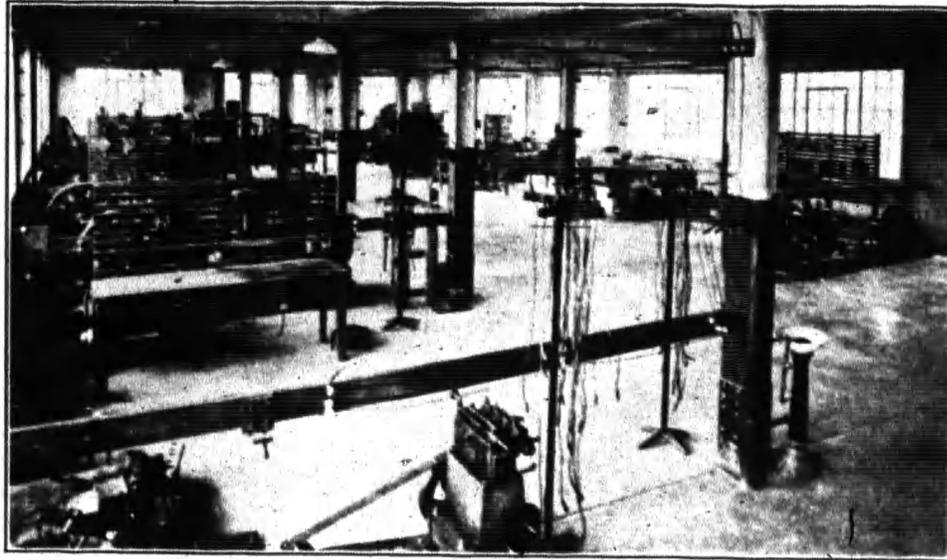
The third especially noteworthy agency mentioned, the conference on commercial training for engineers, had a profound effect upon



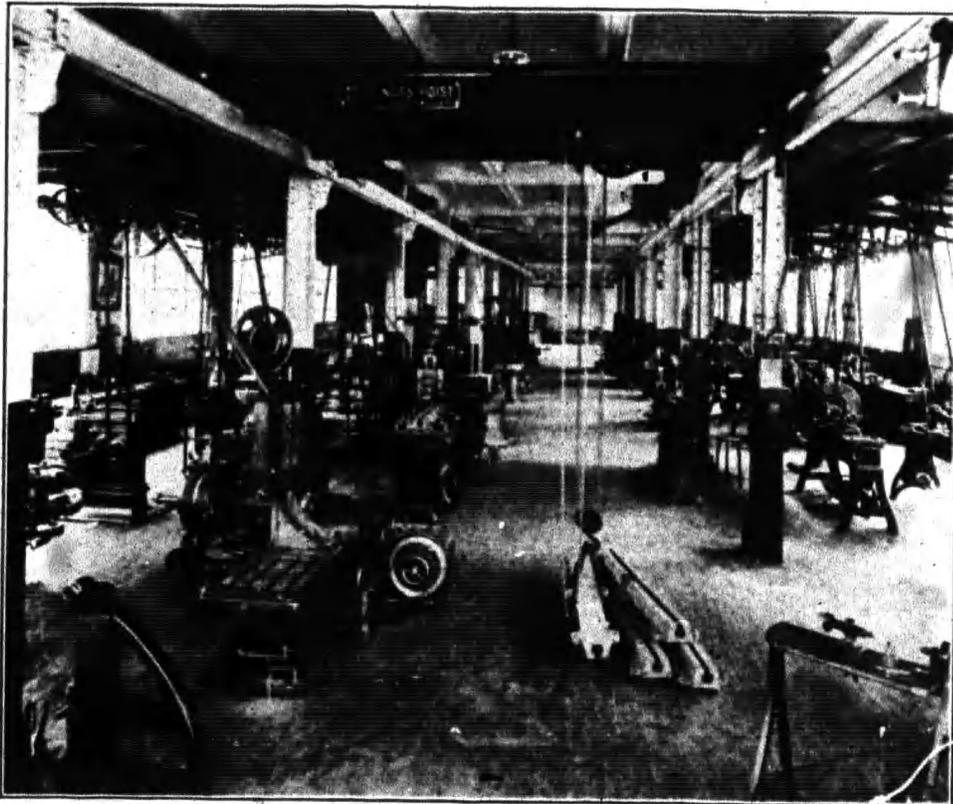
A. IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS
Electrical engineering laboratory



B. UNIVERSITY OF MARYLAND, COLLEGE OF ENGINEERING
Core drill outfit

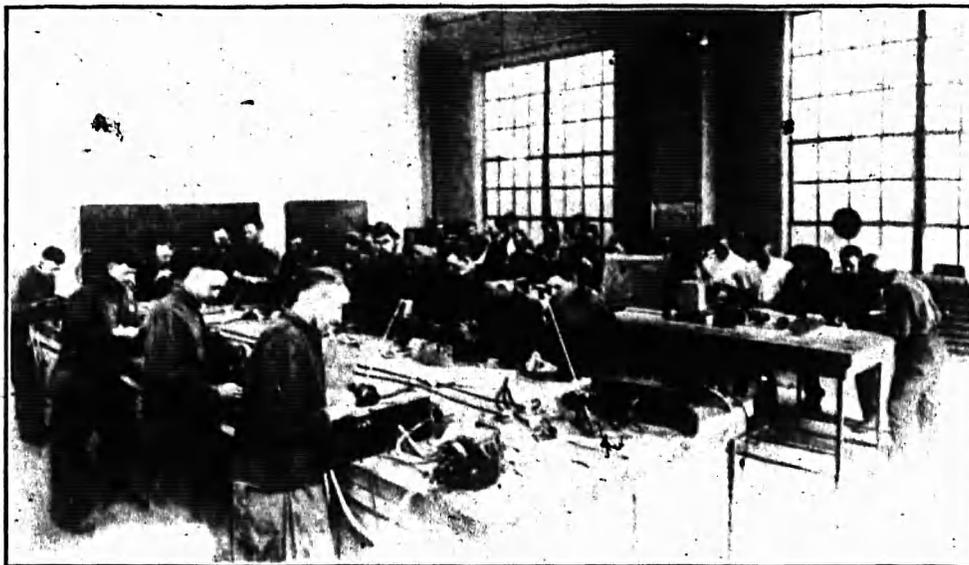


A. ELECTRICAL LABORATORY



B. MACHINE SHOP

CORNELL UNIVERSITY, COLLEGE OF ENGINEERING



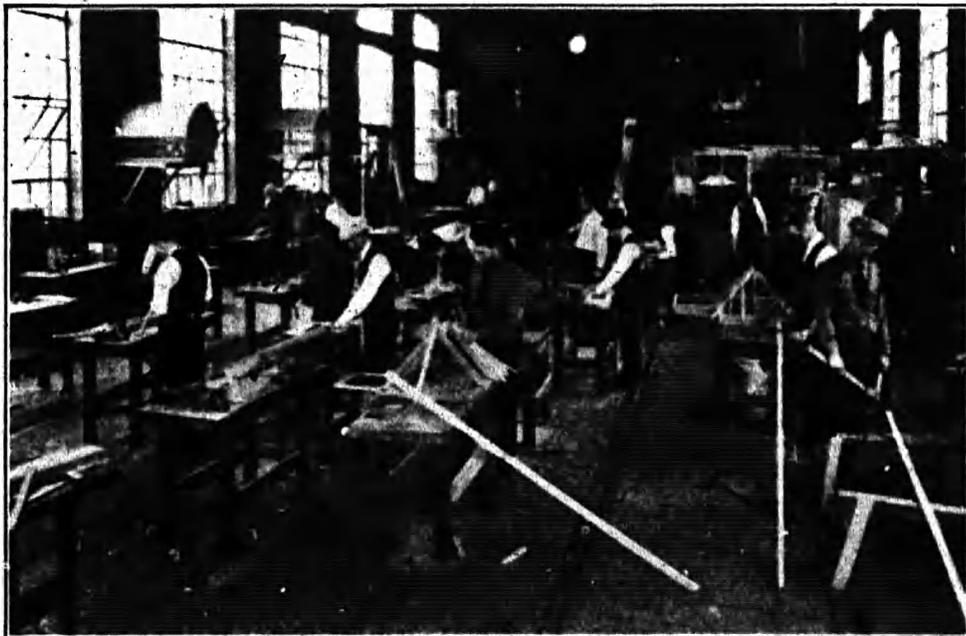
A. CLASS IN IGNITION AND LIGHTING.



B. GAS TRACTOR WORK
MICHIGAN AGRICULTURAL COLLEGE, DIVISION OF ENGINEERING



A. CLASS IN WOODWORKING



B. TRADES AND INDUSTRIES WORKSHOP

IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS

engineering curricula. At least one-third of the mining courses were thereafter modified by the addition of a greater or lesser amount of required work in economics, accounting, business administration, etc.; and another large proportion of such curricula were so changed as to admit of the election of work in such subjects. Probably never has so sweeping a change been made in so brief a time. It is true that comparatively few schools offering four-year courses in mining require the full minimum of 12 hours of commercial subjects recommended by the committee that collaborated with the Commissioner of Education in calling and planning for the conference, but deficiencies are doubtless attributable to the terribly crowded conditions of mining curricula. It is really surprising that so much has been done along this line without lengthening courses, at least in most instances; and it would make an interesting study to ascertain whether so-called "fundamentals" or "specialized subjects" were curtailed in order to introduce the new material.

That more mining curricula were not modified by the introduction of required commercial work is doubtless partially due to the facts that some of them already demanded some study along this line, and several faculties doubtless tried sincerely, but unsuccessfully, to introduce such courses. It is true, however, that a few mining educators are still unconvinced that the change is necessary or even desirable. They argue that it is not the province of an engineering school to graduate executives from a four-year course—that training for such positions should be left to a fifth or sixth year and made optional to men especially qualified by ability and inclination to pursue it. They take comfort from the knowledge that practically all the great mining executives of the present day had no formal training in such subjects while in college, and express the belief that men qualified to serve as administrators will train themselves for the work after graduation. Time alone will show whether they are right or wrong, but it is certainly a fact that practically all engineering courses have had more economics incorporated into them since the Washington conference, even though formal courses in commercial subjects may not be required. While some institutions have been only slightly influenced by the Washington conference, a number of leading mining schools have swung far to the other extreme and now offer commercial options or distinct curricula leading to degrees in administration engineering; they frankly admit that it is their hope to train administrators rather than technicians. This admission is characteristic of schools that have courses extending over more than four years.

Besides the general introduction of commercial subjects, outstanding curriculum changes made since 1910 include the addition of

more required English and a continuation of the drift away from foreign language work. Since 1910 more English has been required in about 25 per cent of the mining curricula, and 10 per cent of the schools offering such courses have dropped foreign languages as a required study. So far as is known, no such school has added foreign languages to its requirements during this period.

A number of new subjects first attracted attention or were greatly developed during the decade following 1910. A list of such subjects would include the microscopic study of opaque minerals, metallography, ceramics, oil flotation, electro-metallurgy, the application of electricity to mining, the standardization of mining methods and equipment, and petroleum geology. Several of these topics have been incorporated as required work into most mining courses and the remainder are offered as electives. In a number of instances petroleum geology has been elevated to the dignity of an optional course that leads to a specific degree. This action has been taken in response to a demand that arose as a result of the oil boom of a few years ago. It is, however, undoubtedly true that so much attention was in this way attracted to geology that it has become difficult to find satisfactory employment for the over-supply of "geologists" now graduating.

An extremely interesting and important feature of the decade was the lengthening by at least two schools of the course of study considered necessary for the theoretical training of a mining engineer. These schools seek to place mining engineering education on the same plane as that required for the practice of law or medicine, by requiring three or four years of general college work, followed by three or two years of professional study. It is noteworthy that in the two institutions that have adopted this plan the enrollment is now less than 25 per cent of what it was in 1910 when four-year courses were offered. In fact, the actual enrollment in these schools is so small that a decidedly specialized engineering course which demands the use of expensive equipment and the employment of well-paid instructors can only be given at a very high cost per student. Possibly, however, the research work done or directed by the faculties of these schools is a sufficient justification for the continuation of their present plan of operation.

Even more significant than the actual lengthening of the curricula in two institutions is the opinion expressed by 25 per cent of the deans or professors of mining engineering in other schools that the prevailing four-year course should be extended over one or two additional years. Several other executives are far from satisfied that four years are long enough. In several instances the tendency to lengthen the period of preparation is shown by definite catalogue recommendations that graduates of the four-year course in mining

engineering should continue their study for one or two additional years. Of course such lengthened courses lead to advanced degrees.

Since a material decrease in the enrollment must inevitably follow lengthening of curricula as long as there exist good schools granting a mining degree after a four-year course, it is unlikely that many such courses will be lengthened in the near future, although several mining colleges seem about ready to take that step. That the majority of such institutions will cling to the four-year course for some time to come is indicated, however, by the fact that 40 per cent of the men in charge of mining engineering courses believe that the work now offered is satisfactorily meeting the needs of the mineral industries, and 15 per cent more are fairly well satisfied with present conditions.

It has frequently been suggested that too many young men are being encouraged to study mining engineering, and that the mineral industries can not properly absorb the product of the many mining schools. In this connection it is interesting to note that 30 per cent of the mining educators (most of them are situated in the West) believe that the number of students studying mining engineering should be increased, while 15 per cent (practically all of them are located in the far East) think that it should be diminished. The remainder believe that it is about right now, should be increased "when normal conditions again prevail," or express the opinions that "there is lots of room for the broadly trained mining engineer—perhaps in other industries," "the quantity should be a secondary consideration," "the students should be more carefully selected," etc.

Many mining schools have made material improvements in plant and equipment since 1910. In fact 60 per cent of the institutions offering mining courses report that advances of this kind have been made, and it is evident that the average student of mining engineering is now working under much better conditions than formerly prevailed. Even more gratifying is the expressed belief that 60 per cent of the mining courses are adequately supported and equipped, or approximately so.

Investigation shows that there is still much diversity in the degrees conferred on completion of a four-year mining course, but about 30 per cent of such courses lead to the title of bachelor of science in mining engineering, and 15 per cent more terminate in degrees that are only slightly different, such as bachelor of science in mining, bachelor of science in mining and metallurgy, etc. Twenty-five per cent of the mining courses lead to the degree of bachelor of science without modifying the phrase, while only 15 per cent of the mining schools give the degree of engineer of mines on the completion of a four-year course. At least three institutions that conferred the degree of engineer of mines, after a four-year

course in 1910, now give the bachelor's degree, and at least one school does not confer the degree of bachelor of science in mining engineering until the completion of a five-year course. The general and growing practice is, then, to grant some form of bachelor's degree after four years, and to consider the degree of engineer of mines a professional title to be earned only after the completion of one or more years of graduate work.

One of the most gratifying developments of the decade is the increased attention that is being given to research work. Eighty-five per cent of the mining educators report material improvement in this particular and the remainder have always emphasized research as much as possible. To some extent this change may be attributed to the United States Bureau of Mines experiment stations or field offices established in about a dozen institutions since 1910, but the real explanation is doubtless found in the fact that engineering educators now have a different conception of their task from that formerly held. At first, trade or industrial school ideals prevailed to a greater or lesser extent even in institutions that claimed collegiate status, and engineering graduates rarely expected or secured a standing better than that of high-grade artisans. With the transition of engineering from a vocation to a profession it has been generally recognized that engineers are obligated to render service by contributing to human knowledge in accordance with professional standards, and good engineering schools are now definitely committed to extensive research programs, with a consequent revivification of the technical courses and material benefit to the industries concerned.

The fact that the mineral industries are benefiting from research carried on in mining schools is only one indication of the tendency shown for such industries and schools to draw together and to cooperate more closely than in the past. This movement toward cooperation has taken various forms, such as the establishment of research scholarships or fellowships by several great corporations, the formation of experiment stations or bureaus mainly designed to solve technical problems encountered by the industries, and the perfection of arrangements that give mining students an opportunity to gain a variety of practical experiences during vacation periods. So far has this movement gone that the students of one mining school who choose to do so may work two shifts each week, Friday and Saturday nights, in productive mines.

From what has been said, it must be evident that mining engineering education in the United States made material advances in the last decade, and the conditions under which it is now carried on may be regarded as generally good. The willingness of the educa-

tors to modify their curricula to meet changing conditions and recognized needs has been demonstrated, and the fact that many of them still differ as regards questions of considerable importance may be accepted as an indication of further improvements yet to come. Opposed to this satisfying outlook, however, there are a number of disquieting facts which may be briefly summarized as follows:

1. Forty per cent. of the mining schools are inadequately supported and equipped, and several of them are badly overcrowded. In many instances the best quality of instruction can not be offered on prevailing salary schedules, and good teachers who may be developed are soon lost.

2. Fifty per cent of the institutions offering mining courses have each less than 75 students enrolled in mining, and 25 per cent have each less than 50 mining students. With the exception of the few institutions in which work in mining engineering is now conducted on a strictly professional basis and some relatively young schools that can look forward to early and notable increases in registration, it is hardly conceivable that the smaller mining colleges can afford to provide the equipment and instruction that a highly diversified technical course demands. Where such facilities are offered, the cost per student must usually be exorbitant, and it would seem to be wise for the administrators of these institutions to investigate the desirability of discontinuing the work in mining and devoting the money now spent there on work for which there is greater demand. At least two institutions offering mining courses of study in 1910, have abolished them, and it is to be hoped that others will follow their example. The figures quoted would seem to substantiate the statement made by a considerable number of mining educators that, while there may not be too many mining students, there are certainly too many mining schools; and it is certainly true that a young man who desires to study mining engineering should in justice to himself study carefully the equipment available and the advantages offered by several institutions before enrolling in a mining course.

Chapter VII

ARCHITECTURE AND ARCHITECTURAL ENGINEERING

By L. H. PROVINE

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Among the courses of study suggested by those in charge of the organization of the early land-grant colleges, several proposed "polytechnic departments," which included architecture and the fine

arts. However, instruction in these fields was not introduced at first. To those colleges which did incorporate such courses of study in the first organization, great credit is due. Several departments of architecture are now 50 years old, and each has contributed its share to the betterment of the community, the State, and the Government.

Many difficulties were encountered in the introduction of the earlier courses in architecture. There were no courses in this country to pattern after; there were but few textbooks in English; the libraries, so important for a course in architecture, were not in existence; and teachers were scarce. The pioneers in architectural education had to begin at the bottom and feel their way along.

Practically all of the early courses of study in architecture were organized on the premise that the architect was a builder. The curricula, therefore, included shop work and a certain amount of instruction now known as "manual training." In order to provide textbooks for class use in these newly formed courses, those in charge had to translate foreign books on the history of architecture, design, and construction. These translations were written on transparent paper, and blueprint copies were furnished to the classes.

The beginnings of the architectural libraries were also discouraging. Those in charge of the earlier courses realized from the start the importance of architectural libraries. Funds for these new land-grant colleges were small; imported books were expensive, so that the library additions were few in number each year.

Although at the time there were architects in the country who had studied abroad and who might have qualified as teachers, those responsible for the beginning of architectural education in the country were generally young men who, after spending the daylight hours at their trade, spent those in the stillness of the night in preparation for the work which, unknown to them at the time, they were presently to assume. As the departments increased in enrollment, assistance in teaching was usually obtained by employing upper classmen to teach the elementary work.

The development of the curriculum is an interesting story. With nothing in this country which would serve as a guide, the educators studied the courses in foreign countries in an effort to adapt them to the conditions in this country. Starting with manual training and mechanical drawing as the major work in architecture, these courses answered temporarily the needs of the time, but as the duties of the architect changed and the building of a structure gradually developed into a separate business, the curricula in architecture gradually changed. The manual training work was replaced by drawing, the aesthetic phases were given greater emphasis and in time became the major part of the course of study. The study of

the orders first introduced consisted of abstract exercises in the memorizing of the profiles, dimensions, and characteristics, accompanied by mechanical reproduction on paper. Later this was changed, the drawing of the orders becoming exercises in original architectural design.

From the beginning, the list of prescribed courses included not only the technical studies but cultural studies, and while few schools believed that the entire time of the curriculum should be spent on architectural subjects, the older schools felt that this was inadvisable; therefore, from the beginning cultural studies have made up a large part of some curricula.

With increased library facilities, lantern slides, and photographs, the older methods were replaced by better methods. Instead of copying mechanically architectural plates, more freedom developed in the presentation of the student work; emphasis was placed upon developing the creative ability, thus encouraging the imagination. From time to time the influence of the foreign educational methods has been felt more or less in the schools in this country; this is due largely to those instructors who have been trained under foreign influence.

ARCHITECTURAL ENGINEERING

The early conception of the term architect was that of a master builder. The great painters were not only artists but architects and builders. This idea prevailed, as previously stated, in the organization of the early schools of architecture in this country. With the introduction of steel for structural members, and a few years later the use of reinforced concrete and the complicated mechanical installations in certain types of buildings, the duties and responsibilities of the architect were increased. It, therefore, became apparent to certain educators that a division of the course in architecture was fast becoming a necessity to meet the changed conditions. In 1891, Prof. N. Clifford Ricker established at the University of Illinois the first course of study in architectural engineering. A few years later a similar course was introduced at the Massachusetts Institute of Technology, and gradually other institutions have added such courses. While many of the courses in architectural engineering follow clearly the curriculum in architecture, diverging only at points, Illinois and Massachusetts Institute of Technology offer a four years' course in architectural engineering which is separate and distinct from the course in architecture. The students in architectural engineering are given a thorough grounding in the science of building, to which is added work which will give them an appreciation for the aesthetic. The schools of architecture believe that

an architect must not only be a designer, but he must have a grounding in the fundamentals of construction; the architectural engineer must have a knowledge of the building science, with an appreciation for the artistic.

One of the greatest factors in recent years in strengthening the architectural education in this country was the organization of the Association of Collegiate Schools of Architecture in 1912. In the early seventies there were but two or three schools of architecture in the country. As time passed other schools were organized until there are now more than 40 schools giving instruction in architecture. Prior to 1912 there was no attempt on the part of the schools to standardize or conform to a uniform practice in curricula. As a result one school was giving one curriculum, another something different. This situation resulted in much confusion among students desiring to enter a department of architecture. It was quite serious for the student who wished to transfer from one institution to another; and educators, in discussing architectural education, had no starting points in common. On December 19, 1912, the time of the annual convention of the American Institute of Architects, those in charge of the older schools of architecture met in Washington, D. C., and perfected an organization known as the Association of Collegiate Schools of Architecture. After thorough study and investigation this association prescribed certain minimum requirements for schools of architecture; there were certain minimum standards as to the requirements for admission to the schools of architecture; the recognized course in architecture must contain certain minimum requirements in design, construction, history, and drawing, as well as a certain amount of training in English, foreign languages, mathematics, science, and cultural subjects. There were 10 schools of architecture in 1912 whose curricula were such as to meet these prescribed requirements. Since that time 5 additional schools have modified their work so as to comply and now belong to the association. Other schools are using these requirements as a basis for revising and building up their curricula. The association, at the annual meeting, presents for discussion by the schools modern methods of teaching, careful consideration being given at each meeting to a thorough discussion of the curricula.

Architectural education to-day is on a firmer footing, on a more logical basis because of the work of this association. The product of the schools, the graduate, is a more uniform product; not that the schools are turning out machines who do work in only one way, but because of the minimum requirements of the recognized schools the education of the student has been along well-defined lines covering a more or less uniform course. No attempt is made to standardize

the student, on the other hand each student is encouraged to express his own personality in all that he does. Another result of this co-ordination of curricula is that the profession knows that a graduate from one of the association schools has had certain training, whether or not the student remembers all that he was taught. The course of study contained certain fundamentals, and the employer profits by such. One of the great results of modern architectural education is the attitude of the student toward further study after graduation. While four years seems a sufficient time to devote to the academic training, the student is now taught that the four years in college is but the beginning of his education. After graduation comes a period of apprenticeship, followed by study at home or abroad, to be continued throughout the rest of his life.

From the very beginning of architectural education, research work has been a part of the work of the schools. The pioneers in education were investigating and developing fundamentals and principles. Many of the early books published in this country were contributions to the information on architecture. As time has passed, more importance has been given to research, books have been added to the architectural libraries which perhaps were of little value to the undergraduate, but which were needed for the advanced student. Some schools now offer research fellowships. The development of our country's resources depends upon the research student, and opportunities and facilities are being offered to encourage scientific investigation along architectural lines. With regard to the contention that more architects are graduated than the needs of the country justify, it may be said, as in other professions, so in architecture, not all graduates expect to follow it as a profession. Some take the course merely as a cultural education, some expect to use the training in architecture as a background to business, while some expect to follow the profession. There is now and always will be room for the graduate in architecture, for the one who is willing by study and hard work to conceive something that is useful and beautiful.

The future of architectural education holds unlimited opportunities and possibilities. The profession is making an honest effort to study and understand the work now being carried on by the schools; the schools are looking to the profession for advice and criticism. As yet the great field of art appreciation is almost untouched in the secondary schools of this country, and herein lies one of the greatest opportunities for the schools of architecture. Indeed, the schools of architecture are endeavoring to meet a variety of social needs; they are keeping their fingers on the pulse of the life of this great Nation, and are making an honest effort to prepare students to take their places as leaders in the affairs of the world.

Chapter VIII

HIGHWAY ENGINEERING

By T. R. AGG

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Prior to the year 1910, highway engineering instruction in American colleges and universities was confined almost entirely to the conventional course in roads and pavements. A few institutions included in the instruction in surveying certain problems in highway or street surveying. In general, there was no attempt to differentiate highway engineering from general civil engineering.

A notable exception existed at Harvard, where the late Dean Shaler introduced a few elective highway courses in the civil engineering curriculum. Several engineers who now hold positions of the highest responsibility in the highway engineering field received their training under Dean Shaler.

The reason for the relatively meager treatment of highway engineering during the period prior to 1910 was that the highway problem was principally one of providing for horse-drawn traffic. While there had developed a considerable volume of motor traffic by the year 1908, the percentage of such traffic was small and did not constitute the controlling element in highway design or maintenance.

The rapidity with which the motor vehicle increased in popularity during the period beginning in 1908 was entirely unexpected by highway officials and adequate maintenance developed slowly. In consequence, many miles of what had been considered substantial roads were seriously damaged before steps could be taken to provide suitable maintenance. An enormous maintenance problem therefore developed within a period of five years, and personnel for supervising the work had to be assembled and trained. Along with the necessity for maintenance, there developed an insistent demand for better road surfaces than could be provided by reconstructing existing roads and for great extensions of the mileage of surfaced roads. These demands necessitated the employment of a personnel technically qualified to supervise the construction of high-class types of road surfaces.

By the year 1912 engineering schools had begun to react to the demand for engineers prepared for highway engineering by increasing the amount of highway instruction included in the curricula. Since that time the importance attached to highway engineering instruction has steadily increased, despite the constant debate on the desirability of permitting specialization in civil engineering. It is

doubtless true that the opposition to the inclusion of strictly highway engineering subjects in the civil engineering curricula arose from opposition on the part of educators, who feared a loss of prestige for some of the older established lines of civil engineering, or who doubted the wisdom of including options in the course of study.

A survey of the present status of highway engineering instruction, in the various engineering schools, indicates that three general plans are being followed:

1. A certain amount of general highway engineering instruction is given through the medium of a course of the nature of the old standard one in "Roads and pavements," the amount of such instruction varying from two semester hours to five semester hours. It appears that a considerable number of institutions follow this plan.

2. A limited number of schools offer a four-year course in highway engineering carrying a bachelor of science degree. Obviously such a course includes many subjects that are usually included in civil engineering.

3. Many institutions include a definite amount of required highway engineering instruction in the civil engineering course and then offer a certain additional number of subjects as options open to senior students. The amount of required work varies from three to eight semester hours, and the amount of optional work varies from three to six semester hours.

Typical required courses are: Roads and pavements, highway design, road materials testing, and highway bridges design.

Typical optional courses are: Highway administration, highway drainage, highway specifications, and highway finance. In some schools, certain of the courses listed above as required are optional, and likewise some of the courses listed as options are required, but the usual arrangement is as indicated.

The content of the several courses of study seems to vary considerably, but the following will indicate in a broad way the usual character of the subject matter.

Roads and pavements.—Types of roads and pavement surfaces, methods of construction and maintenance, elements of design, and fundamental economic considerations.

Highway design.—Problems involving the actual working out of designs for roads and pavements, including establishment of grades, alignment, and slab thicknesses; and the design of such details as curves, intersections, and warped surfaces.

Highway drainage.—Application of the theory of land drainage to highway drainage and consideration of the various accepted methods of highway drainage.

Highway bridges.—Application of the principles of structural engineering to the design of bridges and culverts for highway loading and consideration of the types of structure usually adopted for highway improvements.

Road materials testings.—Laboratory work, covering the accepted methods of testing nonbituminous and bituminous road materials. Sometimes supplemented by lectures and recitations intended to emphasize the significance of the results of the tests.

Highway administration.—Highway laws, highway finance, methods of administration, organization of municipal and State highway departments, and day labor or contract construction organization.

Highway specifications.—Critical analysis of current specifications for road or pavement construction and practice in the writing of specifications for specific projects.

Highway finance.—Usually taught by the department of economics as an exposition of the principles of public finance.

SHORT COURSES

In order to bridge over the period during which an insufficient number of properly trained men are available for highway work and to enable ambitious men to prepare themselves for advancement, some institutions give intensive instruction in highway engineering during periods of one, two, or three weeks. Courses of this character meet a real need, and when the subject matter is well chosen and presented, with a regard to the limitations of those in attendance, are of great value. These courses must be intensive, not too highly technical, and must be closely correlated to current highway practice in the area from which the students are drawn.

In some States an act of the State legislature requires that those responsible for the building and maintenance of State roads shall attend, at the expense of the State, a short course or road school maintained at the land-grant college.

HIGHWAY ENGINEERING GRADUATE COURSES

A few institutions offer graduate instruction in highway engineering, and this field probably is susceptible of considerable development. Under the most favorable conditions it is impossible to go very far into the ramifications of highway engineering during the undergraduate years nor is it probably wise to attempt to do so. Highway research is beginning to receive deserved attention, and presents a virgin field for graduate study. It therefore follows that highway engineering graduate work should, for many years to come, offer an attractive field for engineers who wish to avail

themselves of the undoubted advantage that accrues from graduate study.

In order to make available to practicing engineers the opportunity for graduate study, some institutions offer the graduate work during a period of six or eight weeks during the winter. This enables engineers to attend during what is usually their slack season. But in any case the graduate courses should be available during the regular collegiate year.

RESULTS AND PROBABLE DEVELOPMENTS

From time to time, various organizations engaged in the promotion of highway improvement have urged the educational institutions of the United States to train men for highway work. There is ample evidence that the requirements for success in the highway engineering field will become more rigid as practice conforms to the underlying basic principles involved. This is indicated by the fact that notable progress has been made in the science of road building since trained engineers have been placed in responsible positions.

The conclusion is reached that the road-building program of the United States will require a large number of new engineers annually for many years and that the field is a promising one for ambitious men. Consequently, educational institutions will do well to plan to meet this need for properly trained men.

SUMMARY

The trend in highway engineering instruction seems to be toward a system whereby certain fundamental courses are required of all civil engineering students. In general, this amounts to about five semester hours. Supplementing the required work there is offered about an equal amount of optional highway engineering instruction for men who wish to specialize in the subject.

It seems to be assured that the need for additions to the supply of trained highway engineers will continue for a long time.

Short courses to fill a present need have been successful in many institutions and may extend through a week or through as many as three or four weeks.

Graduate work in highway engineering is being developed rapidly and affords a real opportunity for educational progress.

Chapter IX

HYDRAULIC AND SANITARY ENGINEERING

By R. L. SACKETT

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HYDRAULIC ENGINEERING

The mechanics of fluids was a part of early instruction in physics. The development of mechanics as an advanced subject, including the experimental treatment of fluids, followed, and hydraulics became a part of the pioneer engineering curricula, though not necessarily as a separate subject.

The earliest course in hydraulics as a separate subject, so far as inquiry has discovered, was at the Massachusetts Institute of Technology, where, in 1866, "the first courses in hydraulics were introduced." In 1867 the subjects of "supply and distribution of water" and "drainage" were added.

The development of laboratories for the study of the flow of water is much more recent, although pumps were operated and pump tests were frequently made before separate laboratories had been built. Irrigation, hydroelectric power, and the more scientific study given water distribution and friction in pipes led to the development of distinctive or separate hydraulic laboratories. The first instruction given in hydraulic laboratory experiments, at the Massachusetts Institute of Technology, appears to have been in the year 1871. Says Prof. G. E. Russell:

At that time, in the Rogers Laboratory of Physics, experiments to determine the coefficients of efflux of weirs and orifices were made; also experiments dealing with flow under pressure. In 1885, there was installed in the laboratory of mechanical engineering a 6-inch Swain turbine, together with a steam-driven pump, and in 1889 or 1890 there were added to the laboratory a pressure tank, a standpipe and apparatus for experimenting with flow through orifices, mouthpieces, pipes, and over weirs. I should say that this latter date marked the real beginning of laboratory instruction in hydraulics.

In general, instruction in hydraulics was given in the land-grant colleges having engineering courses before 1890. Laboratories were built at Iowa State College and at Purdue University in 1908 and at Illinois University at an earlier date. Says Dean E. A. Hitchcock: "Instruction in hydraulic machinery, including chiefly pumping machinery, in a two-hour semester course since 1896, at least, has been given at Ohio State University. Some instruction "in hydraulic laboratory experiments was given as early as 1895 and to nearly all engineering students in 1897."

A number of land-grant colleges offer courses in irrigation or hydraulic engineering as electives in the senior year of the civil engineering course or offer a year's consecutive line of courses or a curriculum as an option in the senior year. The latter has been the plan at the Massachusetts Institute of Technology since 1886; of Purdue University since 1908 or perhaps before; and several others offer options for a semester.

A number of textbooks on hydraulics or hydraulic engineering subjects have been written by members of the faculties of land-grant institutions.

Mechanics, by Prof. Irving Church, of Cornell University, was one of the first to contain a thorough treatment of hydraulics. Other and later texts have been written by Professors Daugherty, of Cornell; Russell, of Massachusetts Institute of Technology; and Mead, of Wisconsin.

Among the earliest texts are Weisbach's *Mechanics, Hydraulics and Hydraulic Motors*, which was translated into English in 1877. *Hydraulics, Weirs, and Orifices*, by Hamilton Smith, was published in 1886; *Bedner's Hydraulic Motors* in 1897; *Hydraulics and Water Supply Engineering*, by Fanning, in 1899, followed closely by numerous others.

At the present time, practically all the land-grant colleges give instruction in hydraulics, both theoretical and experimental.

The engineering research laboratories of these institutions have made very considerable studies and have published valuable bulletins on the following subjects:

Iowa State College

Field measurements of K in actual tile drains. Iowa Engineering Experiment Station. Bulletin no. 4, vol. 4.

Gauging the flow of sanitary sewers. (Engineering thesis prize, 1896.)

Gaugings of flow of sanitary sewers. *Engineering News*, 1896.

Marston, A. and Anderson, A. O. The theory of loads on pipes in ditches and tests of cement and clay-drain tile and sewer pipe. Bulletin, vol. 31, February, 1913.

Measurements of coefficients of friction K in Cutter's formula for drain tile in actual drains. (About 1908.)

Measurements of coefficients of friction K in Cutter's formula for sanitary sewers. (About 1909.)

Measurements of run-off from drainage ditches and outlets of large tile drainage systems. 1916 to date.

Measurements of run-off drains from tile drains from heights of ground water at different distances from tile drains. 1908-1916.

Measurements of run-off from tile drains and level of ground water. Iowa Engineering Experiment Station. Bulletins nos. 50, 51, 52.

Photographic studies of fire streams. Bulletin, 1898.

Photographic study of fire streams. *In Iowa Engineering Society. Proceedings, 1899.* (Also the same data have been used in Turneaur's and Russell's "Water supply engineering.")

Kansas Agricultural College

Walters, John D. The water supply for country homes. Bulletin no. 45, vol. 42, January, 1916.

Massachusetts Institute of Technology

A determination of the coefficient of discharge of the Charles River Dam at Newton.

Comparative studies of the weir formulae of Francis, Stearns, and Bazin. Discharge through a trapezoidal weir, with side sloping at 60 degrees with the horizontal.

Experiments on Herschel's round crested weir.

Experiments to determine the velocity of bodies dropped in water.

Investigations of the coefficient to be applied to the use of Pitot tubes of Gregory's design.

Studies of the measurement of streams by the chemical dilution method.

Study of a turbine draft tube model to determine the effect of bottom clearances.

Study of discharge through diverging tubes.

The determination of orifice coefficients.

The effect of viscosity on the flow of fluids through pipes.

The laws of hydraulic similitude applied to models.

The measurement of streams in rectangular channels by means of a moving screen.

The reactions from hose nozzles.

Ohio State University

Boyd, James E. and Judd, Horace. Pitot tube applied to water tube. *Engineering News*, 51: 318, 1903.

Judd, Horace. Research in progress on effect of pulsations on fluid flow.

— The orifice as pipe diaphragm. *A. S. M. E.*, 38: 331, 1916.

— and King, R. S. The frictionless orifice for water flow. *Engineering News*, 56: 326, 1906.

Purdue University

Ewing, O. D. and Blalock, G. C. Electric driven water works in Indiana. Bulletin no. 3, vol. 3, December, 1919.

Grave, Fred W. Flow of water through 1½-inch pipe valves. Bulletin no. 2, vol. 2, July, 1918.

University of Illinois

Davis, R. E., and Jordan, H. H. The pipe orifice as a means of measuring the flow of water through a pipe. Bulletin no. 109.

Leely, F. B. The effect of mouth pieces on the flow of water through a submerged short pipe. Bulletin no. 96.

University of Washington

Creosoted wood stave pipe and its effect upon water for domestic and irrigation uses. Bulletin no. 1.

SANITARY ENGINEERING

The work of Pasteur and Koch necessarily preceded the development of sanitary engineering. It was not until the causes of epidemics were discovered that preventive medicine and sanitation became such important factors in community life and health. The application of sanitation to cities received a great impetus in the nineties, with an agitation for better sewer construction, drainage, and later came the science of treating sewage by chemical, then biological methods to reduce odors and the danger from sewage. The study of water filtration began to be followed by investigations in storage and sterilization, and the use of ozone, chlorine, and ultra violet rays, in an attempt to find the best and cheapest methods of protecting water supplies.

One of the earliest experiments on the tank treatment of sewage was made at the University of Illinois. Various types of spray nozzles and filters were tested at the same institution.

More recently the use of chlorine, either as hydrochlorite of lime or, as liquid chlorine, has been experimented with to determine the advantages of each. Studies of creamery and canning plants for the purpose of reducing or overcoming odors and of the clogging of sewers and filters have been made.

A number of land-grant colleges had organized courses in sanitary engineering before 1900. They generally include the fundamental subjects of civil engineering plus bacteriology, water and sewage analysis, the study of sewerage, sewage treatment, and water purification. In some instances a curriculum is organized in this subject, and in other institutions the civil engineering course permits of specialization in sanitary engineering subjects during the senior year.

Colonel Moore, an Englishman, in his preface to Sanitary Engineering, published in 1898, says: "Considering the grave importance of sanitary engineering, it is remarkable that no book dealing with the subject as a whole has hitherto been issued." The Elements of Sanitary Engineering was published by Mansfield Merriman in the same year, which indicates what has frequently occurred, viz, a recognition of a need on two continents at about the same time.

The first instruction in sanitary engineering at the University of Illinois was given in 1889, which is probably the earliest formal organized instruction in that subject in a land-grant college. A course in drainage was offered at the Massachusetts Institute of Technology in 1867-68, and one in sewerage of cities and towns in 1881-82. A course in sanitary engineering was first offered there in the academic year 1883-84, and in 1889 a four-year curriculum in sanitary engineering, leading to the degree of bachelor of science in sanitary

engineering, was first offered. This is the oldest four-year curriculum of this title so far as the author has been able to discover. Iowa State College had organized courses in sanitary engineering "long prior to 1890."

Experimental studies have been made of a wide variety of subjects related to drainage, water supply, water purification, the treatment of sewage and related subjects. The most important bulletins on these subjects are as follows:

Iowa State College

- Barr, W. M., and Buchanan, R. E. The production of excessive hydrogen sulphide in sewage disposal plants and consequent disintegration of the concrete. Bulletin, vol. 26, January, 1912.
- Marston, A., and Okey, F. M. Sewage disposal plants for private homes. Bulletin, vol. 4-6, December, 1909.
- Schlick, W. J., and Clemmer, H. E. The supporting strength of sewer pipes in ditches, and methods of testing sewer pipes in laboratories to determine the ordinary supporting strength. Bulletin, vol. 47, October, 1917.
- Nichols, C. S. Sewage treatment for village and rural homes. Bulletin.
- Schlick, W. J. Recommendations for farm drainage. Bulletin, vol. 51, October, 1918.
- Supporting strength of drain tile and sewer pipe under different pipe laying conditions. Bulletin, vol. 57, April, 1920.
- The spacing and depth of laterals in Iowa under drainage system and rate of run-off from them, with data for investigation. Bulletin, vol. 52, October, 1918.
- The theory of under-drainage. Bulletin, vol. 50, September, 1919.

Kansas State Agricultural College

- Frazier. Sewage disposal for country homes. Bulletin no. 46, vol. 42, April, 1916.

Pennsylvania State College

- O'Donnell, R. Rural sanitation. Part 2, Sewage disposal, fly control. Bulletin no. 29.
- Waterman, E. F. Rural sanitation. Part 1, Water supply. Bulletin no. 28.

Purdue University

- Grave, R. W., Jr., and Stanley, W. E. Coefficient of discharge of sewage sprinkler nozzle. Bulletin no. 2, vol. 11, November, 1919.

University of Arizona

- Dickinson, S. C. Keeping your town clean. Bulletin no. 2, vol. 86, 1917-18.

University of Missouri

- McCaustland, E. J. Water supply and sewage disposal for country homes. Bulletin no. 17, vol. 21, January, 1920.

Texas Agricultural and Mechanical College

- Miller, Dan C. Sewage disposal for country homes. Bulletin no. 2, vol. 1, November, 1915.

Chapter X

CERAMIC ENGINEERING

By ARTHUR S. WATTS

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Ceramic engineering education began as a result of the efforts of Edward Orton, jr., a graduate of the School of Mines at the Ohio State University, who, with the aid of the clayworking industries of Ohio, secured the passage of a special act by the State legislature in 1894, creating the department of clayworking and ceramics at the Ohio State University. This was the first school of its kind in the United States, and probably in the world, although a ceramic course of study is reported as having been provided at the University of Tokio, Japan, about this time. Professor Orton was placed in charge of this original school and remained its head until 1914, when he retired from the university staff.

The term "ceramics" was understood as covering crude and decorated clay wares.

There was very little literature on the subject published in English, and the theories governing the behavior of such silicates were found to apply seldom to the cases under consideration. The early conception of silicate control was by application of chemical principles, but the fact was soon established that ceramic bodies were not homogeneous mixtures and did not respond to the treatments applied. The losses in the manufacture of all kinds of crude clay wares were so frequently traced to mechanical difficulties that for the first few years Professor Orton gave special attention to the preparation of crude clays and their forming, drying, and burning into crude ceramic wares.

This work was highly successful and the reputation of the department in producing men for technical control of heavy clay wares, such as brick, sewerpipe, hollow building, and drain tile, was established and has been enjoyed ever since. The investigations concerning the rôle of carbon and sulphur in crude clays during the burning process eliminated enormous financial losses in established industries, and made possible the use of many extensive clay deposits previously considered worthless.

The early study of clay ware decoration was confined chiefly to the simple glazes used on stoneware and common pottery. These glazes rarely matured to a state of complete fusion during the firing treatment, and the principal effort of early investigators was to produce glazes having a longer range of temperature within which

they were commercially satisfactory. Much was accomplished from a commercial viewpoint along this line, but very little was learned of the basic principles that control silicate fusions.

In 1898 the American Ceramic Society was founded for the encouragement of ceramic research through the efforts of Prof. Edward Orton, jr., who for about 15 years was its secretary and editor. The researches and other contributions to the society were published for 20 years in an annual volume. In 1900 a portion of the annual was devoted to "Ceramic Calculations," a brief treatise on methods of solving simple ceramic problems and a proposed uniform system of expressing chemical compositions of ceramic bodies and glazes. This was used as an elementary textbook for many years, but the edition was exhausted and not reprinted. In 1902 the members of the American Ceramic Society translated from the German and published in English "The Collected Writings of Herman A. Seger," at that time the foremost authority on ceramics. This publication and the Ceramic Calculations referred to above are the only books that have ever been used as textbooks in ceramics. Up to about 1910, chemistry was the foundation of all ceramic research, on the theory that the composition, as indicated by chemical analysis, furnished all the necessary information for control. The behavior of all silicates under heat treatment was believed to be dependent entirely on the elements present. About 1910 the application of physical chemistry to the solution of certain ceramic problems was found to have definite results, and a course in the fundamentals of physical chemistry was introduced into the ceramic curriculum. As this science has come more thoroughly understood, it continues to increase in its importance to the ceramic field. Another important step in the development of ceramic knowledge was the introduction of "mineral constitution" instead of "chemical composition" as the basis for study of ceramic bodies. Data had been produced to prove that clays of the same chemical composition but of different mineral sources possess widely different properties. A careful survey of available data indicated that the mineral constitution of both natural and artificial ceramic bodies is a very important factor except in the few cases where complete and prolonged fusion is accomplished and entirely new chemical compounds are formed. This indicated the importance to the ceramic student of a knowledge of mineralogy, and in 1913 a course in the fundamentals of mineralogy and the effect of heat on the ceramic minerals was added to the ceramic curriculum.

The use of the microscope in studying the progress of fusions and the resulting changes was found very valuable, and such a course was made available to the student by election. This course has become a very important part of postgraduate study.

The industry of clayworking, which was the basis of ceramic engineering, is one of the oldest known industries, but up to about 1900 it was recognized as one of the least progressive, not only as regards a knowledge of the means of control but especially as regards apparatus or machines employed.

The call for trained men in the field of manufacture had exceeded the supply from the beginning, but instruction in the design and arrangement of ceramic machinery for best results was not attempted until 1911, when a lecture and laboratory course in the design and construction of ceramic machinery and plants was introduced.

The progress in the control of drying and burning processes, made in the past decade, is equal if not greater than that in any other branch of the ceramic industry. The development of systems of draft and humidity control during the drying process has reduced the losses in ceramic wares to a fraction of former figures and at the same time reduced the time required to about one-fifth that required in early practice. Many products heretofore considered impossible are now made with complete success.

The development in the design of kilns for burning ceramic ware has undergone equally important changes. The continuous tunnel kiln through which the ware travels on insulated cars has revolutionized the firing process in many branches of the ceramic industry, and as yet is in its infancy of industrial application. The problems of placing or setting the ware, which was always a source of difficulty and loss in the old type of kiln, have been largely eliminated and the fuel consumption reduced to approximately 20 per cent of that required with the older types of kilns.

The development of the recording pyrometer, by which the development of temperature in the kiln can be accurately recorded and the value of each addition of fuel observed, has contributed enormously to the success of kiln firing. A course of instruction in the operating principles of these instruments was found necessary and introduced in 1918.

The most recent addition to the ceramic curriculum is a course designated as "refractories and furnaces." The field of refractories, in 1900, included only clay and silica brick, and the latter had only a limited use. The developments of metallurgy and the introduction of the electric furnace for the production of high temperatures have encouraged research in special refractories. These superior refractories being produced for definite services demand technical control in the various processes of manufacture, and special preparation in this field was found necessary. This course, introduced in 1918, consists of a study of the laws governing the various classes of refractories, the controlling factors in the production of first-grade ware, the application of the ware to the various branches of refractory

service, and especially the design and construction of high-temperature furnaces.

The original ceramic department at the Ohio State University provided for two courses of study, one a regular four-year course leading to a degree in the school of mines, mining engineer in ceramics, and the other a two-year course provided for men of practical experience who sought only a limited training in the principles controlling ceramic operations. Students in the two-year course rarely had the elementary preparation necessary for admission to the regular engineering courses, and therefore it was found necessary to prepare special simplified courses for this class of students. After completing this short course of simplified study, the student so frequently elected to proceed with more advanced work leading to a degree that the adjustment of credit for this short course in the regular engineering curriculum was a constant source of controversy. From 1906 to 1912 the number of students terminating their university studies at the end of the two-year course was so small that this short course was abandoned and a special curriculum arranged to meet any case arising. Such a course does not lead to a degree, but the subjects covered are those provided for regular students, and the credits are, therefore, easily adjusted in case the special student decides later to work for a degree.

The curriculum, as originally outlined, consisted of 50 per cent fundamental and cultural, 30 per cent ceramics, and 20 per cent other advanced engineering subjects. This ratio has never been materially altered. All changes made or new courses introduced have been by substitution in kind. This has necessitated abbreviation of some ceramic courses not considered fundamental, but the course has from the beginning been recognized as covering fundamentals essentially, any special courses given being treated in an introductory manner. To obtain a thorough knowledge of any special branch of ceramics the student must devote a period of apprenticeship in that special industry after graduation or take a postgraduate course on the subject.

In 1908 the degree conferred was changed to ceramic engineer, and in 1915 it was again changed to bachelor of ceramic engineering.

The object of the curriculum is strictly professional. It does not give or pretend to give manual skill in any of the practical arts of modeling, forming, or decorating. It is a study of the technology—the engineering, both civil, mechanical, and chemical, which is used in the clay and allied silicate industries.

No special consideration was given to ceramics as a postgraduate subject until 1917, when several special ceramic courses were added to the graduate school catalogue. These courses cover a broad range, enabling the student to develop along any line included in

the field of ceramics, special encouragement being given to those branches most closely related to applied sciences. Since the introduction of postgraduate courses, the department has never been without these postgraduate students, and much progress has been made in this department toward the solution of problems which are retarding the progress of ceramics.

The popularity of ceramic engineering was soon evidenced by the creation of similar departments in other universities and colleges.

In 1900 the New York State School of Clay Working and Ceramics was created largely through the efforts of President B. L. Davis, of Alfred University, and this department was established at Alfred, N. Y. It provided two courses, one consisting largely of art and design and the other containing a considerable amount of engineering.

The first land-grant college to follow the Ohio State University in creating a department of ceramic engineering was Rutgers College and the State University of New Jersey, where such a department was created in 1902. This department created and still provides a short course in clay working and ceramics. It also provides a regular four-year course leading to the degree of ceramic engineer. This course at present consists of about 64 per cent fundamental and cultural, 22 per cent ceramics, and 14 per cent advanced engineering. The ceramic courses are the same as those offered at the Ohio State University, the difference being in the time allotted to each subject.

The University of Illinois created, in 1905, a course of ceramics as a special branch of the department of geology. Two courses of study were provided, one majoring in science and one majoring in engineering, both in the college of liberal arts. In 1912 the ceramic department was transferred to the college of engineering.

The course in ceramic engineering was considerably changed at this time to provide for much more chemistry than was included in the curriculum up to this time. There is but one course of study provided at present. This requires four years and leads to the degree of bachelor of science. The subjects covered are not dissimilar to those of other ceramic schools, but a large number of special ceramic courses not scheduled in the regular curriculum are available to advanced and postgraduate students. These include glass technology, cements, and metal enamels, which are treated in a more complete manner than is provided in the curricula of the other ceramic schools.

In 1906 a course in ceramic engineering was authorized at Iowa State College by the Iowa Legislature. The course did not find immediate favor, and the first student was enrolled in 1907. In 1914

the course proposed consisted of four years of mechanical engineering, to be followed by one year of special study in ceramics. In 1915 a course similar to that provided at the Ohio State University was introduced and four students enrolled. The present curriculum consists of 60 per cent fundamentals, 19 per cent ceramics and 21 per cent advanced engineering. The ceramic industries of Iowa produce chiefly heavy clay wares. The course of study has been devoted chiefly to brick and heavy clay products, although courses are also provided in the problems connected with finer ceramic wares.

The tardy development of the ceramic department at Iowa State College led many to believe that the demand for ceramic education had been fully provided for, and no additional ceramic departments have been created in land-grant colleges.

In 1918 a ceramic department was created in the College of Mines, University of Washington, through a cooperative agreement between the university and the United States Bureau of Mines.

In 1921 a ceramic department was created at the University of Saskatchewan, Canada.

The progress made during the past 10 years in the knowledge of ceramic engineering has made it impossible to cover the entire field in more than a general manner in the time available in a four-year course. The early conception of the subject limited it to claywares, but its expansion has divided it into at least six fairly well-defined groups, as follows: (a) Crude ceramics; (b) architectural and majolica ceramics; (c) fine ceramics and ceramic colors; (d) refractories; (e) glass and enamels; and (f) cements.

Crude ceramics include wares made from a single clay or a blend of two clays, as common and paving brick, sewer pipe, and stoneware.

Architectural ceramics include all types of terra cotta bodies, vitreous coatings, and enamels.

Majolica includes all types of colored glazes on both natural and artificial bodies.

Fine ceramics include both bodies and glazes of all the white wares, i. e., earthenware, china, and porcelain for tableware, art ware, sanitary ware, electrical ware, and tile.

Ceramic colors include all artificially made colors for overglaze and underglaze decoration and for body coloration.

Refractories include not only all the regular refractory wares, such as clay, silica, magnesia, chrome, bauxite, and zirconia, but also the special refractories, such as spinels, sillimanite, dolomite, carborundum, and alundum.

Graduates in ceramic engineering have never had any difficulty in finding profitable employment, since the industries have demanded

more men than have been graduated each year. There is, however, little call for men lacking energy and resourcefulness, and such men are discouraged from taking the course.

The distribution of ceramic graduates of the Ohio State University in the different branches of the industry is as follows: Of 166 graduates, 53 (32 per cent) are in crude ceramics; 23 (14 per cent) are in architectural ceramics; 34 (20 per cent) are in fine ceramics; 21 (12½ per cent) are in refractories; 13 (8 per cent) are in cement, glass, and enamels; 13 (8 per cent) are in teaching or Government research; and 7 (5½ per cent) are not following ceramics.

Regarding the salaries received by ceramic graduates, an estimate computed in 1915 indicated an average salary of \$2,667 for a ceramic engineer seven years after graduation. Recent incomplete data indicate that graduates from 1916 to 1920, inclusive, are receiving an average of \$2,844 four years after graduation.

The probation salary of graduates in 1921 and 1922 averaged \$1,850, against \$1,050 in 1912.

Of 81 graduates from the University of Illinois, 16 (20 per cent) are in crude ceramics; 4 (5 per cent) are in architectural ceramics; 11 (14 per cent) are in fine ceramics; 12 (15 per cent) are in refractories; 9 (11 per cent) are in glass or enamels; 2 (2½ per cent) are in teaching or Government research; 23 (28 per cent) are not following ceramics so far as known; and 4 (5 per cent) are deceased.

Ceramic engineering is firmly established as an applied science. Its influence upon the clay industries of the United States is more pronounced each year. In the minds of discerning observers, this branch of engineering will have a place in the engineering world of increasing importance.

Chapter XI

TEXTILE ENGINEERING

By CHARLES S. DOGGETT

Director of Textile Department and Professor of Textile Chemistry and Dyeing, Clemson Agricultural College, South Carolina

In this country instruction in textile subjects is given in two types of schools; viz: In independent textile schools, and in some of the land-grant colleges of the Southern States. In the latter the textile course of study is one of several engineering courses offered.

In 1884 the Philadelphia Textile School was opened, but the real era of textile schools started four or five years later with the textile school at Lowell, Mass., the textile departments of the land-grant

colleges of North and South Carolina, and the A. French Textile School as a part of the Georgia School of Technology. Later followed the building of the textile schools at Fall River and New Bedford, Mass.; and the State agricultural and mechanical colleges of Mississippi and Texas also added textile departments. The textile schools at Putnam, Conn., Providence, R. I., and New York are of quite recent date.

In the textile schools thorough courses of study in textile subjects are given; regular three and four-year courses, and shorter ones for special and evening students. A limited amount of time is also given to related subjects, such as mathematics, mechanics, and English.

The land-grant colleges having textile departments are: North Carolina Agricultural and Engineering College, Raleigh, N. C.; The Clemson Agricultural College of South Carolina, Clemson College, S. C.; Agricultural and Mechanical College of Texas, College Station, Tex.

The textile department of the Mississippi Agricultural and Mechanical College was closed about a dozen years ago, the machinery sold, and the building used for the institution's school of commerce. While the A. French Textile School, Georgia School of Technology, cannot be classed as the textile department of a land-grant college, the courses of study offered are essentially identical with those of the land-grant colleges. This school, the three land-grant colleges, and the Lowell Textile School confer the degree of bachelor of science upon those completing the four-year textile course. The other schools referred to in this article do not.

The degree curriculum in textile engineering, as given in the textile departments of the land-grant colleges, consists of general courses in English, higher mathematics, economics, and history. Free-hand and mechanical drawing, descriptive geometry, surveying, shopwork, mechanical engineering, electrical engineering, and the laboratory work in connection therewith are considered as fundamental subjects. About one-half of the time during the junior and senior years is devoted to purely textile subjects, theory and practice. All of these colleges are fully equipped with textile machinery.

These land-grant colleges also give special textile courses. These are designed for young men of limited education who already have had some experience in mill work. As no one of these colleges is situated in a mill center there is no opportunity to conduct evening or part-time classes.

These special textile courses cover two years only. Under existing conditions the number of students must be limited, as the college curriculum is not designed for any who are not graduates of a high school. In general, the two-year courses are the same as those taken by the candidates for a degree, but in other respects, the individual's

needs are met so far as possible; elementary mathematics and English, high school chemistry, and physics being the subjects pursued.

There is a wide field of usefulness open to the agricultural and engineering colleges having textile departments somewhat along the lines of the extension work of the agricultural department of these colleges. Textile schools, specially planned to meet the local conditions of the larger textile centers and supported by the industrial establishments but closely articulated with the State college, would afford mill operatives the opportunity for getting the same type of textile training as given in the evening and short-term courses of the textile schools in the Northern States and very generally what England offers to her workers.

At the present time no close connection exists between the textile departments of these colleges and the manufacturing establishments, but if these schools are to serve the purpose for which they were established and the manufacturers secure well-trained men for their more important positions, there must be such cooperation. With the rapid development of the textile industry in the Southern States, especially in the manufacture of fine goods, men of technical training will be needed as foremen, overseers, and superintendents.

A testing and research laboratory for the textile industry comes naturally within the province of an engineering college. In fact, the textile department should be expected to serve the industry in settling disputes, making impartial reports, and carrying on research work more fully, and for the benefit of the industry at large, as, perhaps, but few manufacturers could or would. A laboratory of this character, serving the industry as a whole, should be liberally supported, not by the State in general, but by the industry itself.

One of the needs in textile engineering, as pointed out by numbers of successful mill executives, is training in the handling of the human factor. This is not peculiar to textile engineering, but is general in all engineering courses. In the textile industry, more so perhaps than in any other industry, the item of labor is relatively high in proportion to the cost of materials and the output. Consequently, the human factor is a very vital question. While there has been considerable discussion on the need for this type of training in engineering courses, especially textile, it is to be doubted whether it can ever be given with any degree of success, as a subject, and must be obtained by actual contact with the working people in their daily employment and home life.

By the employment of textile-engineering graduates as teachers of related subjects supplementary to the daily employment of operatives in the mills, opportunity is afforded these graduates of learning first hand this human factor. The extent of this opportunity is shown in the number of Smith-Hughes classes that are

operated in the mill villages of the Southern States. These classes have grown in number to 400 during the past year, affording to some 4,000 operatives opportunities of promotion which they had lacked because of early educational handicaps, though skilled in daily production work. The Smith-Hughes classes are under the direct supervision and control of the State boards of vocational education and are carried on in close cooperation with the textile engineering schools.

The land-grant colleges are not "trade" or "vocational" schools, but becoming more and more (as they should) articulated with the leading occupations of the citizens of their respective States. Their textile departments should develop and carry on some type of textile education for the operatives in the cotton mills. In some way the educational work of the evening classes in the textile centers of New England and Great Britain should be duplicated by these land-grant colleges.

Chapter XII

SHORT COURSES IN MECHANIC ARTS AND INDUSTRIES

By ADOLPH SHANE

*Professor of Trades and Industries, Iowa State College of Agriculture and the
Mechanic Arts*

The rise of mechanic-arts instruction, or that relating to the trades and industries in the United States, took place coincidentally with the development of industry itself. School training for pupils in handcraft or manipulative skill was advocated as early as the beginning of the nineteenth century—almost in the lifetime of Washington. But support of this form of education at public expense did not become popular until after the passage by Congress of the first Morrill Act, which provided Federal aid, through land grant, for each college established by the States, "to teach such branches of learning as are related to agriculture and the mechanic arts * * * in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

While the development of the principal courses in our land-grant colleges has been collegiate in character, the act itself did not specify this should be so; and from the beginning to the present day, shorter courses, principally noncollegiate, have been offered by many of these State institutions. Whereas the four-year engineering courses, if not actually standardized, are, nevertheless, now

fairly uniform in content and more or less common to all land-grant colleges; on the other hand there has been little uniformity in the number or character of the short courses given, nor has there been virtually, up to the present time, any well-defined tendency that way.

It is true that some of these colleges, especially those of later birth in the less-developed sections of the country, emphasized in the beginning those courses in which manual skill played a prominent part. Indeed, some of their engineering courses at inception were little more than what we now conceive to be vocational courses—using the word “vocational” in its more restricted sense as distinguished from “professional.” But as the States developed, their colleges advanced with them, and it was not long before the courses in the newer colleges became definitely professional in character. As the engineering courses developed, the practical mechanic arts courses assumed less prominence, although they were not entirely abandoned.

The land-grant colleges of the East, particularly those situated in the industrial sections, have never been, and are not now, identified to any extent with short courses relating to the trades and industries. This is also partly true of those located in the North Central States and the far West. These sections have developed vocational schools under public and private support, which have taken over the responsibility of educating and training workers for industry. The principal development of the courses has been in the State colleges of the West and to some extent of the South. At the present writing about one-third of the colleges coming under the Morrill Act offer short courses of some kind in engineering or the mechanic arts. Several have dropped them and several have taken them on in recent years. Naturally, where they have been given with success, the offering of noncollegiate instruction alongside of the collegiate is approved; where success has not been pronounced, or where the shorter courses are not given, the teaching of the two together is not approved. Excepting the State colleges for the colored in the South, the degree of contact which the land-grant colleges as a whole have had with the shorter mechanical courses has been so small relatively that it has exerted a very minor influence on their development. Even the colleges for the colored people show some tendency to become collegiate in the character of courses given.

The principal industry in most of the States where the short courses are offered is agriculture. The farmers' needs, therefore, were from the first, and still are, an important influence on the type of work given in the several colleges. These were of a few days' or a few weeks' duration and generally consisted of practical shop courses that were intended to aid the man who had to depend largely

on his own skill to maintain his buildings and equipment. They were given during the winter when the farm labor was at a minimum and were of a "rough-and-ready" variety for which there was little or no accounting, educationally. There were isolated exceptions to this.

About 15 years ago the extension service in the mechanic arts began to assume some importance. Correspondence instruction and class instruction carried to industrial groups served to spread the influence of the State college. This particular field of service—which is no part of this exposition—has been taken up seriously by the majority of the land-grant colleges, and a real development in this phase of education may be pointed out. One of the results has been to bring the colleges into closer touch with industry and the educational needs of industry. This fact and the rapid growth of industry itself began to influence some of them to consider the situation and to broaden the range of short courses offered. It is difficult to place any approximate date for the occasion when the formal short courses, regularly outlined in the catalogues and educationally accounted for, began to assume something like general importance. But perhaps the past decade fairly represents the principal period of this development.

Early in 1918 the resources of the country were taxed to the limit to obtain training facilities necessary for the great army of young men enrolled in the Army training courses. Naturally, the agricultural and mechanical colleges, with their extensive shop and laboratory equipments, were important factors in this training program. But, when a single training quota numbered hundreds and even thousands, against an ordinary shop accommodation of 20 or 30, it became necessary to enlarge very greatly the existing facilities. This was particularly true of the equipment necessary to train the automobile mechanics and truck drivers, who represented by far the largest training groups. The way these colleges carried forward this tremendous responsibility was an inspiration to all, even in the days when patriotic zeal was at its height. For the first time, short-course work had top place on the program. To win the war was first—everything else was secondary to that.

Immediately following the war, the disabled soldier had to be rehabilitated. The land-grant college has served, and is still serving, an important rôle in this respect. Special courses had to be organized and fitted to the needs of the different groups in accordance with the aptitudes and physical handicaps of the disabled. Much of the war training material was put to use again for this purpose; but whereas the war training work was done through short intensive 2-months' courses, the postwar training tends to cover a 2-year period. This necessitated more deliberate and

carefully thought out programs of organization, administration, and execution.

While, doubtless, some of the training courses for the disabled veteran will be dropped after their special purpose has been accomplished, others bear the earmarks of permanence and are open to any student qualified to enroll in them. With the experience gained from the war and postwar training, and a realization on the part of the college authorities of what may be accomplished through a short course intelligently organized and enthusiastically administered, it does not seem likely that all the fruits of this experience are destined to be lost.

Aside from the negro colleges of the South, we find at the present time a wide range of the shorter courses offered scatteringly among the institutions organized for the service. They vary in length and cover periods of 1, 2, 3, 4, or 6 weeks; 2 or 3 months; and 1 or 2 years. With a few exceptions in the 2-year group, all are noncollegiate. In the 1 to 6 weeks' group we find courses in gas engines and tractors, dyeing and cleaning, printing, electric meters, filter-plant operation, mining, telephone practice, baker's short course, road building, etc. Among the 2 or 3 months' group we find carpentry, machine shop, automobile mechanics, blacksmithing, tractor (or a combination of blacksmithing and tractor); electricians', foundry, printing, farm engineering, and drafting courses. The 1 or 2 year group comprises courses which are semitechnical to a greater or less extent. They appear formally outlined in the college catalogues; generally students entering them must meet certain definite educational requirements; especially in the 2-year work, groundwork in mathematics, physics, mechanics, and English of secondary school grade is included in the outlines. These include electrical and mechanical courses or combinations of both, power machinery, machinists', automobile mechanics, automobile electrics, building construction, carpentry, mining for foremen, textile, printing, road building, and architectural courses. The 2-year collegiate courses are rarely found in our land-grant colleges. Among the several colleges offering 1 of the 2 courses last named, 1 course in road building was found to be collegiate and 1 course in architecture to be noncollegiate. One 4-year noncollegiate course in printing and one 3-year noncollegiate course in mechanics respectively are given by 2 of our western institutions.

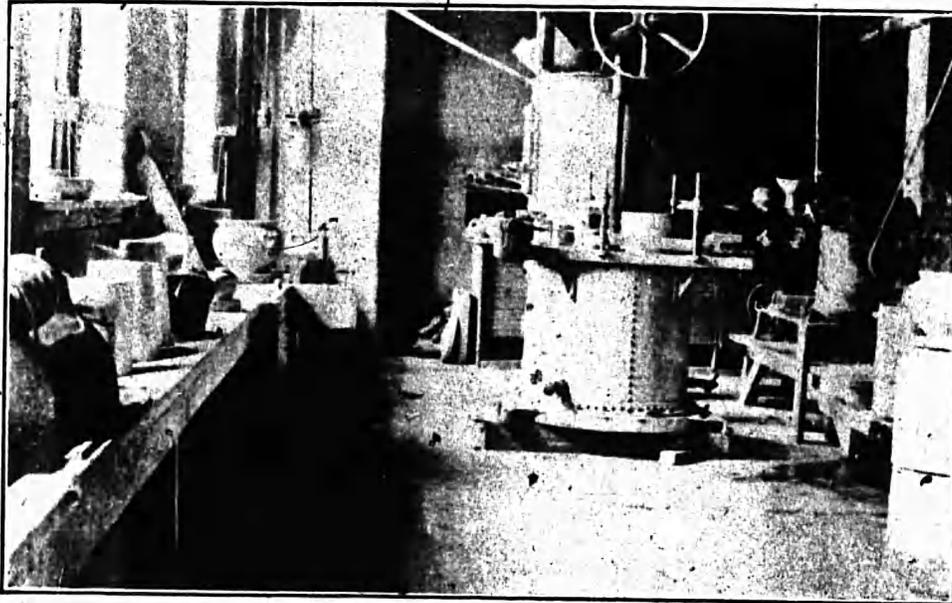
The rapid development of the tractor and its use on the farm during the past decade has made the gas engine and tractor courses fairly popular. However, the universal use of the automobile introduced the automobile mechanics course and made it the most popular of all. The 2-year courses, in general, are the most important of the noncollegiate instruction developments in recent

years. They are less specialized than a regular trade course and in briefer and more elementary form have some resemblance to the regular 4-year engineering courses, but still tend to emphasize hand-craft skill. In addition to automobile mechanics, the 2-year electrical, the 2-year mechanical, and a 2-year course for builders are gaining a degree of popularity and are meeting a real need. It is a question if the short architectural courses are meeting any demand. It would seem to the writer that a 2-year drafting course, including related work and permitting of specialization along architectural, mechanical, or structural lines, would open up a broader field.

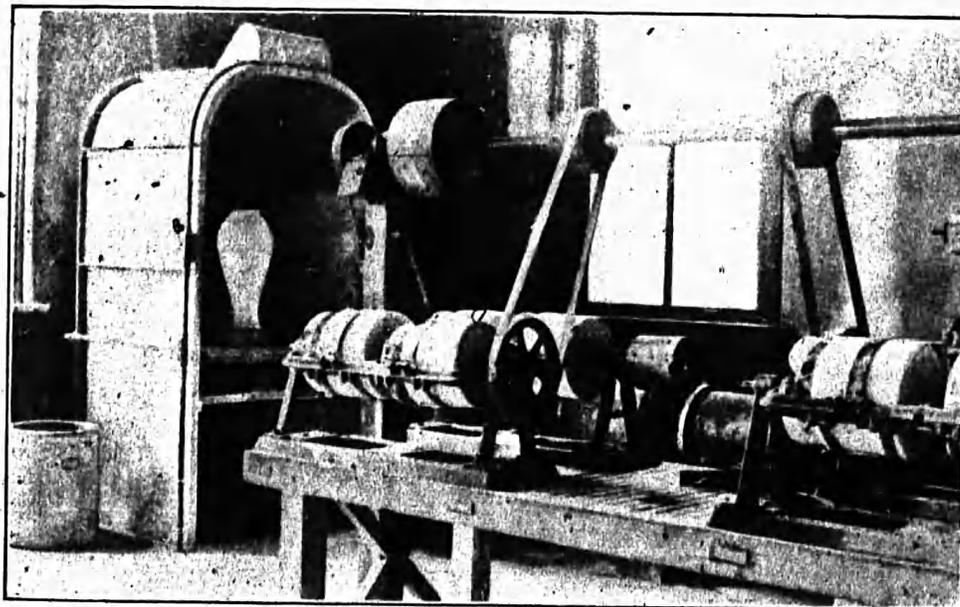
Among the very recent developments is a 2-year course in road construction which should equal or even surpass the others in point of usefulness. Immediately following the close of the World War, a nation-wide program of road building was launched under the Federal Act of 1916, "to aid the States in the construction of rural post roads and for other purposes." It was soon found that the program was handicapped through the fact that a sufficient number of trained men were hard to find. It was not so difficult to secure the staffs of engineers, as it was to find the skilled assistants to fill the minor positions of timekeepers, foremen, bridge, gravel, and materials inspectors, engineers' assistants, men for the road machinery, etc. The purpose of the road construction course is to meet these needs. It may be either collegiate, or noncollegiate, but the tendency is toward the noncollegiate, thus making it a course for the many rather than for the few. It is not to be considered temporary in its period of usefulness because the program of road construction will go on for many years, after which the labor of maintenance will employ many thousands.

The near future should see a 2-year trade and industrial course appear in the State college catalogs. The passage of the Smith-Hughes vocational educational bill, in 1917, created an increased demand for qualified teachers in vocational subjects. Four-year courses of this class have already appeared, but it is doubtful if they will soon become popular. A 2-year course, collegiate in character, should prove more effective, for the time being, in popularizing this type of training, and still tend to raise the quality of teachers going into such an important field of service. The noncollegiate classes would provide excellent supervised teaching and observation experience, and the shops and laboratories the general shop experience necessary to the teacher.

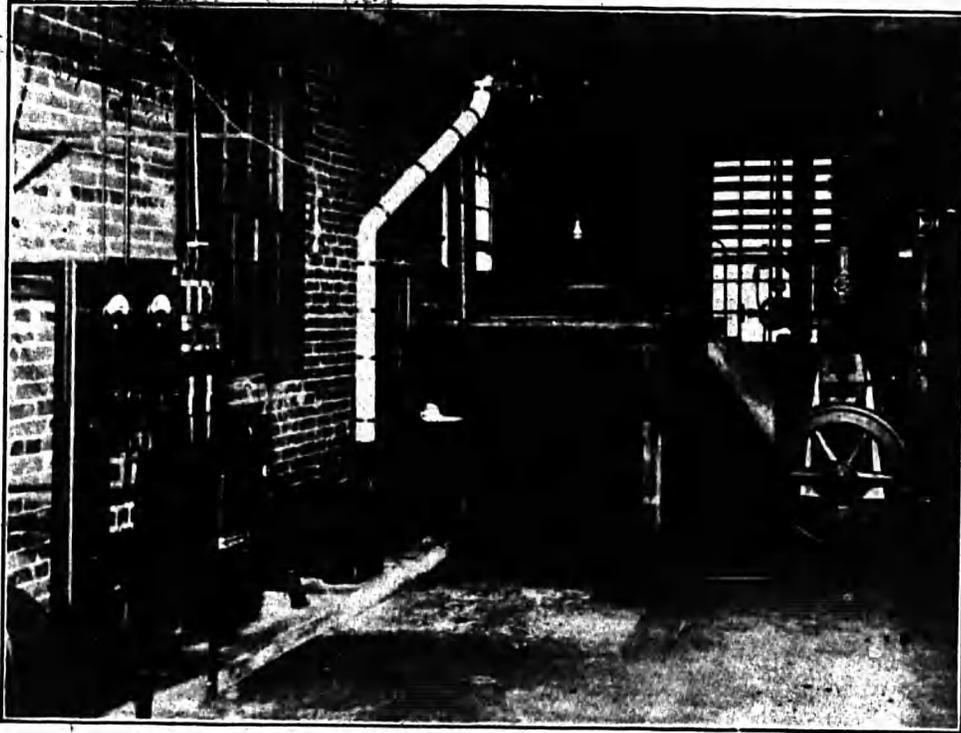
With regard to the general trend of short courses in recent years—if it may be said there is a trend—there seems to be a leaning toward the regularly organized and definitely outlined two-year courses. They tend to be less of the trade or very specialized types than of those giving fundamental and practical instruction of a



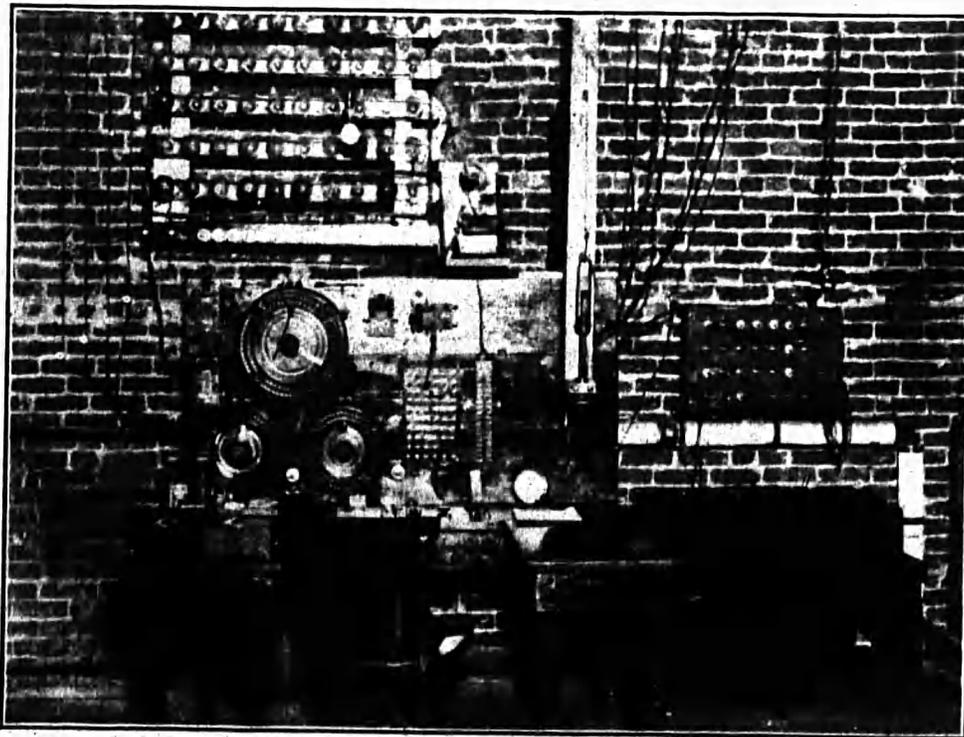
A. NEW CLAY-WASHING APPARATUS



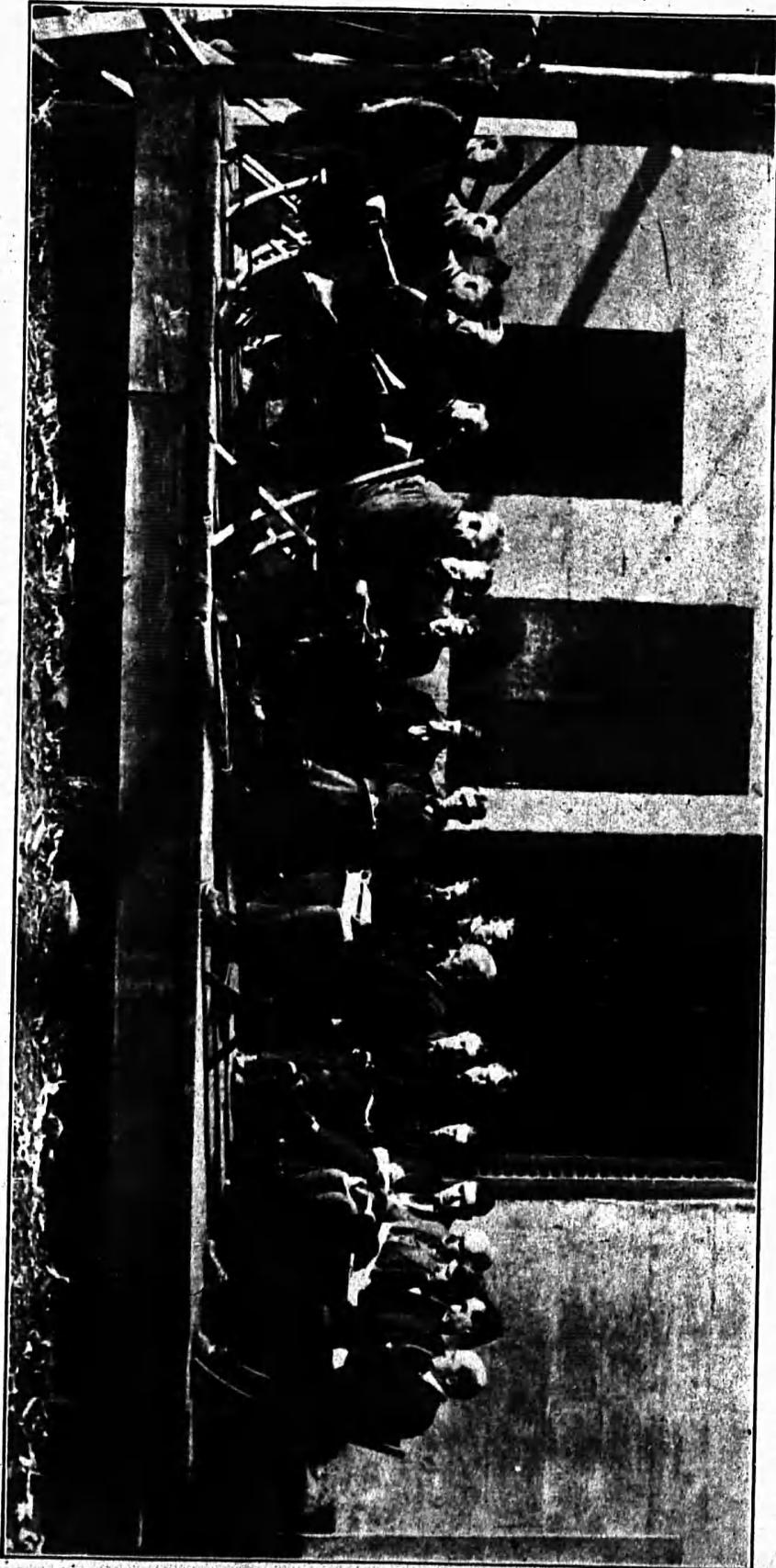
B. BALL MILLS FOR GRINDING GLAZES; SPRAY CABINET IN BACKGROUND
OHIO STATE UNIVERSITY, CERAMIC ENGINEERING DEPARTMENT



A. INTERIOR OF POWER PLANT .



B. TEMPERATURE CONTROL APPARATUS
PENNSYLVANIA STATE COLLEGE, ENGINEERING EXPERIMENT STATION



PENNSYLVANIA STATE COLLEGE. EXTENSION ENGINEERING CLASS
Valley Mold & Iron Co. employees enrolling for class work

more inclusive nature. They tend to educate as well as train in skill. They tend to train young men along lines of general importance to all sections of the country rather than along those of local importance. There are sufficient exceptions to these tendencies that a stronger statement expressing the situation would be both unsafe and unwise. In this connection it may be stated that the very short courses of from one week to three weeks' duration are also being more generally recognized and promoted with some degree of enthusiasm. But these are more of the convention order and the persons enrolled in them are regarded as visitors who enter but little into the life of the school.

As might be expected, all is not plain sailing in the teaching of the noncollegiate courses in institutions where the major interests are the four-year collegiate courses. We have still much to learn about the administrative details of this dual educational program, which will conserve the best interests of each class of instruction. In the matter of shop and laboratory instruction, for instance, both the four-year and noncollegiate students largely use the same equipment, in order to reduce the expense of duplication. Not infrequently, class instruction in some of the subjects to noncollegiates is given by instructors whose principal experience has been with collegiate students along similar lines. The results in both instances have not always been of the best. These difficulties, however, will be largely reduced when the noncollegiate enrollment reaches a point where it can expect to support its own equipment and complete staff. The present noncollegiate enrollment in those State colleges which offer such courses vary from 1 to 33 per cent of the total, with perhaps an average for all such colleges of 15 per cent.

In searching for a reason why more colleges are not offering short courses of serious import in the mechanic arts, a very common answer is, "There is no demand." This is hard to understand in view of the fact that industry is becoming more and more exacting in its demands for ability and skill among the employed. According to the last census, 37 per cent of all the employed above the age of 10 years are in industry. Despite the great increase in enrollment in our engineering colleges, their yearly quota of graduates fills but a tiny fraction of the total needs of industry. For every professional engineering graduate there should be 10 graduating from semitechnical courses similar to the two-year courses mentioned above, unless it be the expectation that the former continue to fill the positions which could be occupied by the latter. But the tendency of the four-year engineering courses is to advance farther in its professional standing. Already five-year courses above the high school are being considered seriously. This will leave a wider gap

than ever between the trade and the profession in the field of mechanic arts, which must be met by an intermediate course of education or training. This, it would appear, is the big field for non-collegiate instruction in our land-grant colleges and the tendency among the types of instruction now given, if only slight, points in this direction.

It can not be expected that the colleges should take care of all this class of training if developed to its best possibilities. The undertaking would be too big for that. But because of its outstanding position in education, because of its sympathetic contact with the people and their practical educational problems, the State college is in excellent position to take the leadership in a type of training which eminently belongs to an industrial age.

Chapter XIII

THE TRAINING OF TEACHERS IN THE FIELD OF INDUSTRIAL EDUCATION

By FRANK CUSHMAN

Chief, Industrial Education Service, Federal Board for Vocational Education

Forty-seven of the States are doing regularly organized work in teacher training for the preparation of new teachers and for the professional improvement of teachers in service in the field of industrial education. This work is being done under a number of different organizations, the State board for vocational education being responsible for the work in each case. The various agencies for doing this work may be classified as follows:

(1) State board and its agents.....	19
(2) State agricultural and mechanical colleges.....	19
(3) State universities separately organized from the agricultural and mechanical colleges.....	4
(4) Jointly by the agricultural and mechanical college and the State university, or other State institution.....	2
(5) State institutions other than universities or agricultural and mechanical colleges.....	2
(6) Jointly by State board and State normal schools.....	1
(7) States having no program.....	1

The land-grant colleges at this time are functioning officially as teacher training institutions in the field of industrial education in 21 of the 48 States. At the beginning of the development of the national program for vocational education a much larger number of

¹ In 11 of these States the A. & M. College is a department of the State university.

land-grant colleges set up training courses for trade and industrial teachers, but this number has decreased from year to year and in all probability will continue to do so.

Because of the qualifications demanded of teachers of trade and industrial subjects, it is particularly difficult to secure attendance of these people in residence courses at any institution, especially where the institution is located in a rural section of the State a considerable distance from the larger cities. The great majority of men and women who have the necessary trade qualifications to become candidates for teaching positions in vocational schools must be served, from the standpoint of teacher training, if served at all, in leisure-time classes organized in cities where they live. This is due to the fact that in most cases their responsibilities are of such a character that they can afford neither to take the time nor to spend the money necessary to secure residence training at a State institution.

A number of land-grant colleges, however, have rendered an important service in the field of industrial teacher training through summer courses in which provision has been made for an intensive program of work especially designed to serve the prospective or employed teacher who has but a limited amount of time to give to professional preparation or improvement work. In a number of instances both land-grant colleges and State universities have taken care of this situation by putting their instructors or professors out into the field on an extension or itinerant basis. In this way they have been able to reach the particular groups which needed their help.

To sum up, it may be said that the degree to which the land-grant colleges have effectively advanced State programs of industrial teacher training has been proportional to their willingness to extend their activities to the industrial centers of the State and conduct courses of training under such conditions and at such time as make it possible to reach the people to be served. Conversely, the teacher training work at land-grant colleges has been ineffective in proportion as continued effort has been made to secure an enrollment from the student body with the idea of carrying on strictly residence work at the institution. The number of cases where teachers have been trained in this way and have actually rendered service in the trade and industrial schools of the State is so small as to be negligible, except in one or two cases where the State has in some way provided scholarships. So far as we have information concerning scholarships for prospective industrial teachers, only two States have tried this plan. In both cases groups of prospective teachers were trained under exceedingly favorable conditions, but because of

the high per capita cost it is extremely doubtful if this plan will ever-become widely adopted.

Regardless of the agency which does the work of training trade and industrial teachers, it is probably true that the most effective work which has been done has been characterized by a willingness to carry the training to the people to be served rather than to try by some means or other to get people to enroll in residence courses at State institutions. As the work is now developing, it would appear that this is the line of development to be expected and in all probability is the sort of thing that should be encouraged.

Chapter XIV

THE ENGINEERING EXPERIMENT STATIONS

By R. L. SACKETT

Dean of the School of Engineering, Director of Engineering Experiment Station, and of Engineering Extension, Pennsylvania State College

1. INTRODUCTION

The engineering experiment stations of the land-grant colleges are the research laboratories in engineering and industrial fields of the colleges organized under the Morrill Act of 1862. Investigations were carried on by individuals in fields of special interest to them long before the formal organizations of these agencies was considered.

The agricultural experiment stations were organized at an early date, and problems involving drainage and road construction related to engineering were referred to the engineering divisions of the institutions for solution. Rural water supply, concrete construction, and electric light for farm buildings were later matters on which advice was sought.

Inventions and improvements in apparatus were submitted to the engineering schools for test and improvement.

Samples of raw materials were submitted for analysis, for advice in methods of manufacture, and new processes for developing natural resources were considered, experimented on, and advice given.

The publication of the results was in local engineering society journals, and occasionally in technical periodicals of national character. But the conclusions of important tests were often not published, and, in consequence, problems of interest in other States and of a similar character were repeated.

The success of the agricultural experiment stations of the land-grant colleges and the need for similar work along engineering and

industrial lines led to individual effort and the development of engineering experimental work, first, in a spontaneous movement and later in an organized State service.

It is impossible to say where the development of engineering research began; probably it grew at numerous land-grant colleges simultaneously and as a result of similar causes—*demand*.

The Association of Land-Grant Colleges was organized in 1887 as the Association of American Agricultural Colleges and Experiment Stations. The engineering divisions did not have an association until 1913, when the Land-Grant College Engineering Organization was formed. This delay, no doubt, was responsible in a measure for engineering experimental work not being promoted in an aggressive manner until about 1918. The proceedings of the "organization meeting" of that year mentions both engineering extension and the experiment station as two important adjuncts of engineering divisions.

2. EARLY ENGINEERING EXPERIMENTATION

The University of Wisconsin issued its first engineering bulletins in 1894, and so far as the writer has been able to discover is the pioneer in research and the publication of results of engineering studies in the experimental field. In the following year An Experimental Study of Field Methods in Stadia Surveying, by Prof. L. S. Smith, represents an early report of field or laboratory investigation published as a bulletin of the university. Thirty-eight bulletins had been published before 1910, representing various fields of practical study and laboratory experiment work. The authors included 32 different workers. Dean C. E. Turneure has been active in promoting the work of engineering research.

The University of Illinois was one of the first to take an active part in and to organize engineering investigations. In 1903 the trustees made an appropriation of \$77,000 for apparatus and for "experimentation in engineering problems." Prof. A. N. Talbot, who was very active in promoting this pioneer work, published Bulletin No. 1 on Tests of Reinforced Concrete Beams, in 1904. This was followed by High Speed Tool Steels, by Prof. L. P. Breckenridge, in 1905; Drainage of Earthworks, by Prof. Ira O. Baker, in 1906; Tests of Reinforced Concrete Beams, and Tests of Concrete in Shear and of Bond, by Professor Talbot, in 1906. In all, 39 bulletins had been published before 1910. The names of 32 different experimenters and authors appear on these bulletins.

At the Iowa State College a fund of \$10,000 was provided in 1913 for engineering research. At that time the first bulletins, three in

number, were in the hands of the printer. The first was a study of the "Cost of production of power for plants of different design and different size." The second was the "Result of three years' work in the study of temperatures inside the masses of concrete in bridges," and the third gave "The results of about six years' work on the loads carried by drain pipes and sewer pipes in ditches." The above is from a statement made in 1913 by Dean Marston, who has been responsible for the initiation of research work in the engineering field at Iowa State College.

3. THE ORGANIZATION OF ENGINEERING EXPERIMENT STATIONS

Early investigations at the land-grant colleges in the engineering field were carried on under serious difficulties. Federal funds were not available as they were for agricultural research. The engineering faculties were overworked with their regular teaching duties. In addition they were asked to promote numerous outside activities, such as good roads movements over the States, drainage, municipal improvements, and to aid in the inception of engineering extension, which also had no funds and was dependent in the beginning on the aid given by the regular teaching faculty. Also much very valuable work was done by studious professors who were overworked and did not publish the results of their studies. Frequently funds were not available to pay the cost of bulletins.

While a large amount of valuable work had been done and is still being done where an organized research staff does not exist, still it is generally recognized as desirable to organize the engineering research work in order that such work may be urged and so that means of carrying on the routine tests may be assured, thus relieving the teacher-investigator of this burden.

There was an increasing appreciation of the importance to American industry of organized research. It was necessary to train men who had the special qualities which an able research man must have. The function of the college experiment station is to carry on certain basic research and to train men for this service.

The University of Illinois was the first land-grant institution to organize an engineering experiment station. It was established by act of the board of trustees on December 8, 1903, in recognition of the need for more accurate knowledge of the materials and processes of engineering and the conservation of those resources upon which engineering industries depend.

At the time the engineering experiment station was established, the trustees made an appropriation of \$77,000 for the purchase of

apparatus to advance work in engineering research and for experimentation in engineering problems. The work of the engineering experiment station was to be under the direction of a board, consisting of the dean and four professors in the college of engineering.

In 1905, however, Prof. L. P. Breckenridge was appointed director of the engineering experiment station, and filled the position with distinguished ability until 1909, when he resigned to accept a position at Yale University. Upon the resignation of Professor Breckenridge, Dean W. F. M. Goss was appointed director and served from 1909 to 1917. Since the appointment of Dean Goss as director of the station in 1909, the dean of the College of Engineering has always served as the director of the engineering experiment station. Dean Goss was succeeded in 1917 by Dean C. R. Richards, and when the latter resigned in September, 1922, Dean Milo S. Ketchum was appointed his successor.

Iowa State College organized its station in 1904. No other station was formally founded until in 1909, when the University of Missouri organized its staff, and, in 1910, Kansas State College of Agriculture and Mechanic Arts created its engineering experiment station. Then followed Ohio State University in 1913. The University of Texas and the University of Wisconsin followed in 1914; the University of Maine and the Pennsylvania State College in 1915.

In some instances, no special funds were set aside by the State or the board of trustees. The station had no special facilities set aside for research but used the apparatus of the various departments or made its own. Often there were no special headquarters and no persons giving full time to research. Gradually the older stations have justified their existence and now have equipment, offices, special research laboratories, and full-time staffs in addition to the large number of teachers who direct or give part time to work on problems of special interest.

The following table will give information of a general character. It will be noticed that in January, 1922, there were annual appropriations amounting to \$318,760; that there were 53 full-time and 324 part-time investigators. Thirty-four bulletins were published in 1921; 55 in 1922; and 332 in all had been distributed to thousands of those interested.

Statistics of engineering research at the land-grant colleges of Continental United States, November, 1921

[From the Engineering Experiment Station Record. Bulletin, January, 1922, Series 2, No. 1.]

State	Date station was founded	Annual engineering research funds	Staff		Engineering research bulletins			
			Full time	Part time	Total	Total engineering experiment station	Station, 1920	Station, 1921
1	2	3	4	5	6	7	8	9
Alabama.....	None.			0	0	0	0	0
Arizona.....	None.			0	0	0	0	0
Arkansas.....	1921	0	0	3	0	0	0	0
California.....	None.		0		18	0	0	0
Colorado.....	1919	\$10,900	1	3	21	0	0	0
Connecticut.....	None.		0			0	0	0
Delaware.....	None.		0			0	0	0
Florida.....	None.		0		0	0	0	0
Georgia.....	None.		0			0	0	0
Idaho.....	None.		0		2	0	0	0
Illinois.....	1903	93,110	10	56	124	124	3	17
Indiana.....	1917	25,000	5	8	14	10	3	14
Iowa.....	1904	45,000	7	17	62	62	3	4
Kansas.....	1910	6,750	1	33	10	10	0	1
Kentucky.....	None.	3,000	1	1		0	0	0
Louisiana.....	None.					0	0	0
Maine.....	1915	0	0	0	10	7	0	0
Maryland.....	1920	6,500	0	8	0	0	0	10 ²
Massachusetts.....	1920	75,000	11	100	?	11	40	0
Michigan.....	None.	0			?	0	0	0
Minnesota.....	None.		0	13	?	0	0	0
Mississippi.....	None.		0			0	0	0
Missouri.....	1909	7,500	0	4	22	22	2	1
Montana.....	None.		0			0	0	0
Nebraska.....	None.		0			0	0	0
Nevada.....	1921		0	6	11 ⁴	11	0	11
New Hampshire.....	None.		0			0	0	0
New Jersey.....	None.		0	0	0	0	0	0
New Mexico.....	None.	0	0		0	0	0	0
New York.....	None.		4			0	0	0
North Carolina.....	None.	1,000	0			0	0	0
North Dakota.....	None.		0			0	0	0
Ohio.....	1913	14,800	2	9	20	12	1	8
Oklahoma.....	None.		0			0	0	0
Oregon.....	None.	0	0		0	0	0	0
Pennsylvania.....	1915	8,200	5	4	30	30	2	10 ²
Rhode Island.....	None.		0	0	0	0	0	0
South Carolina.....	None.	0	0	0	0	0	0	0
South Dakota.....	None.		0			0	0	0
Tennessee.....	1921	1,500	0	9		0	0	0

¹ Agricultural experiment station conducts irrigation research. State bureau of mines, with engineering dean as director, conducts geological and ore dressing research, employing 5 full-time and 4 half-time men.

² Division of publications, engineering section, publications not necessarily research.

³ Branch of Colorado Agricultural Experiment Station. Funds given are the average from July 1, 1920, to July 1, 1922.

⁴ Maintain road materials' laboratory. Mining research is at school of mines.

⁵ Seven or eight by Jan. 1, 1922.

⁶ Four or five by Jan. 1, 1922.

⁷ Besides fees.

⁸ Hoping for early organization.

⁹ About.

¹⁰ Two or three by January, 1922.

¹¹ Maintain division of industrial cooperation and research, which is practically an engineering experiment station, but its research is not exclusively engineering and its functions include industrial cooperation. The data given here are for staff and funds and publications devoted to engineering research. Hence the figures are approximate only as no exact division could be made as between engineering research and general scientific research.

¹² Prospects fair for early organization.

¹³ Prospects very good for early organization.

¹⁴ There are prospects of early organization.

¹⁵ One or two by Jan. 1, 1922.

¹⁶ Cornell carries on engineering research actively but has no formal organization

¹⁷ Prospects good for early organization.

¹⁸ Two or three by Jan. 1, 1922.

¹⁹ \$800 to \$2,500.

Statistics of engineering research at the land-grant colleges of Continental United States, November, 1921—Continued

State	Date station was founded	Annual engineering research funds	Staff *		Engineering research bulletins			
			Full time	Part time	Total	Total engineering experiment station	Sta- tion, 1920	Sta- tion, 1921
1	2	3	4	5	6	7	8	9
Texas.....	1914	3,000	0	3	3	3	1	1
Utah.....	1918	10	0	0	0	0	0	0
Vermont.....	None.	1,500	0	2	0	0	0	0
Virginia.....	None.	0	0	0	0	0	0	0
Washington.....	1919	5,000	1	5	2	1	0	2
West Virginia.....	1921	6,000	0	12	2	1	0	1
Wisconsin.....	1914	5,000	1	28	59	9	0	0
Wyoming.....	None.	0	0	0	0	0	0	0
Total.....	19	318,700	53	324	400	332	55	34

* Twenty-four bulletins published but only 3 of real research character.

¹ Active work postponed by after-war deficits.

² Expect trustees to organize engineering experiment station in near future, with but small amount of annual funds at first. Two research fellowships of \$700 and \$900 established in 1920.

³ Now taking steps to begin work. Organization to be by college authorities for present. One bulletin now in view for 1922.

⁴ One or two by station in 1921 and one earlier.

⁵ Seven other States report prospects favorable for the early organization of engineering experiment stations.

⁶ Estimated to Jan. 1, 1922.

4. BULLETINS

While many of the earlier publications were library studies or embodied engineering experience gained in the usual course or practice or observation, the later ones, and, in fact, the great majority of them, represent thorough study and the soundest scientific results of careful investigation.

Some of the work is monumental and deserves personal mention. Prof. Arthur N. Talbot, of the University of Illinois, is the author of 21 bulletins, and "nearly as many more have been written under his direction. He is responsible for 6 of the first 14 bulletins, and he has continued to be responsible for nearly the same proportion of the bulletins which have been issued to date." (May, 1923.)

The engineering experiment station at Purdue University was authorized by the board of trustees in May, 1917, under the direction of Dean Benjamin. The following statement by Dean Potter, director since 1920, explains the plan pursued there, which is somewhat different in its details from that usually followed:

The publications of the station are of two classes, bulletins and circulars. The bulletin presents the results of original investigation in the laboratory or in the field, is rather technical in character, and is of interest usually to a limited number of engineers and scientists working in that particular field.

The circular, on the other hand, gives a compilation and discussion of existing data, embodying but little original work, but putting in a convenient form timely information on the subject studied.

The circulars are more general and popular in character than the bulletins and sometimes reach a larger circle of readers.

The following bulletins and circulars have been issued:

Pamphlet. The Engineering Experiment Station of Purdue University, 1917. (Out of print.)

Circular No. 1. Lightning protection, by C. F. Harding, 1918.

Bulletin No. 1. Flow of water through one and one-half-inch pipe and valves, by F. W. Greve, Jr., 1918.

Bulletin No. 2. Electric ranges, by C. W. Piper, 1919.

Bulletin No. 3. Coefficient of discharge of sprinkler nozzles, by F. W. Greve, Jr., and W. E. Stanley, 1919.

Bulletin No. 4. Electric-driven waterworks in Indiana, by D. D. Ewing and G. C. Blalock, 1919.

Bulletin No. 5. The carburetion of gasoline, by O. C. Berry and C. S. Kegerreis, 1920.

Circular No. 2. Preservative treatment of wood poles, by R. V. Achatz, 1920.

Bulletin No. 6. Sewage disposal for residence and small institutions, by R. B. Wiley, 1920.

Bulletin No. 7. Tests of road materials of Indiana, by testing materials staff, 1921.

Bulletin No. 8. Flow of water through spiral riveted steel pipe, by F. W. Greve and R. R. Martin, 1921.

Bulletin No. 9. The production of nitric oxides and ozone by high-voltage electric discharges, by K. B. McEachron and R. H. George, 1922.

Bulletin No. 10. Truck-operating costs, by Ben H. Petty, 1923.

There have been 11 publications on civil engineering subjects, 12 on electrical engineering, 45 on mechanical engineering, and 1 on chemical engineering subjects.

The purposes of one station—that of the Pennsylvania State College—is stated as follows:

(a) To make available data on subjects which will be of use to the people of the State.

(b) To investigate the engineering problems presented.

(c) To establish a bureau of information having at its command complete data on research subjects.

(d) To consider the investigation of the specific problems for or in connection with industries outside the State when proper support is given for such work.

(e) To investigate a subject, in order to corroborate old or produce new data.

(f) To train young engineers for research work.

A BRIEF REVIEW OF THE WORK

The engineering experiment station of the Pennsylvania State College had its inception about 1910 in the desire of some of the members of the faculty to be of the greatest possible service to the community and to the college. With this in mind they managed, in spite of heavy teaching schedules, to devote some time to research

and to the presentation of the results in bulletin form for the information of the public.

Thirty bulletins have been issued by the station. Some of the subjects relate particularly to civil and sanitary engineering and others to mechanical, electrical, architectural, and industrial engineering.

The following are some of the problems worked up and the results published as a bulletin:

1. Economics in the use of coal.
2. Practical suggestions on building construction.
3. Blower heating systems for factory and shop buildings.
4. Heat treatment and welding of steel.
5. Comparison of heat insulating values of various building materials.
6. Flour mill investigations, especially those relating to grain dust explosions, the results of which have been published as a bulletin of the United States Department of Agriculture.
7. Household electric light and power plants.
8. Sanitation and sewage.

WORK IN HEAT TRANSMISSION

Our engineering experiment station is best known for its work in heat transmission, in which its equipment and facilities are probably second to none in the country. This work has been undertaken as a problem in science, but the ultimate purpose has been to adapt the results directly to a useful end. With the higher cost of food products, cold storage has become more important and is, in part, a question of insulation. Our problem has been to aid in the standardization of the method of calculating and determining the heat transmission through cold storage and other walls.

PRESENT PROJECTS

The projects under way include the following:

1. Standardization of methods and apparatus for heat transmission tests.
2. Comparison of the results of the oxidation of sewage in an open and in a closed sprinkling filter.
3. The possibilities of grain dust fires occurring from electric lamps.
4. Relative merits of liquid chlorine and calcium hypochlorite as disinfectants of sewage filter effluents.
5. A new application of the induction motor to signaling devices.
6. A study of creamery wastes in connection with sewage disposal.
7. Heat transmission and efficiency in steam boiler tubes.
8. The economics in the transportation of vegetables and fruits.

5. IMPORTANT INVESTIGATIONS UNDER WAY

The following titles indicate the general character of the most important researches now being carried on or just completed:

Colorado Agricultural College: Treatment of alkali and other waters for domestic purposes.

University of Florida: Effect of Florida climate on construction materials.

University of Illinois: (1) *Investigation of the fatigue phenomena of metals.*—This investigation has been carried on in cooperation with the Engineering Foundation and the National Research Council, and the General Electric Co., and more recently with the assistance of the Allis-Chalmers Co., the Copper and Brass Research Association, and other industrial concerns. The results of the investigation have been published in Bulletins Nos. 124 and 136. The contributions for this investigation to date approximate \$100,000.

(2) *Investigation of the stresses in chilled cast-iron car wheels.*—This investigation has been carried on in cooperation with the Association of Manufacturers of Chilled Iron Car Wheels. The results of the investigation have been published in Bulletins Nos. 129, 134, and 135.

(3) *Investigation of warm-air furnaces and furnace heating.*—This investigation has been carried on in cooperation with the National Warm Air Heating and Ventilating Association. The results of the investigation thus far have been published in Bulletins Nos. 112, 117, and 120. The annual appropriation for carrying on this work is \$8,000.

(4) *Investigation of the friction losses and power requirements in the proposed ventilating system for the New York and New Jersey vehicular tunnel to be constructed under the Hudson River.*—This investigation has been carried on in cooperation with the United States Bureau of Mines, the New York State Bridge and Tunnel Commission and the New Jersey Interstate Bridge and Tunnel Commission. These experiments have been completed, and the results will be published in a forthcoming station bulletin.

(5) *Investigation of the coking of coal.*—This investigation has been carried on in cooperation with A. T. Hert, of Louisville, Ky. The results have proved to be of great value and have been published in various bulletins of the engineering experiment station under the authorship of Prof. S. W. Parr.

(6) *Investigation of coal mining in Illinois.*—This investigation is carried on in cooperation with the United States Bureau of Mines, and the Illinois State Geological Survey. The results of this investigation have been published in a series of 41 bulletins; 15 of which have been published by the engineering experiment station, 17 by the Illinois State Geological Survey, and 9 by the United States Bureau of Mines.

(7) *Investigation of the manufacture of gas from Illinois coal.*—This investigation is being carried on in cooperation with the Illinois Gas Association. This association contributes the funds to pay the salary of two research graduate assistants in gas engineering.

(8) *Investigation of the viscosity and electrical conductivity of glass.*—This investigation has been carried on in cooperation with the National Research Council and the Corning Glass Works. The results of this investigation will be published in a forthcoming station bulletin.

(9) *Investigation of the stresses in railway track.*—This investigation is carried on in cooperation with committees of the American Society of Civil Engineers and the American Railway Engineering Association. Prof. A. N. Talbot is the chairman of the committee on track of each of the above societies. The work has been done at the engineering experiment station under the direction of Professor Talbot, with funds supplied by the two societies above named and the American Railway Association.

(10) *Investigation of the effect of the size of coal on locomotive performance.*—This investigation has been carried on in cooperation with the International Railway Fuel Association. The results of this investigation are given in Bulletin No. 101.

Purdue University: (1) *Test of road materials.*—This investigation consisted of a survey of the deposits of road materials in the various counties, including stone and gravel pits.

A special series of investigations was also made for the Indiana Sand and Gravel Producers' Association.

Bulletin No. 7, Tests of road materials of Indiana, gives the results of tests made over a period of 20 years.

(2) *Hydraulics*.—Valuable contributions have been made through research in the hydraulic laboratory, as follows: Flow of water through 1½-inch pipe and valves (Bulletin No. 1); Loss of head in 1-inch pipe; Flow of water through spiral riveted pipe (Bulletin No. 8); Discharge of water from sewage sprinkler nozzles (Bulletin No. 3); Measuring water by a parabolic weir; Characteristics of sewage sprinkler nozzles (now in progress).

Many other investigations of less importance have been started. (See complete list under Projects.)

(3) *Carburetion*.—Extensive studies are being made on problems of carburetion.

Bulletin No. 5, The mixture requirements of internal-combustion engines, was the first of a series of bulletins to be published.

The foregoing bulletin sets forth the results of hundreds of accurate tests, showing the character of the mixture which will give the best results in an engine, considering its richness, its dryness, and its temperature.

The continued investigation of the subject of carburetion involves:

(a) A study of the best mechanical means of atomizing the fuel and mixing it with the air.

(b) A development of the best means of heating and drying the mixture when using different kinds of fuel. This involves the design of an intake and exhaust manifold that will accomplish the results which our long series of tests shows are necessary for perfect carburetion.

(c) A study of the fluidity of liquid fuels.

(d) The amount of vaporization of liquid fuels at varying degrees of temperature.

Bulletin No. 11, Effect of speed on mixture requirements, is now in press.

(4) *Tractor testing*.—A well-equipped tractor testing laboratory is now carrying on extensive tests on tractors. At the present time extensive tests are being made on Government tractors for the United States Army, viz:

(a) Those made with the tractor to be tested mounted on the moving platform and run in its usual manner transmitting its energy through the platform, the wheels, and the geared train to the generator which acts as a brake.

(b) Those in which the engine and main driving shaft of the tractor are connected more or less directly with the generator, either with or without the use of the transmission gears, the tractor wheels and the moving platform being "cut out."

(5) *High voltage and nitrogen fixation research*.—The most important investigation undertaken in the electrical laboratory is that concerning the production of nitric acid from the nitrogen of the air. A new electrical process for the production of nitric acid has been experimented upon for several years, and quite recently has reached such a point as to warrant the publication of a progress report which will be forthcoming in an early bulletin.

Other investigations now being carried on are: (a) Design, construction, and test of an experimental high tension transmission line; (b) ozone production; (c) alternating current corona discharge.

(6) *Electrical apparatus*.—Commercial electrical testing and the calibration of watt-hour and other meters are being undertaken upon a much larger scale than ever before. The standardization laboratories of the School of Electrical Engineering are equipped with primary standard electrical instruments which are regularly checked by the Bureau of Standards at Washington, and which

are available for the accurate calibration of all types of electrical instruments. An oscillograph, by means of which the wave form of voltage and current in electrical apparatus and circuits may be photographed, has been very extensively used for both outside testing and laboratory investigation.

(7) *General*.—Work is under way in a number of special investigations, while in some the data are practically complete. The following is a partial list of these: (a) Friction and endurance of motor lubricating oils; (b) the slippage and windage of high speed belts and pulleys; (c) composition of so-called standard liquid fuels; (d) combustion of crushed and pulverized coal; (e) effect of load and power factors on central station rates; (f) farm lighting plants; (g) adaptation of electrical energy for service in the house and on the farm; and (h) electrification of grain elevators.

(8) *Radio communication*.—Now that radio communication may be undertaken without restriction, a 2-kilowatt licensed radio station has been completed for experimental investigation in this important field. Its sending radius is approximately 1,000 miles. During the past winter California and the Canal Zone received messages sent out by the Purdue station.

(9) *Railway work*.—Apparatus specially constructed for determining the impact of flat wheels on rails has already been utilized to measure and record the impacts at different speeds, loads, and widths of spot.

The resistance of steel rails to shocks at temperatures ranging from the normal to 24° below zero is another subject under investigation.

(10) *Cooperative tests*.—Two tests in cooperation with the Bureau of Public Roads are now being carried on in the testing materials laboratory.

(11) *Fatigue of concrete*.—Concrete is being subjected to alternate loading by means of a special machine and behavior studied.

(12) *Ball test*.—Slabs are subjected to loads, such as truck wheels would cause on a pavement, and the effect of this load upon the concrete studied by means of the pressure necessary to a small steel ball to one-half its depth.

Iowa State College: A study of existing industrial conditions in Iowa; safe bearing values of large bridge rollers; culvert load investigations; chemical determination of the cement content of concrete; economic theory of highway improvement.

Kansas State Agricultural College: Lewis tractors for nonstandard gear teeth; durability of belt lacings of fastenings.

University of Maine: Study of Maine sands as regards cement necessary to give certain tensile and compressive strengths; comparison of 14 and 28 day test on mortars; abrasion test for Portland cement mortars; classification of Maine sands as regards mineral content and shape of particles, surface area and fineness modulus; a study of the variability of different mixes of sand and cement in compression; development of a field and laboratory method for determining the workability of concrete.

University of Nevada: Investigation of the lubricating properties of oil made from Elko, Nev., shale.

New Mexico College of Agriculture and Mechanic Arts: Investigation of static electrical conditions in the atmosphere in New Mexico; adobe bricks for building construction; a study of audio frequency amplification; simple radio receivers.

The Pennsylvania State College: Heat transmission through surfaces.

Rhode Island State College: Durability of belt fastenings.

The University of Tennessee: Highway economics and highway transport; Tennessee road materials; power for coal mines.

University of Vermont: Investigation of the methods of heating residences.

The State Agricultural College of Colorado: Heat conductivity of commercial wall board.

University of Georgia: The effective life of topsoil, sand, clay, and similar roads on the State system of Georgia; tractor survey of Georgia.

University of Illinois: Influence of dissolved gases upon the properties of glass; the measurements of viscosity of glass at high temperatures; stresses in statically indeterminate frames; tests of reinforced concrete arch; experimental study of explosions of gaseous mixtures; investigation of twist drills; reheating of compressed air; air-steam mixtures; analysis of stresses in boiler heads; warm-air furnace research; tunnel gas investigation no. 3, or determination of friction and power losses in concrete air ducts; an experimental investigation of the thermal and chemical phenomena occurring in the cylinder of the internal combustion engine; capacity of soil pipes and their ventilation; test of residential septic tank; test of cast-iron column; stresses in unsymmetrical sections; compression and cross-bending tests of steel columns; strength and action of bolted and riveted connections; study of methods of standardizing testing machines; stresses in bumped boiler heads; strength and ductility of steel under rapid loading; fatigue phenomena of metals; pressure through granular materials; reinforced concrete columns; web stresses in beams; general investigation of concrete; measurement of mobility of fresh concrete; subsidence of surface due to coal mining; coal washing; breakage of coal; haulage practice; ignition point of fuels; pounding and wearing of trolley cars; effect of pressure between trolley wire and collector and the loss in collecting current from a trolley wire; antiseptic treatment of timber used in freight-car construction; friction of railway car journals; an investigation of the properties of chilled car wheels; tractive effort of steam locomotives; tests of road-oiling methods.

University of Minnesota: Radiant heat from direct radiators; heat transmission through insulating materials; value of marl as a binder for sand roads.

Pennsylvania State College: Heat transmission and efficiency in steam boiler tubes; a new application of the induction motor to signaling devices; comparison of the results of the oxidation of sewage in an open and in a closed sprinkling filter.

Rhode Island State College: Adaptation of domestic heating appliances to burning of wood.

University of Tennessee: Concrete tests (reported originally as cement tests); some properties of Kentucky and Tennessee coal; central power plants; air infiltration; vapor tension of mixtures of volatile liquids.

State College of Washington: Series of street-lighting systems; irrigation power from current wheels along the Snake and Columbia Rivers.

CONCLUSION

The above sketch does not do justice to many institutions and pioneer investigators responsible for the inception, organization, and marked growth of research in engineering at our land-grant colleges. The results show the need for and the value of such work to science and to industry.

The number of organized stations is certain to increase materially in the next few years, and the contributions to engineering knowledge are certain to be a material aid in the economic development of industry.

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