GRADUATE WORK IN ENGINEERING IN UNIVERSITIES AND COLLEGES IN THE UNITED STATES

By

WALTON C. JOHN

Senior Specialist in Higher Education
Office of Education

and

H. P. HAMMOND

Society for the Promotion of Engineering Education

Bulletin, 1936, No. 8

UNITED STATES DEPARTMENT OF THE INTERIOR - *Harold L. Ickes*, Secretary
OFFICE OF EDUCATION - - - - - - - - - - - - *J. W. Studebaker*, Commissioner

UNITED STATES GOVERNMENT PRINTING OFFICE - - - - - - - - WASHINGTON : 1936

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - Price 15 cents

CONTENTS

	Page
FOREWORD	VII
INTRODUCTION	IX
CHAPTER I: DEVELOPMENT OF GRADUATE WORK IN ENGINEERING IN THE UNITED STATES	1
Historical	1
CHAPTER II: PRESENT STATUS OF GRADUATE WORK IN ENGINEERING	5
Institutions offering graduate work	5
Enrollments and degrees conferred	5
Comparison with other science divisions	9
CHAPTER III: ADMINISTRATION OF GRADUATE WORK IN ENGINEERING	10
General administrative control	10
Official in responsible charge	11
Nature of departmental organization	11
Relationship of administration of graduate work in engineering to other graduate work	13
Most desirable form of administrative and supervisory organization	15
Control by graduate school	15
Control by committee	16
Independent or other forms of control	16
Graduate work in engineering during the summer term	17
Cooperation among institutions	18
CHAPTER IV: TEACHING STAFF AND GRADUATE WORK	20
Problems of administration	20
Adjustment of teaching loads	20
Extra compensation	21
Visiting and exchange professors	21
Recruitment and training of teachers	22
Elevation of standards of instruction	23
Self-advancement of teachers	23
Conferring of advanced degrees on members of the institution's own staff	24
CHAPTER V: GENERAL CHARACTERISTICS OF THE PROGRAM OF GRADUATE WORK IN ENGINEERING	26
Proportion of major fields in graduate programs	26
Work in science, engineering, and humanistics required for the master's degree	26
Work in science, engineering, and humanistics required for the doctor's degree	28
Opinions as to place of economics and economic factors in courses leading to the master's degree in engineering	29

CHAPTER V—Continued.
Proportion of major fields in graduate programs—Contd. Page
Opinions as to place of economics and economic factors in courses leading to the doctorate in engineering 30
Relation of work in course to work in research 31
Master's degree 31
Doctor's degree 32
Extent of the use of the seminar in graduate courses in engineering 33
Master's degree 33
Doctor's degree 34
Plan of prescribed majors and minors 34
Master's degree 34
CHAPTER VI: COOPERATIVE AND PART-TIME GRADUATE WORK 39
CHAPTER VII: ADMISSION REQUIREMENTS 45
Specifications imposed as to the quality of undergraduate records of applicants for admission to graduate study 45
Procedure as to admission of graduates of nonengineering curricula, and of engineering curricula other than the proposed field of graduate work: systems of prerequisites 46
Basis of evaluation of credentials of graduates of other institutions 47
Evaluation as to specific courses pursued 47
Evaluation as to the general standing of the institution 48
Appraisal of the quality of the undergraduate record of the applicant 48
Policies and methods pursued 48
Administration of admission procedures 48
Admission to candidacy for a degree 49
Master's degree 50
Doctor's degree 51
CHAPTER VIII: GRADUATION REQUIREMENTS—THE THESIS—EXAMINATION METHODS—DEGREES 52
Time in residence for higher degrees 52
Transfer of credits from other institutions 53
Graduation requirements in quantitative terms 54
Master's degree 54
Doctor's degree 54
Classification of graduate courses 55
Foreign language requirements 57
Master's degree 57
Doctor's degree 58
Views as to the foreign language requirement 58
The thesis 59
Examination methods 60
Advanced degrees in engineering 62
CHAPTER IX: RELATIONSHIP OF GRADUATE WORK TO UNDERGRADUATE WORK 65

	Page
CHAPTER X: SUBSIDIZED GRADUATE WORK, SCHOLARSHIPS, FELLOWSHIPS, ETC	69
Scholarships and fellowships classified according to type	69
CHAPTER XI: IMPROVEMENT OF GRADUATE WORK IN ENGINEERING	71
Views of correspondents as to general policies and methods	71
Cooperation among institutions in the development of graduate work in engineering	73
CHAPTER XII: INDUSTRY AND THE GRADUATE OF ADVANCED COURSES	76
CHAPTER XIII: INTERPRETATION OF THE SURVEY BY THE COMMITTEE ON GRADUATE WORK IN ENGINEERING OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION	82
Graduate work in the general program of engineering education	82
General characteristics of graduate work	84
Admission and graduation requirements	87
Problems of administration	90
Problems of the teaching staff	91
Selection of teachers	92
Subsidized graduate work in relation to teaching	93
Cooperation among institutions	95
Conclusion	96
APPENDIX: COPY OF QUESTIONNAIRE AND FORWARDING LETTER	99
INDEX	113

FOREWORD

Among important services to the industrial and professional life of the Nation are those being rendered by trained engineers. The responsibility of giving adequate training for those who must take an active part in the material development of the United States is one that not only rests on the colleges and universities but also on technical and educational associations that have taken seriously to heart the problems that are involved in the betterment of engineering service.

Among organizations that have given the closest attention to these problems is the Society for the Promotion of Engineering Education. This society in recent years has done much to improve the conditions of undergraduate instruction in engineering and has seen fit to begin to investigate the rapidly changing situation in the field of graduate work.

The Office of Education has been pleased to undertake a survey of graduate work in engineering in cooperation with the Society for the Promotion of Engineering Education, particularly because graduate work in all its phases is passing through an important period of readjustment.

The responsibility of conducting such a survey was assigned to Dr. Walton C. John, senior specialist in higher education, in this Office, who is also a member of the Society. With the valuable assistance of Prof. H. P. Hammond, chairman of the committee on graduate work of the Society for the Promotion of Engineering Education and other members of the committee, the survey has been completed and the results brought together in this bulletin.

It is hoped that the findings will serve the purpose of enabling the engineering schools of this country to meet more adequately the demands for advanced study in engineering.

BESS GOODYKOONTZ,
Assistant Commissioner.

INTRODUCTION

This survey of graduate work in engineering has for its objective the presentation of the development and present status of graduate work in engineering in this country. The relatively rapid changes that have taken place in engineering education in recent years have caused greater activity and increased responsibility in graduate departments, making necessary new adjustments to meet the needs of increased numbers of advanced engineering students.

In order that adequate standards for higher engineering degrees may be maintained, a study of current practices in graduate work in engineering was considered to be highly desirable by many leading engineering educators.

In the spring of 1933 the Society for the Promotion of Engineering Education approached the Office of Education with the purpose of undertaking a survey of graduate work in engineering on a Nation-wide basis.

In view of the importance of the project the Commissioner of Education approved a plan of cooperative effort between the Society and the Office.

METHOD OF THE SURVEY

The principal basis of the survey is a comprehensive questionnaire which was prepared by the committee on graduate work of the Society for the Promotion of Engineering Education in cooperation with the Office of Education and was sent out on October 15, 1934, to 155 institutions granting degrees in engineering. The engineering schools gave prompt response. Of these, 72 were eliminated because they did not offer advanced degrees in engineering. The survey is, therefore, the result of the analysis of the returns of 83 schools that grant the master's degree in engineering. Of these, 34 also grant the doctor's degree in engineering. The institutions which are the basis of the survey are as follows: [1]

1. University of Alabama, University.
*2. University of Arizona, Tucson.
3. University of Arkansas, Fayetteville.

[1] Institutions starred offer work leading to the doctorate in engineering.

*4. Stanford University, Stanford University, Calif.
*5. University of California, Berkeley.
*6. California Institute of Technology, Pasadena.
*7. University of Colorado, Boulder.
*8. Colorado School of Mines, Golden.
*9. Yale University, New Haven, Conn.
10. University of Delaware, Newark.
*11. Catholic University of America, Washington, D. C.
12. University of Florida, Gainesville.
13. Georgia School of Technology, Atlanta.
14. University of Idaho, Moscow.
*15. University of Illinois, Urbana.
16. Armour Institute of Technology, Chicago, Ill.
*17. Purdue University, Lafayette, Ind.
*18. State University of Iowa, Iowa City.
*19. Iowa State College, Ames.
20. University of Kansas, Lawrence.
21. Kansas State College, Manhattan.
22. University of Louisville, Louisville, Ky.
23. University of Kentucky, Lexington.
24. Louisiana State University, Baton Rouge.
25. Tulane University of Louisiana, New Orleans, La.
26. University of Maine, Orono.
*27. Johns Hopkins University, Baltimore, Md.
*28. Worcester Polytechnic Institute, Worcester, Mass.
*29. Massachusetts Institute of Technology, Cambridge.
*30. Harvard University, Cambridge, Mass.
*31. University of Michigan, Ann Arbor.
32. Michigan State College, Lansing.
*33. Michigan College of Mining and Technology, Houghton.
34. Detroit Institute of Technology, Detroit, Mich.
*35. University of Minnesota, Minneapolis.
*36. University of Minnesota School of Mines and Metallurgy, Minneapolis.
*37. Missouri School of Mines and Metallurgy, Rolla.
*38. University of Missouri, Columbia.
39. Montana State College, Bozeman.
40. Montana School of Mines, Butte.
41. University of Nebraska, Lincoln.
42. University of Nevada, Reno.
43. Stevens Institute of Technology, Hoboken, N. J.
*44. Rutgers University, New Brunswick, N. J.
45. Princeton University, Princeton, N. J.
46. Syracuse University, Syracuse, N. Y.
47. University of Rochester, Rochester, N. Y.
*48. Rensselaer Polytechnic Institute, Troy, N. Y.
49. College of the City of New York, New York.
*50. New York University, New York.
51. Clarkson College of Technology, Potsdam, N. Y.
*52. Cornell University, Ithaca, N. Y.

*53. Columbia University, New York, N. Y.
*54. Polytechnic Institute of Brooklyn, Brooklyn, N. Y.
55. University of North Carolina, Chapel Hill.
56. North Carolina State College, Raleigh.
57. University of North Dakota, University.
*58. Ohio State University, Columbus.
*59. University of Cincinnati, Cincinnati, Ohio.
60. Case School of Applied Science, Cleveland, Ohio.
61. Oklahoma A. & M. College, Stillwater.
62. University of Oklahoma, Norman.
63. Oregon State College, Corvallis.
*64. Pennsylvania State College, State College.
*65. University of Pennsylvania, Philadelphia.
*66. University of Pittsburgh, Pittsburgh, Pa.
67. Lafayette College, Lafayette, Pa.
*68. Carnegie Institute of Technology, Pittsburgh, Pa.
69. Bucknell University, Lewisburg, Pa.
70. Brown University, Providence, R. I.
71. South Dakota State College, Brookings.
72. University of Tennessee, Knoxville.
73. A. & M. College of Texas, College Station.
74. Texas Technological College, Lubbock.
75. University of Texas, Austin.
76. Rice Institute, Houston, Tex.
77. University of Utah, Salt Lake City.
78. University of Virginia, Charlottesville.
79. Virginia Polytechnic Institute, Blacksburg.
80. University of Washington, Seattle.
81. Washington State College, Pullman.
*82. West Virginia University, Morgantown.
*83. University of Wisconsin, Madison.

From one of the schools listed only partial information was returned so that the full report rests primarily on the data from 82 schools.

In the preparation of the text and in partially tabulating the returns of the questionnaires the Office of Education is very greatly indebted to Prof. H. P. Hammond, chairman of the committee on graduate study of the Society for the Promotion of Engineering Education, who prepared chapters I, II, IV, VI, IX, and X. Chapters III, V, VII, VIII, and XI were largely prepared by the Office. Professor Hammond was also of great assistance in making essential revisions and in unifying the entire text from the standpoint of the professional approach of the engineer and engineering educator. The Office is also appreciative of the assistance rendered by Prof. Carlton E. Tucker of Massachusetts Institute of

Technology, who wrote the section on examination methods in chapter VIII. It is likewise thankful to George B. Thomas, personnel director, Bell Telephone Laboratories, for the special contribution, Chapter XII, entitled "Industry and the Graduate of Advanced Courses." Chapter XIII is an interpretation of the results of the survey and was prepared by the committee on graduate study of the Society for the Promotion of Engineering Education.

To facilitate reference to the questionnaire which is found in the appendix, the number of each question that is basic to a particular chapter is found in the footnote at the beginning of each chapter. Owing to lack of returns, no answers are found for questions 13 and 16.

INTRODUCTORY STATEMENT BY THE COMMITTEE ON GRADUATE WORK OF THE SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION

In recognition of the increasingly important, even vital, place that graduate work is rapidly assuming, a special committee of the Society for the Promotion of Engineering Education was appointed in 1931 to consider this phase of engineering education and the problems incident thereto. This committee, under the chairmanship of Dean Dexter S. Kimball of Cornell University, devoted a year to the study of general principles and policies relating to graduate study in engineering and rendered a report as a result of its deliberations at the annual meeting of the Society in June 1932. This report concluded with the recommendation that consideration be given to the making of a comprehensive survey of the status and trends in the field of graduate instruction. The present survey and report are the outcome of that recommendation.

Upon taking up its work, the new committee charged with the conduct of the survey sought means by which it might be conducted, and invited the United States Office of Education to cooperate by gathering comprehensive data relating to graduate work in engineering colleges and by publishing a summary of the information so obtained. The committee, as its share of the project, undertook to prepare an accompanying report analyzing and interpreting the data and giving conclusions and recommendations. It may be remarked at this point that these two parts of the under-

taking, originally conceived as fairly distinct and separate, have largely merged as the project has developed and as the present report has been prepared.

The committee's invitation was cordially received by Dr. George F. Zook, then Commissioner of Education, and by members of the staff of the Office of Education, and the project was launched in accordance with the general plan mentioned above. It has now been brought to successful completion as marked by the appearance of this report.

The committee on behalf of the Society for the Promotion of Engineering Education acknowledges with appreciation and gratitude this latest evidence of a continued policy of generous cooperation which has led the Office of Education to undertake an important, in fact indispensable, share in several of its major undertakings, including the biennial compilation of statistics on enrollment, begun in 1923; the study of engineering curricula, made as a part of the comprehensive investigation of engineering education which the Society conducted from 1924 to 1929, inclusive; and the special supplementary survey of engineering education, made in 1931. The present survey, begun under Dr. Zook's Commissionership, has been continued and completed under that of Dr. J. W. Studebaker, to whom, as well as to Dr. Bess Goodykoontz, Assistant Commissioner of Education, to Dr Fred J. Kelly, chief of the Division of Higher Education, and especially to Dr. Walton C. John, senior specialist in higher education, grateful acknowledgment is made of the obligation of the Society for carrying to completion a project that is believed to be of the highest value to engineering education at large.

The Committee on Graduate Study, Society for the Promotion of Engineering Education,

T. R. Agg,
Edward Bennett,
Dexter S. Kimball,
Parke R. Kolbe,
Thorndike Saville,
George B. Thomas,
Carlton E. Tucker,
H. P. Hammond, *Chairman.*

April 2, 1936.

GRADUATE WORK IN ENGINEERING IN UNIVERSITIES AND COLLEGES IN THE UNITED STATES

CHAPTER I: DEVELOPMENT OF GRADUATE WORK IN ENGINEERING IN THE UNITED STATES

HISTORICAL

SO FAR as can be learned the first earned degree in engineering that we should now call an advanced degree was awarded by Yale University in 1873. It is an interesting fact that this was not the master's degree, but the degree of doctor of philosophy and it is worth recording in the annals of engineering education that this first engineering doctorate was conferred on Augustus Jay DuBois, Ph. B., Yale University (1869); C. E., Yale University (1870). The doctoral dissertation was "Strains in Framed Structures." This work was published by the House of Wiley in 1875. Dr. DuBois later became professor of civil engineering in the Sheffield Scientific School of Yale University, a post he occupied for many years.

The second institution to award an advanced degree for work in engineering was the School of Mines of Columbia University. This degree, also Ph. D., was conferred on Ellwyn Waller, A. B. (1867) and A. M. (1869), Harvard University, E.M. (1871) Columbia University. Dr. Waller's dissertation was on disinfection and disinfectants as applied to mining operations.

Apparently it was not until more than 20 years later that another institution awarded an earned doctorate in engineering, Cornell University, in 1896.

The first master's degree in engineering appears to have been awarded by Iowa State College of Agriculture and the Mechanic Arts in 1879.

Although some graduate work in engineering has been done for more than 60 years, only 6 institutions in the entire country, so far as has been learned in the course of this survey, conferred advanced degrees prior to 1890. At

about the turn of the century, however, the offering of work beyond the baccalaureate began to spread rapidly. By 1920 at least 40 institutions had conferred master's degrees and 11 had conferred doctor's degrees. These figures are probably incomplete since not all colleges are able to state the year in which their first advanced degrees were conferred.

The most rapid expansion of graduate work has taken place since 1920, when the need of industry for men of more advanced scientific and technological preparation began seriously to be felt, and when the colleges, following the era of most rapid expansion in numbers and facilities, had consolidated their positions somewhat and began to push forward into the field of advanced work. Contrary to what has often been said, the effects of the depression have not been to cause an increase in graduate enrollments in engineering education as a whole, though they have probably contributed to the spread of enrollments among institutions. In the 10 years from 1920 to 1930, 21 additional colleges began to offer work for the master's degree, and 10 were added to the number offering work for the doctorate. In the half-decade since 1930 this rate of expansion has been maintained; 10 additional colleges have begun to offer work for the master's degree, and 7 have added programs for the doctor's degree. Nearly as many institutions have inaugurated programs of advanced work since 1920 as had done so in all the previous history of engineering education in this country.

Although approximately 40 institutions were offering graduate work in 1920, such work had not really begun to assume a position of great magnitude in engineering education. In the year 1921–22 there were but 368 students enrolled in graduate courses and but 178 advanced degrees were awarded. There were fewer candidates for master's degrees 15 years ago than there are for doctor's degrees now.

The following tabulation shows the growth of graduate enrollments since 1921–22:

Year	Total number of students enrolled in graduate work	Total number of advanced degrees conferred
1921–22	368	178
1925–26	1, 014	267
1930–31	2, 939	418
1931–32	3, 961	1, 002
1933–34	2, 756	1, 197

It is to be noted that the figures for enrollments and graduations up to and including 1931–32 included all enrollments and advanced degrees in many of the engineering schools and colleges that supplied the figures; they included, therefore, an unknown number of enrollments and degrees in certain nonengineering fields of work that are offered by some engineering colleges, such as chemistry, metallurgy, geology, architecture, biology, and public health and in one or two instances business administration. The figures for 1933–34 omit all enrollments and graduations except those strictly within the field of engineering proper. Apparently, while there has been a fairly large decrease in enrollments since the peak year of 1931–32, the decrease has not been nearly as large as the table indicates.

It may be noted also that number of degrees conferred is a better index of magnitude and growth than is number of enrollments, because the number of degrees conferred gives a suitable weighting to numbers of part-time students where gross numbers of enrollments does not. The number of degrees conferred has increased without interruption for the past 12 years.

Another significant index of the growth in relative magnitude of graduate work in recent years is the fact that in 1925–26 the ratio of the number of graduate students to the number of seniors of the previous year was approximately 1 to 9, while in 1933–34 the ratio was 1 to 4.8.[1]

Until 1912 all graduate work in engineering appears to have been offered on the customary all-residence plan. In that year Carnegie Institute of Technology offered the first program of part-time work in evening hours. Shortly there-

[1] The ratio of master's degrees to bachelor's degrees conferred in 1933-34 was approximately 1 to 9.

after Union College began offering special part-time graduate courses for engineers employed by the General Electric Co. In 1919 Massachusetts Institute of Technology inaugurated its cooperative course in electrical engineering, and followed in 1920 with the establishment of its Practice School of Chemical Engineering. Massachusetts Institute of Technology has also offered a cooperative course in railroad engineering and is about to embark upon a similar program in mechanical engineering. Wisconsin first offered extramural graduate work in metallurgical engineering in 1924 for graduates employed by metallurgical industries in Milwaukee, and inaugurated a similar program in electrical engineering in 1925. The Polytechnic Institute of Brooklyn established the first curriculum in its present extensive evening program of graduate work in 1925. The University of Pittsburgh and the Westinghouse Electric & Manufacturing Co. inaugurated their cooperative arrangement of graduate work in 1927. In the same year the University of Cincinnati extended its program of cooperative engineering education into the graduate field. During the past 5 years several other institutions have established various types of part-time programs of graduate work, as will be mentioned more fully in a later section of this report.

The last 2 decades, during which the most rapid development and many of the most important changes in graduate work in engineering have taken place, have been marked by growth in enrollments, by expansion of graduate work into special professional and technical fields, by inauguration of new types of programs, and by a general increase in diversification of the entire program of advanced study in American engineering colleges. Not the least significant aspect of this development has been the offering of graduate programs on the cooperative plan and the provision of opportunities for advanced study to employed graduates, thus providing, in certain localities, means by which the young engineer can continue his formal education during the period of his professional apprenticeship. This is a significant step in the relationship of engineering education to the profession at large, and emphasizes the importance of the programs of postacademic professional training that are being advocated and promoted by the Engineers' Council for Professional Development.

CHAPTER II: PRESENT STATUS OF GRADUATE WORK IN ENGINEERING [1]

INSTITUTIONS OFFERING GRADUATE WORK

AT THE present time 83 out of a total of 155 institutions in the country that offer work in engineering leading to baccalaureate degrees provide programs of graduate study. While the number of institutions offering advanced work is not greatly different from that in 1925, enrollments in many of these institutions have materially increased during the past 10 years. Furthermore, in 1925 graduate work in engineering was limited almost exclusively to programs leading to the master's degree. Enrollments were concentrated largely in but 10 institutions. While there is still considerable concentration of students in a small proportion of the institutions (two-thirds of all graduate students of engineering are enrolled in but 10 institutions), the spread of enrollments is increasing rapidly.

Work for the doctorate is more limited in its spread among the colleges than is work for the master's degree. Nevertheless, 34 institutions offered such work in 1933–34, and doctoral candidates were enrolled in 27 of these. Four institutions alone, however, conferred more than half of all doctorates in engineering in that year.

ENROLLMENTS AND DEGREES CONFERRED

A summary of enrollments and of advanced degrees conferred in 1933–34 is given in table 1.

The total number of candidates for the master's degree was 2,301, as compared with 455 for the doctor's degree. While there has been a decrease in number of candidates for the master's degree since 1931–32, the number of candidates for the doctor's degree has continued to increase.

[1] Based on questions 1, 2, and 3 of the questionnaire. See appendix.

TABLE 1.—ENROLLMENTS AND GRADUATIONS IN GRADUATE WORK, 1933–34

Enrollments in work for the master's degree	Chemical engineering		Civil engineering						Mechanical engineering		Mining and metallurgical engineering						Mechanics								
	Chemical engineering	Petroleum refining	Civil engineering	Architectural engineering	Municipal and sanitary engineering	Railway engineering	Irrigation engineering	Electrical engineering	Mechanical engineering	Fuel engineering	Mining engineering	Geological engineering	Petroleum production engineering	Metallurgical engineering	Ceramic engineering	Aeronautical engineering	Theory and applied mechanics	Mechanics and hydraulics	Industrial engineering	Agricultural engineering	General engineering	Engineering Physics	Naval architecture	Unclassified	Total
Full-time students	205	....	240	5	3	3	2	342	260	....	33	10	8	72	16	82	1	12	27	8	5	5	13	....	1352
Part-time fellows, etc.	83	....	87	6	....	....	....	124	115	....	3	2	4	26	2	14	6	6	8	7	3	....	....	....	496
Cooperative students	....	....	....	....	....	....	....	85	8	6	....	....	....	....	....	....	....	....	....	....	....	....	....	1	100
Evening students	22	6	88	....	....	....	....	128	50	....	....	....	....	27	....	....	....	....	....	....	....	....	....	28	349
Others	....	....	1	....	....	....	....	1	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	4
	310	6	416	11	3	3	2		434	6	36	12	12	126			7	18							
Total	316		435					680	440		186				18	96	25		35	15	8	5	13	29	2301
Master's degrees conferred	175	....	193	1	1	2	1		244	6	7	....	5	40			4	5							
	175		198					301	250		52				9	16	9		19	23	3	....	....	16	1071

Enrollments for the doctor's degree	Chemical engineering			Civil engineering	Electrical engineering	Mechanical engineering	Mining and metallurgical engineering		Ceramic engineering	Mechanics		Industrial engineering	General engineering	Gas engineering	Aeronautical engineering	Unclassified	Total
	Chemical engineering	Petroleum refining	Electro-chemistry				Mining engineering	Metallurgical engineering		Theory and applied mechanics	Mechanics and hydraulics						
Full-time students	94		1	70	84	31	5	37	8	1	3	5	1	1	2	7	350
Part-time fellows, etc	15	1		9	24	17	5	14	1	1	2						89
Cooperative students					6	3											9
Others	1			2	1	3											7
Total	110	1	1	81	115	54	10	51	9	2	5	5	1	1	2	7	455
	112									7							
Doctor's degrees conferred	46	1	1	8	21	20	1	12	4	2	5				2	3	126
	48									7							

Contrary to what might have been expected fewer fields of work are offered for advanced degrees, at least as shown by catalog designation; than there are for first degrees (38 compared with 79). While 38 fields of work are offered for the master's degree, students are enrolled in but 24 of them as shown in table 1.

The distribution of enrollments, by fields of work, for the master's degree differs appreciably from that for the bachelor's degree. The ratio of number of candidates for master's degrees in 1933–34 to number of seniors of the preceding year in some of the major engineering curricula is as follows: Metallurgical engineering, 1:2.05; Aeronautical engineering, 1:3.9; Electrical engineering, 1:4.4; Chemical engineering, 1:5.4; Civil engineering, 1:6.2; Mining engineering, 1:6.3; Mechanical engineering, 1:6.6; average, all curricula, 1:5.75.

Enrollments for the doctor's degree differ among departments even more strikingly than do enrollments for the master's degrees. It will be noted from table 1 that chemical engineering occupies a position of much greater relative importance in this field, and that it is far in the lead in number of doctor's degrees conferred; more doctorates were conferred in chemical engineering in 1933–34 than there were in any other two fields combined. A majority of these degrees were conferred by two institutions alone—University of Michigan and Columbia University. If the doctorates in chemical engineering conferred by these two institutions were to be deducted from the total of all engineering doctorates, the picture as to the magnitude of the higher phases of advanced work in engineering would be quite a different one.

It is of some significance to note the relationship of part-time enrollments of various kinds to full-time enrollments, the number of part-time students being about three-eighths the number of all graduate students and the proportion of cooperative and evening students being about one-sixth of the total. These ratios are not nearly as large as they were 5 years ago because of a marked decrease in enrollments in some of the special types of graduate programs.

COMPARISON WITH OTHER SCIENCE DIVISIONS

No means are available for determining the relative position of work for the master's degree in engineering with similar work in other fields of science. The relative standing of work for the doctorate may be judged, however, by comparison of the number of degrees conferred in various branches of science. Until 1928 fewer than 10 doctorates were conferred in engineering per year; it was far down the list of the sciences in this regard. By 1930 engineering had risen to eighth place. In 1933 it stood seventh; and in 1934, if the figures gathered by this survey be substituted for those of the Association of Research Libraries (which has taken over the compilations formerly made by the National Research Council), engineering is in second place with 126 degrees, being exceeded only by chemistry, which is far in the lead of all other branches of science with 590 degrees. Physics is third in the list with 121.

CHAPTER III. ADMINISTRATION OF GRADUATE WORK IN ENGINEERING [1]

GENERAL ADMINISTRATIVE CONTROL

CONSIDERABLE diversity of practice exists among institutions in the form of organization under which graduate work in engineering is administered. This is due both to differences as to type of institutions and as to the nature of the graduate programs themselves. The form of organization often differs, for example, between universities and polytechnic institutes, and between those offering the customary all-residence programs and those offering part-time or cooperative programs.

In a considerable majority of institutions work for both the master's degree and the doctor's degree is administered by the same individual, group or school; in a few institutions the two programs are administered by different agencies, for example, by the dean of engineering in the case of work for the master's degree, and by the dean of the graduate school in the case of work for the doctor's degree.

In those institutions where the master's degree in engineering is conferred but the doctor's degree is not, it is found that in 15 cases control rests in the graduate school while in 12 cases it is in the college of engineering. In 6 other cases it is under groups that may be considered as joint agencies of the entire college or institution, such as special committees representing the entire college, the registrar, or a special committee on advanced degrees. In cases where control is exercised by the graduate faculty or graduate school the engineering faculty is represented on the faculty or in the school.

Considering all cases of work for the master's degree, whether or not work for the doctorate is also offered, with the exception of the 6 cases last-named, in 30 institutions the control of work for this degree is under the graduate school and in 30 institutions it is under the college or division of

[1] Based on questions 4 and 15 of the questionnaire. See appendix.

engineering. Among the latter group are included those institutions which offer no work except engineering and the closely related fields of physical science, i. e., the separately organized polytechnic institutes, the schools of mines, and the like.

Work done for the doctor's degree is found to be under the control of the graduate school in 20 instances and under the college of engineering in 11 instances.

OFFICIAL IN RESPONSIBLE CHARGE

The official in responsible administrative authority over graduate work in engineering also differs considerably among institutions as shown by the following tabulation, which reflects not only differences in type of institution and of program of work but also the influence of individuals and of traditional form of organization.

TABLE 2

Individual or group	*Number of cases*
(a) *Institutions offering work for the master's degree only*	
Dean of graduate study or school	15
Chairman of Committee	12
Dean of Engineering	8
Dean of engineering and chairman of committee	4
Head of department	3
Dean of graduate school and dean of engineering, jointly	3
Special faculty adviser	1
(b) *Institutions offering work for both doctor's and master's degrees*	
Dean of graduate study or school	11
Chairman of committee	9
Dean of engineering	6
Head of department or major professor	2
Joint supervision, as by dean of graduate school and dean of engineering	5
Instances where different individual is in control of master's work and of doctor's work	8

NATURE OF DEPARTMENTAL ORGANIZATION

Graduate work and undergraduate work in engineering usually come under the same departmental organization. Although some answers to this part of the inquiry are not

altogether clear this appears to be true for at least 77 of the 82 institutions under consideration. This does not imply that there are not different methods of control exerted over the departments as to the conduct of both graduate and undergraduate work in engineering. The following illustrates various practices:

University of California.—There are no colleges in the graduate school, rather—several departments of engineering, i. e., department of C. E., department of E. E., etc. Each department is represented by an adviser who administers the details in regard to the work of the graduate students in cooperation with the dean of the graduate division.

University of Colorado.—The head of each department in cooperation with the dean of engineering assumes full responsibility under the dean and the executive committee of the graduate school.

Yale University.—There is a director of graduate studies in each department. He is responsible to the dean of the graduate school for the M. S. and Ph. D. degrees and to the dean of engineering for the higher degrees in engineering.

University of Illinois.—Nominally there is no departmental organization for graduate work which is supposed to be conducted by individual professors authorized and controlled by the graduate school. Actually, course offerings are determined yearly by departments, except that new ones require authorization by the graduate school.

State University of Iowa.—The heads of departments are advisers in cooperation with the dean of the college of engineering. General procedures are determined by the graduate faculty of the university.

Johns Hopkins University.—Graduate work in engineering is under the direction of the advisory board of the school of engineering, which is made up of the president of the university, the dean and assistant dean of the school of engineering, all full professors of engineering, the dean of the college of arts and sciences, and certain professors from the faculty of philosophy.

Massachusetts Institute of Technology.—Graduate work and graduate students in each department are in charge of a special committee on graduate students appointed annually by the head of the department who may be the chairman.

Montana School of Mines.—Graduate work is under the supervision of the "graduate and research committee" made up of department heads in major fields. The major professor directs the work in detail.

Columbia University.—For the master's or equivalent degrees, there is no difference in departmental organization between undergraduate and graduate work. For doctorates, the work is under the dean of the graduate faculties, who appoints a special committee for each candidate, usually with the department head as chairman.

University of Pittsburgh.—In undergraduate work department heads are responsible to the dean of the engineering school. In graduate work department heads function directly with the dean of the graduate school. The dean of engineering acts in an advisory capacity only.

University of Wisconsin.—The work of the graduate school as a whole is organized not only according to departments but also according to divisions, each of which includes allied departments.

RELATIONSHIP OF ADMINISTRATION OF GRADUATE WORK IN ENGINEERING TO OTHER GRADUATE WORK

The vast majority of replies relating to the topic of this section indicate that graduate work in engineering and graduate work in fields of science closely related to engineering are administered by the same form of organization, whether it be through a committee, departments, or other type of control. Some replies indicate the degree of coordination or of correlation which it is aimed to secure in administering the two programs, but most replies do not. Some of the practices showing the nature of the relationships and of practices in this connection are given herewith:

Catholic University of America.—Graduate work in the school of arts and sciences is administered and supervised by the graduate council of the graduate school of arts and sciences. Engineering is entirely distinct.

State University of Iowa.—If courses in science departments are closely related, certain of such science courses may be included with the major field in engineering. About five-sixths of the program is comprised in the major.

Johns Hopkins University.—The faculty of engineering and the advisory board of the school of engineering are independent; but, in general, the methods of instruction and the requirements for advanced degrees have been patterned

on those set up in the school of higher studies for the degrees of master of arts and Ph. D. Intimate relations are maintained with the school of higher studies through representatives on the boards of each school from the faculty of the other. All full professors of the school of engineering are members of the board of university studies—a large board of 71 members which makes the arrangements for instruction of advanced students and for the examinations for the Ph. D. and M. A. degrees. Several members of the board of university studies are also members of the advisory board of the school of engineering.

Candidates for the degree of doctor of engineering usually elect as subordinate subjects courses in chemistry, mathematics, and physics. The dissertations for candidates for the Ph. D. degree are subject to two referees—one in engineering and one in a cognate science.

Massachusetts Institute of Technology.—Graduate work in the department of science is organized similarly to that in engineering. Both schools report to the faculty through the committee on the graduate school. The schools of architecture, science, and engineering function as a unit in the graduate school under its dean.

Columbia University.—For the master's degree there is the closest cooperation between the engineering and science departments. For the doctorates the administration and/or supervision of engineering and science degrees is identical.

University of Cincinnati.—There is complete coordination of work in engineering with that of science and other related departments. Those majoring in engineering can minor or take courses in science and mathematics. Those majoring in chemistry, etc., may minor or take courses in engineering.

University of Pennsylvania. Moore School of Electrical Engineering.—Graduate students may elect, and all candidates for the doctor's degree do elect graduate courses in physics and/or chemistry. There is cooperation but no formal relationship between administration and supervision of graduate work in electrical engineering and that in other sciences.

University of Pittsburgh.—The relationship is informal. Each department head is in responsible charge of the work of his department and deals directly with heads of science and other allied departments.

MOST DESIRABLE FORM OF ADMINISTRATIVE AND SUPERVISORY ORGANIZATION OF GRADUATE WORK IN ENGINEERING

With few exceptions the replies to the question inquiring as to views on the topic named above fall in three categories which are named in order of the number of their proponents. Comparison of replies with statements of form of organization existing in the institution indicates a strong tendency to endorse the form of organization with which the individual replying is associated or, as is natural, that which he has established.

1. A large proportion of replies favor the inclusion of graduate work in engineering under the general administration of the graduate school of the university. This type of administration is favored in the larger institutions of complex organization. About half of the institutions under discussion are included in this category.

2. In at least 10 institutions, control of graduate work in engineering through a general committee on graduate studies with the dean of engineering included as a member is favored as a form of organization. This plan is recommended by some of the middle-size or small universities and by some of the polytechnic institutes.

3. In 5 cases it is recommended that graduate work in engineering should be entirely independent of other forms of graduate administration.

Examples of each of the types recommended are given herewith:

CONTROL BY GRADUATE SCHOOL

1. We are satisfied to have our graduate work in engineering under the dean of the graduate school. But work for professional degrees in engineering should be left practically to the college of engineering.

2. Our plan seems to be entirely satisfactory. The graduate work in engineering is placed on the same basis as graduate work in all departments, i. e., under the graduate school, but it is supervised by the departments concerned and also has the general supervision of the dean of engineering.

3. The existing arrangement tends to bypass the college of engineering as such. This has certain administrative disadvantages. However, it is excellent for standardizing the requirements for degrees and for ultimately building up an independent graduate college.

4. We consider some centralization of administration and supervision of graduate work necessary even in an institution of such diverse activities as ours, and feel that by considerable utilization of the committee on which the several schools are represented we secure adequate adaptation to the differences in programs and objectives.

5. Success in an institution of this kind depends on the active cooperation of the faculty. This cooperation can only be assured if the graduate school has a separate budget and if the faculty serving the school receive at least part of the remuneration for their graduate work and consequently are responsible to the graduate school administration.

CONTROL BY COMMITTEE

1. Where the number of graduate students is small a committee on graduate instruction is most desirable. Where numbers are large there should be a dean of graduate students.

2. Administration of graduate work by a dean of graduate study who is chairman of an executive committee from the general faculty and immediate supervision by the engineering department has worked out very well and is believed desirable for similar institutions where the faculty is pracically the same for graduate and undergraduate work.

3. A representative graduate committee seems to be the best way to direct and control graduate work. Such a committee covers all of the fields of the institution and helps correlate the entire graduate work; that is, the standards of the various colleges are consistent in their requirements.

INDEPENDENT OR OTHER FORMS OF CONTROL

1. It is believed that graduate work leading to the equivalent of a master's degree is well administered under the engineering school. For the doctor's degree, if given, it would seem better to have the students come under the dean of the graduate school.

2. It is believed that some slight improvement might be realized in the doctorate work if such were directly under the faculty of engineering.

3. Experience here has shown that graduate work in engineering and commerce should be under the faculty of the college of engineering and commerce with special committees, just as is the practice in the undergraduate work.

4. We consider the departmental organization such as is in vogue at Harvard and the University of Chicago superior to the usual graduate school having a faculty made up largely of men carried on budgets of independent schools.

5. The present system is satisfactory (graduate-school control) where cooperation is good. However, a situation can be visualized where administration would be best if in the engineering college exclusively. Here the term college relates to undergraduate work only.

GRADUATE WORK IN ENGINEERING DURING THE SUMMER TERM

The following 21 institutions indicate that they offer graduate courses in engineering during the summer:

University of Alabama.
University of Florida.
University of Illinois.
Iowa State College.
State University of Iowa.
Kansas State College.
University of Maine.
Massachusetts Institute of Technology.
University of Michigan.
University of Minnesota.
University of Nebraska.
University of North Carolina.
Ohio State University.
University of Cincinnati.
Carnegie Institute of Technology.
University of Pittsburgh.
South Dakota State College.
University of Tennessee.
A. and M. College of Texas.
Virginia Polytechnic Institute.
West Virginia University.

In a few instances graduate work is permitted during the summer under special circumstances such as (1) by special request; (2) when the professor is in residence and willing to supervise the work; (3) when students wish to use laboratories for research work on theses; and similar cases.

Fifteen of the twenty-one institutions listed report enrollments in their graduate programs in engineering during the summer of 1934. These included a total of 504 course enrollments—a small number in comparison with similar enrollments in several other divisions of higher education. The total number of graduate courses in engineering offered was 79. These included a considerable number of courses having the same designations as undergraduate courses, such as water supply and masonry and foundations; a great many theses; and some special types of work provided for summer terms only, such as those in river hydraulics, theory of hydraulic models, special courses in mechanics, etc.

To summarize, it may be said that graduate work in engineering has assumed a place of some importance in summer terms in a very few institutions only and that it does not loom very large in the general picture of engineering education.

COOPERATION AMONG INSTITUTIONS

Twelve of the institutions on our list indicate that they have cooperative arrangements with other institutions for the interchange of facilities or credits in graduate work, as outlined in the following statements:

University of Pittsburgh.—Faculty members of neighboring institutions may take graduate work at half cost.

Case School of Applied Science.—Services are interchanged with Western Reserve University. The use of this plan is limited and occasional. The student registers in one institution only; the latter approves any elections in the other school and accepts its record for credit.

Ohio State University.—Cooperative arrangements exist with Ohio University and Miami University, which are represented on the graduate council of Ohio State University. Part-time assistants connected with the instructional staff of Ohio University and Miami University may pursue work at these institutions, subject to supervision by the graduate council of Ohio State University, and receive degrees from the latter institution.

University of Pennsylvania—Moore School of Electrical Engineering.—The director of the Bartol Research Foundation of the Franklin Institute is a member of the Moore School staff. Doctor's theses may be done at the Bartol Research Foundation on approval of the director. The arrangement has been successful as well as beneficial to the Moore School.

Oregon State College.—All credits are interchangeable within the Oregon State system of higher education.

Polytechnic Institute of Brooklyn, Columbia University, New York University, and Stevens Institute of Technology.—For members of the teaching staff of these four institutions in the metropolitan area of New York there is an informal arrangement for the interchange of credit for advanced study. Several individuals already have taken advantage of this plan, which avoids competition in certain specialized fields.

Syracuse University.—Up to 1934, this institution has accepted up to 6 hours of credit for the master's degree from certain other engineering schools, and Syracuse students could be assigned to do from two-fifths to one-half of their master's work at one of these institutions. Students who have not graduated from Syracuse are expected to complete a minimum of 30 hours at Syracuse.

Harvard University.—"By special arrangement cooperative work is possible."

University of Texas.—The recognition of 6 semester hours' credit in engineering toward the local program is limited to work taken at institutions that are members of the Association of American Universities.

74062°—36——3

CHAPTER IV: TEACHING STAFF AND GRADUATE WORK [1]

PROBABLY in no other respect has the advent of graduate work in engineering had more important effects than in relation to the teaching staff. Information furnished by the survey bearing upon this matter is considered from three standpoints: Problems of administration, recruitment and training of younger teachers, and the elevation of standards of instruction.

PROBLEMS OF ADMINISTRATION

Adjustment of teaching loads.—Practice in this connection differs considerably. In many institutions the load of graduate instruction has been added to the previously existing load of undergraduate instruction, which was already heavy in comparison with other divisions of higher education.[2] The cause of this has been the necessity, in many institutions, of adding graduate work to the undergraduate programs already offered without making any additions to the teaching staffs. In one or two institutions relief of this situation is planned, but has not been carried into effect due to financial limitations. In most institutions where additional staff has been provided to take care of the increased load, hours of graduate and of undergraduate instruction have been given equal weight, though there are one or two important exceptions to this practice. Commenting in this connection administrative officers of colleges that supplied information mention that graduate instruction is carried for the most part by the senior members of the staff whose previously lighter schedules could be increased most readily. One correspondent remarks that the older teachers whose schedules were lighter than average so as to give opportunity for study, writing, and research, have now taken on graduate work. Several institutions report that teachers assigned to graduate work have been

[1] Based on question 5 of the questionnaire. See appendix.

[2] See Bulletin No. 4 of the Investigation of Engineering Education. Society for the Promotion of Engineering Education.

relieved of a corresponding amount of undergraduate work, though in most institutions there has been no such relief.

Little or no attempt is made, apparently, to weight graduate work in relation to undergraduate work in arriving at a measure of teaching loads. In the few schools that report such effort, one unit of graduate work is taken as the equivalent of one and one-half units of undergraduate work. One institution uses a ratio of 1 to 2 in this connection. Graduate thesis supervision is systematically weighted in only a few institutions. One counts supervision of one thesis as 5 percent of a full teaching schedule; another counts supervision of one master's thesis as the equivalent of one unit of lecture or recitation work, and supervision of one doctor's thesis as the equivalent of 2 hours of lecture or recitation work.

To summarize the matter of teaching loads it may be said that the advent of graduate work at a time when budgets were being curtailed, and when some staffs were being decreased in numbers, has prevented the normal adjustment to the increased duties that otherwise could have taken place.

Extra compensation.—In general, no extra compensation is allowed for graduate instruction except when the work is conducted in evening sessions. In such cases compensation is commonly made on an hourly basis. In one case compensation for graduate work is 50 percent greater than for undergraduate work.

Visiting and exchange professors.—Eight institutions report that they have had experience in the exchange of professors, and three others state that they have plans for such exchange in the near future. At least two institutions, Massachusetts Institute of Technology and the University of Michigan, have arranged for visiting professors during summer sessions, the arrangement at Michigan having been in connection with advanced courses in mechanics particularly adapted to the needs of university teachers. It must be remembered that when exchange is between two institutions in this country the same exchange is reported twice. The practice of exchange of teachers is not, therefore, one that has found very wide adoption.

RECRUITMENT AND TRAINING OF TEACHERS

It is evident from statements of fact and of policy submitted by engineering schools and colleges that a marked change of attitude is taking place toward the extent and nature of training demanded of candidates for teaching positions. Approximately five-eighths of all institutions which reported on the subject state that they either require the holding of the master's degree as a minimum or that they give great weight to it in choosing new men. The holding of an advanced degree is an absolute requirement in 23 of 81 institutions reporting; 8 others virtually make the same requirement without having a fixed rule; and 5 others make it as a definite requirement for advancement to posts beyond that of instructor. Replies to questions in this connection indicate that the weight given to the holding of advanced degrees is just about equal to that given to practical experience—the latter being, of course, in relation to instructorships in engineering subjects. Only a small minority of institutions report that little or no weight is given to possession of advanced degrees.

In a few institutions the attempt is made to require all those appointed to full professorships to hold the doctor's degree. Information is not available to indicate how completely this rule is enforced as to members of the engineering faculty.

Nearly half of all institutions reporting state that they have changed their attitude and policy in recent years in the matter of requiring newly appointed teachers to hold advanced degrees, the change having been in the direction of much greater emphasis on advanced training. The present situation is quite different from that of the days when practical experience was the sole requisite for appointment, except, of course, the holding of the bachelor's degree, and when possession of an advanced degree was so uncommon as not to be a factor.

It is quite possible that the change which has occurred in this connection is due as much to the fact that candidates having advanced degrees are now available as it is to the desire to lay down definite prescriptions. Whatever the cause, however, possession of an advanced degree has become so much an asset among applicants that a recent

graduate applying for a teaching post who does not hold such a degree can scarcely expect to receive consideration in a majority of institutions; the most he can look for is some form of fellowship under which he can pursue graduate work before he can be appointed to a regular instructorship.

ELEVATION OF STANDARDS OF INSTRUCTION

Self-advancement of teachers.—For the purpose of the improvement of instruction it is the policy of nearly all institutions to encourage and systematically to aid their younger teachers to continue their academic training. Nearly three-quarters of the institutions report that they have definite plans in this connection. Comparatively few of them go so far, however, as to have systematic provisions for sabbatical leave.

Evidence points to the fact that teachers are availing themselves of opportunities for advanced study and that they are fully awake to the fact that more extended academic training is becoming essential to promotion. Among the staffs of 68 colleges reporting, 443 teachers were pursuing graduate courses in 1934–35, an average of more than 6 teachers per institution, or about 15 percent of the entire staffs of those institutions. Among the teachers of 69 institutions which supplied information, 655 teachers, or nearly 10 per institution, and about 17 percent of the entire faculties, earned advanced degrees during the past 6 years; a truly remarkable record, particularly in view of the fact that several of the larger institutions are not included in this summary because they could not assemble the information.

The chief means by which teachers have earned degrees is through the opportunities afforded by their own institution, though a significantly large fraction of the work has been pursued in summer sessions of other institutions. During the summer of 1934, 15 institutions provided such work, the total number of engineering students enrolled being 422, of whom 123 were teachers. Nearly two-thirds of this enrollment was in two institutions: Massachusetts Institute of Technology and the University of Michigan.

Some of the most interesting developments in post-graduate work have had important connections with these

summer sessions: The work in hydraulics under Woodward, Mavis, and the late Professor Nagler, at the State University of Iowa; photoelasticity under Frocht at Carnegie Institute of Technology; theoretical and applied mechanics under Timoshenko, Erickson, and others at the University of Michigan being conspicuous illustrations of the development of distinctive programs around teachers of particular qualifications.

It is in just such ways as these that graduate work is probably destined to have its most beneficial effects on engineering education in this country; that is, by tending to aid in the development of centers of particular types of advanced work of high quality and of distinctive characteristics. It is only in the cases of a minority of the engineering schools of the country that staffs, facilities, and resources are such as to provide for comprehensive programs of graduate work of high quality in all fields in which undergraduate curricula are offered, but many institutions can capitalize particular assets in the way of staff, facilities, and location, and provide distinctive programs in special fields.

Conferring of advanced degrees on members of the institution's own staff.—The taking of advanced work in the teacher's own institution has intensified a situation that has been something of a problem in many institutions, namely, the conferring of degrees upon members of the institution's own staff. Two views as to this matter are commonly expressed: (1) that there should be no discrimination against the institution's own teachers and that the school should be free to profit by the advanced training of its own men; and (2) that restrictions are needed to guard against the danger of questionable practices in degree-conferring.

The prevalence of various practices in this connection is shown by the following statistics: No limitations, 22 institutions; advanced degrees limited to assistants and instructors, 38; advanced degrees limited to assistants, instructors and assistant professors, 12; all except full professors eligible, 1; none conferred on any member of staff, 2; no answer, or no definite policy, 6.

Several interesting variants on the usual regulations are reported. One institution provides that all teachers of any rank higher than that of instructor must receive special

permission from the dean of the graduate school to enroll for an advanced degree. Another permits instructors to earn degrees in any field, but will not permit an assistant professor to take work in his own department. Another will not permit its own teachers to take work for the master's degree, but will permit them to work for the doctorate. Still another will not confer a degree on a member of the faculty of the graduate school, but imposes no limitations on other teachers.

CHAPTER V: GENERAL CHARACTERISTICS OF THE PROGRAM OF GRADUATE WORK IN ENGINEERING [1]

THIS CHAPTER is concerned with the general nature and content of graduate work in engineering and with methods of conducting it. Only those elements that are capable of quantitative analysis are included, which implies, of course, that some of the most vital aspects of graduate work are excluded, because being largely intangible, they escape any statistical analysis.

Specific matters presented herein include the following:

Proportion of required work in science, engineering, and humanistics.
Place of economics and of economic factors in graduate work.
Relation of work in course to research.
Use of the seminar.
Plan of prescribed majors and minors.

PROPORTION OF MAJOR FIELDS IN GRADUATE PROGRAMS

WORK IN SCIENCE, ENGINEERING, AND HUMANISTICS REQUIRED FOR THE MASTER'S DEGREE

As the usual requirements for the master's degree seldom cover more than 1 academic year of study the tendency of engineering schools is to devote the major share of this time to advanced courses in engineering and technical subjects, although pure science may occupy a considerable portion of the year's work. Humanistic subjects also are given some recognition in a number of schools, although in at least 10 cases these are not recognized as a part of the program for the master's degree. It is generally expected that the necessary humanistic subjects will have been completed during the undergraduate period of study.

According to the information supplied, the three fields, advanced engineering, pure science, and humanistics, are recognized as basic for the master's degree program in engineering in 26 institutions, while but two fields, advanced

[1] Based on questions 6 and 7 of the questionnaire. See appendix.

engineering and pure science, are recognized in 31 institutions (in addition to the 26 mentioned).

According to the accompanying table we find that 18 schools indicate the amounts for the three fields in terms of percentages and 9 schools indicate the percentage for two fields only.

In the eight schools that do not give the percentage for the three fields the statements indicate that the main emphasis is given to advanced engineering, with minor emphasis on pure science and mathematics.

In the schools that do not give the percentages for the two fields the statements indicate that emphasis is either on a balanced program or on advanced engineering.

TABLE 3.—PROPORTION OF WORK IN ADVANCED ENGINEERING, PURE SCIENCE, AND HUMANISTICS

THREE FIELDS		
Percent in—		
Advanced engineering	Pure science	Humanistics
32	35	33
33⅓	33⅓	33⅓
40	50	10
45	45	10
50	25+	25+
50	25+	25+
50–66⅔	Minor.	Minor.
60	Part or all.	Part or all.
60	30	10
60	0 to 40	0 to 40
66⅔	20	20
66⅔	0 to 33⅓	0 to 33⅓
66⅔	Permitted.	Permitted.
66⅔	Permitted.	Permitted.
75	Permitted.	Permitted.
75	15	10
66⅔	0 to 25	0 to 25
87½		33⅓
		12½
TWO FIELDS		
50	50	
50	50	
50	50	
50	50	
66⅔	33⅓	
66⅔	33⅓	
100		
100		
100		

WORK IN SCIENCE, ENGINEERING, AND HUMANISTICS REQUIRED FOR THE DOCTOR'S DEGREE

Relatively few institutions reported on the distribution of courses in the three fields referred to in the programs leading to the doctorate. Definite figures were given by 5 institutions as shown in the following table. These figures represent the general tendencies of practice in these institutions.

TABLE 4.—PROPORTION OF WORK IN ENGINEERING, PURE SCIENCE, AND HUMANISTICS IN PROGRAMS LEADING TO THE DOCTORATE IN ENGINEERING

Institution	PERCENTAGE		
	Engineering	Pure science	Humanistics
Colorado School of Mines	45	45	10
Minnesota School of Mines	50	50	.....
Columbia University	50	50	.....
Johns Hopkins University	66⅔	33⅓	.....
Carnegie Institute of Technology	80	20	.....

Other institutions reported these relationships in general terms. Both the University of Illinois and Purdue University offer specialized courses which include a considerable contribution from the basic sciences. The correspondent for the University of Illinois holds the view that humanistic study carried on by the engineering doctoral candidate for his degree should be self-directed. Cornell University, the University of Michigan, Pennsylvania State College, and Syracuse University indicate that the relative distribution of work in these three fields depends largely on the individual case.

The University of Colorado and Michigan College of Mining and Technology indicate that there is a high degree of specialization in the combined fields of engineering and pure science.

Rensselaer Polytechnic Institute recommends a large amount of science. There is less necessity for general courses. Iowa State College gives no credit for humanistics in the doctoral program.

New York University in its course leading to the doctorate in chemical engineering includes 6 courses in engineering and 6 courses in pure science and mathematics, 12 in all for

the Ph. D. in addition to the doctoral dissertation. The University of Minnesota indicates that when the major is in engineering the minor should be in allied lines.

At Stanford University the program for the doctorate is based on original research.

OPINIONS AS TO PLACE OF ECONOMICS AND ECONOMIC FACTORS IN COURSES LEADING TO MASTER'S DEGREE IN ENGINEERING

Of the 82 institutions which replied to the questionnaire 15 feel that economics and economic factors are important and should have a prominent place in the program for the master's degree in engineering. The following schools suggest that economics should be taken as a minor: Iowa State College, University of South Dakota, University of Southern California, University of Colorado, University of Minnesota, University of North Carolina, and the University of Washington. The Towne Scientific School of the University of Pennsylvania indicates that economics and economic factors are next in importance to science and technical study.

Economics is recommended as an elective for the master's degree in engineering by Johns Hopkins University, Carnegie Institute of Technology, Lafayette College, and Purdue University. At least 24 institutions think that the matter depends on the need of the individual.

The percentage of time suggested for the study of economics and economic factors is indicated by the following institutions: University of Florida, about 10 percent; University of Idaho, 15 to 20 percent; University of Texas, 20; Polytechnic Institute of Brooklyn, 20; Stanford University, 25 (engineering degree); Iowa State College, up to 33⅓; Catholic University of America, 33⅓; New York University, about 33⅓, depending on field.

Quite a few schools approve the combining of economic factors with advanced engineering courses, otherwise it is generally expected that sufficient economics will have been taken in the undergarduate course.

The University of Utah states that the whole master's program in certain cases could be appropriately devoted to economic and social studies.

OPINIONS AS TO THE PLACE OF ECONOMICS AND OF ECONOMIC FACTORS IN ENGINEERING LEADING TO THE DOCTORATE IN ENGINEERING

The following institutions believe that the study of economics and economic factors is of considerable importance as a part of the doctoral program in engineering: Rensselaer Polytechnic Institute, University of Rochester, and the Montana School of Mines. The University of Louisiana believes it should be definitely required. The University of Arizona considers that some work of this type is essential. Carnegie Institute of Technology believes that economics should be included.

On the other hand the State University of Iowa views the engineering doctorate primarily as a research degree with little time for economics. Iowa State College would not recommend the study of economics beyond the master's degree. Massachusetts Institute of Technology does not recommend it unless the student has had none in the bachelor's course or unless he needs it in the field of business. At the University of Michigan it is considered of minor importance for this degree.

The following schools are of the opinion that the taking of economics is a matter which should be governed by the student's particular needs, the nature of his field, or the thesis: Ohio State University, University of Wisconsin, Columbia University, New York University, and Rutgers University. Purdue University would encourage the study of economics but would not require it for the advanced work.

Johns Hopkins University advocates this subject as an elective except as included in the formal engineering course.

The University of Minnesota suggests economics as a minor, and the University of Colorado as a second minor.

The following schools indicate the amount of economics that is required for the doctorate in engineering: Catholic University of America, and the University of Arkansas, about one-third of the work in course; New York University, about one-third, depending on the field; the University of Idaho indicates about 10 percent.

Michigan College of Mining and Technology recommends economics and business administration as electives for higher degrees.

The Pennsylvania State College recommends both economic and social factors in some cases.

The Moore School of Electrical Engineering of the University of Pennsylvania offers electives which contain courses that give an understanding of economic principles in marketing electrical products.

RELATION OF WORK IN COURSE TO WORK IN RESEARCH

MASTER'S DEGREE

Attention is directed first to the requirements in course work and research work in programs leading to the master's degree. Seminars are included in course work, and the thesis in research work.

In 65 of the 82 institutions considered there is quite a variation in the percentage of the requirements which must be satisfied by course work and in the percentage which must be satisfied by research work for the degree indicated.

The percentage of course work varies from 30 percent to 100 percent and the percentage of research work from zero to 70 percent. The following table indicates the practices by groupings:

TABLE 5.—RELATION OF WORK IN COURSE TO WORK IN RESEARCH FOR THE MASTER'S DEGREE

Number of cases	Percentage	
	Work in course, including seminar	Work in research, including thesis
1	30	70
2	33⅓+	66⅔−
5	50	50
5	60–80	20–40
4	60	40
2	65	35
10	66⅔	33⅓
5	70	30
1	73	27
11	75	25
15	80	20
2	87−	13−
2[1]	100	

[1] 1 case, engineer's degree.

The principal frequencies are those in which 66⅔ percent is course work and 33⅓ is in research; 75 percent course

work and 25 percent in research; and 80 percent course work and 20 percent research. A number of schools do not express these amounts in terms of percentages. Several schools state that the case of each student is determined on its merits since no rule exists as to the proportion between course work and research.

The University of California has two plans. Under plan I, with the approval of Graduate Council, the candidate may satisfy the unit requirement for the master's degree (20 semester units plus thesis) by a comprehensive plan of research leading to an acceptable thesis. The schedule indicated is research (designation and number of course), 10–12 units per semester, or 2 to 4 units per summer session.

Ohio State University requires in its course work a reasonable concentration on interrelated subjects under at least two professors.

The University of Cincinnati in referring to the sixth year of study following the 5-year cooperative period of work makes the statement:

In general it is preferred that the sixth year be spent in full-time attendance at the university, but half-time employment in the Institute of Scientific Research may be permitted. If an outside cooperative job is held, a minimum of 2 years additional time will be required unless special arrangements are made with the cooperating firm so that outside work is of a definite research character. If a student does not attend the university full time, its faculty committee in charge of graduate work must approve the arrangement that is made either with the Institute of Scientific Research or with the cooperating firm. The appropriate technical degree will be given at the end of the fifth year for satisfactory work. At the end of the sixth year of satisfactory full-time work or cooperative work of a definite research character the master's degree will be given. If the cooperative work is not of research character, the master's degree will be given at the end of the seventh year, provided the requirements are met.

DOCTOR'S DEGREE

Sixteen, or approximately half of the schools offering the doctor's degree in engineering, indicated the percentage of work in course and the percentage of the work in research usually required for the doctorate. The table following shows the different frequencies:

TABLE 6.—RELATION OF WORK IN COURSE TO WORK IN RESEARCH FOR THE DOCTOR'S DEGREE

Number of cases	PERCENTAGE	
	Work in course, including seminar	Work in research, including thesis
3	40+	60−
5	50	50
1	60	40
3	66⅔	33⅓
2	70	30
2	75	25
1	80	20

As in the case for the master's degree, several schools indicated the absence of any definite proportion between course work and research. Flexibility is emphasized because of the needs of the individual or because of the nature of the problem.

EXTENT OF THE USE OF THE SEMINAR IN GRADUATE COURSES IN ENGINEERING

MASTER'S DEGREE

Data as to the extent of the use of the seminar in graduate courses in engineering were seldom given in quantitative terms by those who supplied information. The following statements summarize practices in a general way.

Of the 82 institutions reporting 24 cite little use of the seminar in connection with the program for the master's degree. A few of the remaining schools indicate the proportion of time devoted to this method of instruction.

Three schools devote about 10 percent of the time to seminar work; 4 about 20 percent; one between 12 and 25 percent; 2, 33⅓ percent; one 50 percent. Other statements included the following: Seminary and Journal Club, 1 hour each week; at least one seminar course is required per semester; one meeting per week in the major subject; one meeting including preparation, 2½ hours a week.

At least 26 schools, in addition to those referred to, report a considerable use of the seminar. In some cases it depends on the subject or the major; again it depends on the discretion of the instructor; in other schools it depends on the department.

Only three schools definitely report the nonuse of the seminar.

DOCTOR'S DEGREE

The seminar method is used to a considerable extent in work leading to the doctor's degree in the field of engineering.

Only a few institutions indicate the amount quantitatively; two indicate 10 percent; one not more than 20 percent, depending on the thesis; one requires attendance at the Seminary and Journal Club 1 hour a week; another requires attendance at one weekly meeting on research and one on the major subject. In one school all graduate students must attend the seminar of their major subject. In another the student must attend a seminar while he is candidate for a degree.

Eleven institutions report the extensive use of the seminar without indicating the amount of time. Five institutions stated that the seminar was little used.

PLAN OF PRESCRIBED MAJORS AND MINORS

MASTER'S DEGREE

Among the 82 institutions reporting on this question 18 indicate that they do not have any particular plan of majors and minors for the master's degree in engineering. Certain of them indicate their general plan in this connection in descriptive terms. The following illustrative cases are samples of practice in this regard: (1) The requirements for the major and minor are set up by the departments concerned; (2) a minor is not required, but if taken must be at least 10 semester-hours; (3) all the work may be in one department and part may be in one or more closely related departments; (4) the program consists of a highly professional curriculum mostly prescribed; (5) the practice varies with the student; (6) a major is required and in such cases courses in related fields that seem to support the program of study are required.

TABLE 7.—PROPORTION OF TIME DEVOTED TO MAJORS AND MINORS FOR THE MASTER'S DEGREE IN ENGINEERING

[Cases in which the major and minor are expressed in fractional or percentage terms. Figures for major in general are in descending order]

Institution	Major	Minor
State University of Iowa.	At least ⅔ of work including thesis.	Usually a minimum of ⅓ of the work.
South Dakota State College.	In major field ⅔ or ½.	⅓ of time; 2 minors of ¼ of time each.
Stevens Institute of Technology.	⅔ of course credits and thesis.	⅓ in related fields.
University of Colorado.	⅔ in department in which bachelors degree was received, and thesis.	7 to 12 hours. If a second minor is permitted must not be less than 6 hours in other branches of engineering, or allied fields of pure science.
Michigan State College.	⅔ to ¾	¼ to ⅓.
University of Florida	⅔, major work 12 semester hours in courses for graduates only in addition to thesis.	⅓, 12 semester-hours in 1 or more minors.
Kansas State College	⅔, including thesis.	⅓ in 1 or more minors.
Oregon State College	⅔, including thesis, 30 term credits.	⅓, 15 term credits with slight variations.
Pennsylvania State College.	⅔	⅓.
University of Minnesota School of Mines.	⅔, 18 credits, excluding thesis.	⅓, 9 credits.
University of North Carolina.	⅔, including 6 approved courses in major group.	⅓, including 3 courses from one or two allied departments.
University of Nevada	⅔, 12 semester-hours.	⅓, 6 semester-hours.
State College of Washington.	62 percent, 20 semester-hours in major.	1 or 2 minors or at least 6 semester-hours each.
University of Texas	60 percent	

TABLE 7.—PROPORTION OF TIME DEVOTED TO MAJORS AND MINORS FOR THE MASTER'S DEGREE IN ENGINEERING—Continued

Institution	Major	Minor
University of Southern California.	60 percent	1 or 2 from related field as physics.
New York University	(5 courses) 60 percent 3 courses in specific branch of engineering.	2 courses.
Rutgers University	60 percent	
Purdue University	60 percent, 18 semester-hours.	40 percent, 12 in other engineering department or natural science department.
University of Arkansas.	58.2 percent or not less than 14 semester hours in major and not less than 8 in minor in a total of 24 semester hours, exclusive of thesis.	
Virginia Polytechnic Institute.	50 to 66⅔ percent	33⅓ to 50 percent.
Cornell University	50 to 75 percent	25 to 50 percent in 1 or 2 minors.
University of South Dakota.	12 units 50 percent, 4 units in thesis.	2 minors 8 units each 50 percent.
University of Wisconsin.	50 percent at least in a single department.	
University of Kentucky.	50 percent+, 12 credits minimum. Thesis also in major.	Remainder, correlative work.
Tulane University	50 percent at least	2 minors.
University of Illinois.	50 percent at least, may be all in major, a major and 1, minor or a major and 2 minors.	Not less than ⅙ of work counts as minor.

TABLE 7.—PROPORTION OF TIME DEVOTED TO MAJORS AND MINORS FOR THE MASTER'S DEGREE IN ENGINEERING—Continued

Institution	Major	Minor
Rice Institute	50 percent minimum in department granting the degree.	
Montana State College.	50 percent of the credits at least.	
Louisiana State University.	50 percent at least.	
North Carolina State College.	50 percent	50 percent.
University of Oklahoma.	44.4 percent, 16 hours in major.	66.6 percent, 20 hours in 2 minors; at least 8 hours in each minor.

The following plans differ somewhat from those just indicated:

Michigan State College.—Requires one-fourth to one-half of the time to be devoted to research, one-half of the remaining time to courses in the field of the major and one-fourth of the time to work in closely related departments.

Johns Hopkins University.—Requires 2 years of graduate study in the major subject.

University of Pittsburgh.—The major being in engineering, the minor or minors should be taken outside of the engineering school. This is a matter of decision with the individual rather than a fixed policy. The terms major and minor are much overemphasized in graduate work.

Iowa State College.—Requires 30 credits in major work of the 45 total. Minor work is usually required and may be taken in the same department as the major. The exact number of credits in a minor is not prescribed. A joint major may be taken in two closely related departments on special recommendation of departments and on approval of the dean of the graduate school.

Massachusetts Institute of Technology.—If 64 of the 96 units of the required "A" subjects including thesis are chosen from a single department, the degree will be recommended with specification of the field, otherwise not.

Carnegie Institute of Technology.—About one-fifth of the work must be in a related minor field.

University of Nebraska.—One major and one minor are required. The major work must be closely related; most of the minor broadly related to the major.

Case School of Applied Science.—The minimum limit of "A" subjects (for graduates only) is prescribed.

Georgia School of Technology.—Seventy-five percent, or 24 of the total 32 credit hours, must be in one department; 15 of the 32, exclusive of thesis in strictly graduate studies. Some credits may be obtained in senior class subjects not before taken.

University of Alabama.—Seventy-five percent or 18 semester-hours in major; 6 semester-hours in either major or a related subject.

Polytechnic Institute of Brooklyn.—Students are required to build a program with structural unity in some particular field of study.

Syracuse University.—The major and minor plan is giving way to an effective unified program.

University of Delaware.—Each student is considered an individual case except that the plan followed is one-third in major branch of engineering, one-third in humanistics, and one-third in pure science or allied engineering.

Montana School of Mines.—Research must be in major field; the balance of work preferably in other fields.

University of Idaho.—The candidate must have a major and a minor in a related subject.

University of Minnesota.—The major includes 40 percent, the minor 20 percent, and the thesis 40 percent. The major must be in the field of the bachelor's degree.

University of Arizona.—Not fewer than 15 nor more than 20 units must be in the major field.

University of Louisville.—A major in chemical engineering requires a minor in chemistry or physics or in economics or mathematics.

CHAPTER VI: COOPERATIVE AND PART-TIME GRADUATE WORK [1]

ONE OF the most significant phases of the development of graduate work has been the provision of part-time courses of various types, many of them for the benefit of graduates who have found regular employment but wish to continue their education through regular academic work.

The ways in which institutions have capitalized the particular advantages of their environment and facilities in this connection provide an interesting study.

Carnegie Institute of Technology appears to have been the first to offer graduate work on a part-time basis, having established such courses in 1912. The first degree was conferred in 1915. The courses are regular graduate engineering courses offered in evening hours. Enrollments in 1933–34 were 52. Twenty-two degrees have been conferred under this plan since 1915.

Massachusetts Institute of Technology inaugurated its cooperative course in electrical engineering in 1919. This program is an integrated 5-year course having the first 2 years on the all-residence basis and the last 3 years cooperative, with alternation of periods at the Institute and in industry on a semester basis (including a summer term). One full year of graduate work is provided. The course leads to two degrees, the bachelor's and the master's. The curriculum provides a comprehensive foundation for engineering, including the scientific, economic, and sociological aspects. Four options are provided as special fields of work, and cooperative employment is provided in each of them with selected industries as follows:

	Practice with—
Electrical manufacturing	General Electric Co.
Electrical communications	Bell Telephone System
Electrical power generation and distribution.	Edison Electric Illuminating Co. of Boston.
Electrical transportation	Boston Elevated Railway

Admission to the course is on a selective basis and places a premium on high scholarship and good personal qualities, a

[1] Based on question 15 of the questionnaire. See appendix.

practice that has done much to insure its success. Classes are continued under resident and nonresident institute instructors while the students are at the plants of the companies on their cooperative work. Many of the students are selected to study under the honors group plan during the junior and senior years which provides unusual opportunities for the development of initiative and resourcefulness by placing the students more largely on their own responsibility.

The total enrollment in the course to date has been 601, the maximum enrollment in any 1 year having been 127, in 1924. The enrollment this year has been 69, a substantial decrease having occurred since 1930 due to industrial conditions. Three hundred and seventy master's degrees have been conferred.

Massachusetts Institute of Technology also offers a cooperative postgraduate course in its school of chemical engineering practice which is essentially a fifth year of work following the normal 4-year undergraduate curriculum. Twenty-four weeks of the year are spent at three practice school stations in industrial plants. These are followed by 15 weeks of graduate study and thesis work at the Institute. Admission is selective and is limited to students of high professional promise. More than half of the students come from institutions other than the Massachusetts Institute of Technology. Members of the institute instructing staff are in charge of the practice stations. Students are assigned regular plant problems, many of which are of direct interest to the plant organization. The practice schools are supplemented by a shorter course for seniors, thereby permitting 12-month operation.

The course was established in 1920. The total enrollment has been 757 since its establishment. Twenty-three students were enrolled in 1933–34. Three hundred and fifty-three master's degrees have been conferred.

From 1928 to 1934 the Massachusetts Institute of Technology offered a cooperative course in railroad operation through an arrangement with the Boston & Maine Railroad.

From 1925 to 1933 a program of graduate study was also provided by the institute for the younger engineers of the Lynn works of the General Electric Co. The instruction consisted of graduate subjects in electric circuits and ad-

vanced alternating-current machinery given by institute instructors over a period of 16 months at the Lynn works. During the same period the students were attending a seminar and starting work on their theses. The requirements for the master's degree were completed by a term of residence at the institute. The course was discontinued in 1933 due to the fact that relatively few younger engineers were being taken on by the company. During its existence 84 students were registered in electrical engineering and 39 master's degrees were granted; approximately 38 students were registered in mechanical engineering, and 15 degrees were granted.

A further step in the program of cooperative postgraduate work in engineering is to be taken at the Institute next year in the form of a new course in mechanical engineering, called II–A, which is to be similar to the existing cooperative course in electrical engineering, VI–A. The course is being established at the request of the General Electric Co.

Polytechnic Institute of Brooklyn began offering graduate work in its evening session in 1926 in chemistry, and in 1929 expanded its program to include all of its engineering curricula as well. The work has met with a widespread response among younger employed engineering graduates in the metropolitan district of New York. The customary types of graduate courses as well as original work and research, carried out through theses, are provided, the thesis work being of very high quality. An average of from 3 to 4 years is required to complete the work for the master's degree. The total enrollment has been 1,423 since the inception of the plan 10 years ago, and 127 degrees have been conferred. The total enrollment in 1934–35 was 295, 153 being in engineering and 142 in chemistry.

The University of Pittsburgh and the Westinghouse Electric Co. inaugurated their cooperative arrangement of part-time graduate work in 1927. Under this plan instruction is provided jointly by the university and the company for young engineers employed by the company. Classes are conducted on the premises of both under teachers designated by the university from among its own faculty and from among the older engineers and research workers of the company's staff. The entire work of the students is done under the broad guidance of the university's school of engineering and the university assumes responsibility for the adequacy of the program. Most of the engineering subjects are given by teachers chosen from the company's staff, while courses in

physics, mathematics, economics, and the like are given chiefly by members of the university's faculty. Experimental work on theses is conducted in the company's laboratories, but no credit is given for any shop, testing, drafting, or regular engineering work done by the student during working hours. Theses are of a high order of excellence.

The courses lead, upon completion, to the master's or to the doctor's degree. Enrollments have run as high as 250 men in a single year (1930), though there has been a considerable shrinkage since 1931, due to the depression. In 1934, 33 men were enrolled. A total of 61 master's and doctor's degrees have been awarded.

University of Wisconsin provides an example of another distinctive departure from the customary all-residence type of graduate program, and one of a high order of usefulness and of quality of work, in that conducted for younger metallurgical engineers employed in industries in Milwaukee. This work was inaugurated in 1924. The program makes it possible for a limited number of properly qualified technical graduates employed by metallurgical industries to advance their knowledge and to develop their research ability under instruction and leadership provided by the university. Instructors make the trip to Milwaukee each Friday, hold regular classes that evening, and spend Saturday with the students at their plants going over their research problems. The students are regularly enrolled as graduate students of the university—not in its extension division—and upon completion of the course work and thesis are awarded the master's degree. The total enrollment in the course to date has been 52. Twenty-two master's degrees have been conferred. The enrollment in 1933–34 was 5.

A similar program was offered by the university in electrical engineering at the solicitation of engineers in Milwaukee during the years 1925 to 1927, inclusive. Forty men were enrolled during the existence of this course.

Other institutions that have offered special types of graduate work, chiefly for young employed engineers, include *Union College*, which offered graduate courses for a period of about 15 years for engineering graduates employed by the General Electric Co. The master's degree was awarded upon completion of a 2-year program and the submission of a satisfactory thesis. The arrangement was discontinued in 1932 when the college temporarily gave up all graduate work because of the depression. Possibility of resumption of the program is now being considered.

Case School of Applied Science, which offered graduate work in evening hours, has also discontinued this type of program temporarily.

In addition to the foregoing, several other institutions offer special types of programs, chiefly in evening sessions. Among these are the courses that have been provided by *Columbia University* since 1932. The work is offered in late afternoon and early evening hours. Twenty-eight men are enrolled in this work during the present year, many of whom are employed in such organizations as the Bell Telephone Laboratories. *New York University* inaugurated a program in 1933 in its evening engineering division whereby the degree of master of science in the field of hydraulic and sanitary engineering may be earned in 2 years. An average of 10 students has been enrolled annually. The *University of Pennsylvania* also offers work in evening hours both in the *Moore School*, where 40 students are enrolled, and in the *Towne School*, where there are 25 enrollments. The *University of Minnesota* has recently launched a program of evening graduate work and has 22 men enrolled in the electrical engineering courses this year. In addition to the foregoing, the *University of Cincinnati*, *Detroit Institute of Technology*, *Louisiana State University*, the *Montana School of Mines*, and *Virginia Polytechnic Institute* offer special types of cooperative courses in which a total of 16 students are enrolled.

In all, 15 institutions now offer various special types of postgraduate work, the total enrollment of engineering students in such programs during the year 1933–34 having been 330. This is a sizable fraction of the entire enrollment of graduate students and the types of work provided form one of the most significant developments in graduate work in engineering.

As a phase of cooperative and part-time graduate work, attention is called at this point to the special arrangements that a number of institutions have made for the offering of postgraduate work for employees of industry either on a part-time or on a full-time basis. A number of the more significant practices are given herewith:

Virginia Polytechnic Institute.—This institution which owns and operates the local power plant offers a full engineering program in connection with the operation of the plant. This plan works very well. There are six cooperative fellowships in fuel engineering requiring 25 hours a week for 12 months in the operation of the power plant, including com-

bustion studies on Virginia coal. The stipend is $540 for 12 months.

University of Maine.—The university has maintained cooperative relationship with several large paper mills. Employees have taken advantage of the scientific courses given in the subject of paper manufacture.

University of Southern California.—Arrangements have been made whereby city and county employees may have their tuition paid by city or county if they successfully pass advanced work in the school of government which counts toward a master's degree in engineering.

Catholic University of America.—Employees of the United States Bureau of Standards enrolled at this university may receive credit for research work done at the Bureau.

Yale University.—There have been special cases of fellowships provided by industrial concerns.

Montana School of Mines.—The plan here is moderately successful. Industry furnishes $2,500 a year of which $1,800 goes to stipend and $700 to equipment, etc.

New York University.—Various companies cooperate. The Westinghouse Co. accepts credits from this school for transfer to Pittsburgh.

University of Oklahoma.—The university is situated within 16 miles of the Oklahoma City oil field. Producing and refining work runs 24 hours a day. Officials arrange working hours for men who desire to take graduate work at the university. A man may take up to 8 semester-hours in the graduate school if he is employed elsewhere full time. Graduate students are permitted to use equipment of the neighboring companies. The university cooperates further with the American Society of Mechanical Engineers, the American Petroleum Institute, and the American Gas Association in conducting certain cooperative research projects.

University of Cincinnati.—In addition to the regular channels of research there has been organized an institute of scientific research which has a fundamental relation to several basic industries. The institute comprises four major units: The Research Laboratory of the Tanners Council of America, the Commercial Club of Cincinnati Resource Survey, the Research Laboratory of the Lithographic Technical Foundation, and the Basic Science Research Laboratory.

Cooperative graduate study in engineering was begun at this university in September 1927.

In 1933 there were 260 firms cooperating with the school of engineering.

CHAPTER VII: ADMISSION REQUIREMENTS [1]

TWO PHASES of admission methods and requirements in graduate work are considered in this chapter: Requirements for admission to graduate study and requirements for admission to candidacy for a degree, the former being, in many cases, admission merely to a probationary stage preceding formal recognition of the applicant's status as a candidate for a degree.

The several aspects of admission to graduate study that are considered include (1) nature of the specifications imposed, particularly as to the quality of the student's undergraduate record; (2) procedures employed in the admission of graduates of nonengineering curricula and of undergraduate engineering curricula other than that of the proposed field of graduate work; (3) evaluation of the credentials of graduates of other institutions; and (4) administration of admission procedures.

SPECIFICATIONS IMPOSED AS TO THE QUALITY OF UNDERGRADUATE RECORDS OF APPLICANTS FOR ADMISSION TO GRADUATE STUDY

Almost all institutions admit students to graduate study on the basis of credentials in the form of a transcript of the undergraduate record of the candidate. If the student comes from another institution the additional requirement is often made that he be endorsed by some official of the institution from which he comes. Acceptance of the student, therefore, involves some evaluation of the undergraduate record and, if the student comes from another institution, of that institution itself. Replies to inquiries on these points indicate that 64 of 82 institutions reporting impose more or less definitely formulated specifications as to the quality of the undergraduate record; 15 indicate that no such specifications are imposed. While it is not entirely clear from the replies, it appears that most of the institutions in the latter group have admitted to graduate study only students holding their own baccalaureate degrees and have admitted these students simply as a matter of course.

[1] Based on question 8 of the questionnaire. See appendix.

In most instances, institutions that impose specifications do so on the basis of grades. Several state that an average of "B" or better is required, and some make virtually the same requirement in terms of grades expressed as percentages. In other instances, requirements are stated in more general terms, such as the fraction of the class in which the student must stand—for instance, the upper half. In other cases, requirements are stated in still more general terms, for example, possession of "superior grades" or "evidence of high scholastic ability." In such instances the requirements are usually accompanied by a statement to the effect that each student's record will be passed upon individually by a committee or individual acting as an admissions officer. In a few instances specifications are stated in terms of practices peculiar to the institution, such as the possession of a stated number of "grade points" per credit.

Entrance examinations for admission to graduate study are employed regularly in only a few instances—but 3 institutions of 82 replying indicated such procedure, though 4 others indicated that examinations might be required in case of doubt as to the standing of the institution from which the candidate received his baccalaureate degree.

PROCEDURE AS TO ADMISSION OF GRADUATES OF NON-ENGINEERING CURRICULA AND OF ENGINEERING CURRICULA OTHER THAN THE PROPOSED FIELD OF GRADUATE WORK: SYSTEMS OF PREREQUISITES

Answers to inquiries on this matter, while incomplete, indicate that the prevailing practice is either to require the candidate first to secure a baccalaureate degree in the specific field in which he intends to pursue his graduate work or, if admitted to graduate status, to make up all prerequisite undergraduate courses. There is, however, considerable diversity of practice in the admission of students to special standing status in the institution. Quite a number admit nonengineering graduates to specific courses but will not permit them to work for a master's degree. A few admit them to the status of "auditor." In a few institutions if an appropriate undergraduate major is made up the student will be permitted to go on for the master's degree in that particular field even though he has not pursued a complete

undergraduate engineering curriculum in any field. Most of the replies that were perfectly explicit on this general matter indicate, however, that possession of a baccalaureate degree in the particular field in which the student expects to pursue his advanced work is insisted upon, and if a single practice can be said to be the normal or customary one, it is this.

Practice in admitting graduates of one undergraduate engineering curriculum to a different field of graduate study are similar, in general, to those described in the foregoing paragraph. In somewhat more than half of the institutions that reported, a graduate of one engineering curriculum must satisfy all the undergraduate prerequisites for the new field—either before he enters or concurrently with the pursuit of the advanced work. In some instances these prerequisites must be passed without credit; in some, a certain proportion of the work in the major field of the undergraduate curriculum may be accepted in satisfaction of requirements in the minor elected by the student. If the holder of the baccalaureate engineering degree in one field is admitted as a graduate student in another field, a time limit is often placed on the period in which he must make up the undergraduate prerequisites in the new field, or the requirement is made that 1 full year must be spent in work for the master's degree after satisfaction of all prerequisites.

BASIS OF EVALUATION OF CREDENTIALS OF GRADUATES OF OTHER INSTITUTIONS

Three related aspects of this matter are here considered: (1) Evaluation of the specific courses pursued by the student as prerequisites for the advanced courses he desires to pursue; (2) evaluation of the standing of the institution from which he comes; and (3) appraisal of the quality of his undergraduate record.

Evaluation as to specific courses pursued.—In a considerable majority of institutions the specific courses taken in the undergraduate curriculum are appraised individually, generally by an examination of the catalog, through a conference with the student, or by correspondence with the institution. In some instances admission to the advanced courses is made on a probationary status, or the student is

permitted to pursue the advanced work until his deficiencies in preliminary courses become obvious.

Evaluation of standing of institution.—In 72 of the 82 institutions reporting, evaluation of the undergraduate credentials of other institutions is based on the general standing of the school, though relatively few replies are specific in indicating what is meant by "general standing." Such replies as are specific generally indicate that the institution must be one accredited by some national or regional accrediting agency or by the local State university acting as an accrediting agency. In some instances "equivalence" of the general undergraduate programs is necessary if its graduates are to be admitted.

Appraisal of quality of undergraduate record of the applicant.—In 64 of the 82 institutions which supplied information undergraduate records of students coming from other institutions are scrutinized at least as carefully as are records of students graduating from the same institution. In a few cases definite specifications are made as to grades achieved in undergraduate work. Almost all instances in which definite replies were given indicate that the student is required to have achieved a high standing.

Policies and methods pursued.—As to policies and methods used by institutions in evaluating credentials of prospective graduate students whether from the same or other institutions, it appears that they are quite similar, on the whole. Nearly half of the institutions supplying information indicate that they use all three of the criteria just enumerated, and virtually all of the others use at least two of these criteria. The practice of requiring good or superior records from students who have pursued their undergraduate work in institutions of acceptable quality seems to be virtually universal, though the method of evaluation of specific criteria may differ more or less. As to graduates of institutions of questionable or unknown standing, the practice of admission on probation seems to be fairly common.

ADMINISTRATION OF ADMISSION PROCEDURES

Practice in this connection favors the control of admission procedures by a single individual, as indicated by 49 institutions, though a considerable number—34—place control in the hands of a committee or group.

The individuals most commonly placed in control, named in order of frequency of designation, are the dean of the graduate school, the registrar, the dean of the school of engineering, and the head of the department or professor with whom the student expects to pursue his major. In several instances administration of admission procedures is vested in two individuals jointly, such, for example, as the registrar and the dean of engineering, the dean of engineering and the head of the department, and the like. When committees administer the procedure they are commonly made up of an administrative officer, such as the dean of the graduate school or the dean of engineering and the heads of certain departments or a selected number of members of the faculty of senior rank. In some instances the committee on admissions is chiefly concerned with questions of policy and with decisions as to doubtful cases; in others the committee meets for consideration of all candidates and considers each case individually. In general, replies to the question as to administration of admission procedures served as well to indicate the degree of care in selection of graduate students as did questions specifically intended to bring out this phase of the admissions problems.

ADMISSION TO CANDIDACY FOR A DEGREE

Because of the nature of the replies submitted to questions on this matter, requirements for admission to candidacy to the master's degree and to the doctor's degree will be considered together.

In a large group of institutions formal admission to candidacy for the master's degree involves first, the recognition of the undergraduate degree by an appropriate officer or group of the admitting institution. Registration in the graduate school, the taking of an approved course of study, the passing of language requirements, when specified, or the appraisal of the abilities and the work of the student during a probationary period are among the requirements for formal admission to candidacy. Admission to the graduate school does not, in many instances, imply admission to candicacy for the degree. The latter step is sometimes made a separate matter to be passed upon by some evaluating officer or group—often the latter.

In the case of formal admission to candidacy for the doctor's degree the practice of requiring the completion of a probationary period, the passing of language requirements, completion of all course requirements, or the passing of written and/or oral examinations is almost universal. Requirements and procedures in this connection are much more definitely formulated in the case of admission to doctoral candidacy than in the case of admission to candidacy for the master's degree.

Examples of the practices of various institutions as to requirements for admission to candidacy are given below as typical.

MASTER'S DEGREE

Purdue University.—The candidate must obtain the formal approval of his plan of study and his thesis topic by the major professor and dean of the graduate school.

Iowa State College.—The candidate must be registered in the graduate college at least 1 quarter. The application must show that the modern language and English requirements have been met. Final approval is determined by the graduate committee. Candidacy must be completed at least 1 quarter before graduation.

Kansas State College.—The candidate must obtain the approval of the graduate council after demonstration for 2 months or more that he is of graduate caliber.

Louisiana State University.—The candidate must meet major and minor requirements with the approval of the head of the department. He must satisfy his major professor as to graduate ability. The thesis topic must also be approved. Application must be made not later than the beginning of the second semester of the year.

Missouri School of Mines and Metallurgy.—No formal admission to candidacy for the master's degree is required. The student must complete a course of study approved by the committee on graduate students with a 1.75 grade point average, and must pass satisfactorily an examination on both course and research work taken after the work is all completed.

Syracuse University.—After the formal application the selection of the thesis follows usually after a semester of work. The application and the thesis are acted upon by the dean of the graduate school for the board of graduate studies.

Carnegie Institute of Technology.—On completion of a program of 32 semester-hours as approved by the department and group committee, the student is admitted to candidacy and is eligible for the comprehensive examination.

South Dakota State College.—The student makes application to the graduate committee, naming the departments in which he wishes to major and minor. If approved by the committee, with its help and that of the departments concerned, he should outline the scheme of study which he is to pursue. If after one term's study his work is found to be satisfactory he will be admitted to full candidacy.

DOCTOR'S DEGREE

Johns Hopkins University.—The recommendations of the professors of the principal and two subordinate subjects are required as well as the demonstration of reading knowledge of two foreign languages. Examinations are also required.

Iowa State College.—A preliminary examination is required at least 3 quarters before the final examination. In no case can the final examination be given in less than 6 months from the time of the preliminary examination. Additional requirements for the student to fulfill are filed by the students' committee with the dean.

Massachusetts Institute of Technology.—The candidate must have completed his minor and his modern language requirements, passed the general major examination, and given evidence of ability to do research of a high grade.

Carnegie Institute of Technology.—The applicant may be accepted after passing a preliminary examination. This comes between May 15 and October 15 of the calendar year before that in which the degree is to be granted.

Harvard University.—The candidate must be a graduate of a college or scientific school of recognized standing with at least 2 years of advanced study in engineering and with at least 1 year in the Harvard Graduate School of Engineering.

University of California.—The student must give notice of intending candidacy as early as possible. He must pass the qualifying examinations and meet the language requirements. At least 2 semesters must elapse between advancement to candidacy and the final examination.

74062°—36——5

CHAPTER VIII: GRADUATION REQUIREMENTS—THE THESIS—EXAMINATION METHODS—DEGREES[1]

TREATMENT of the topics listed above is limited, essentially, to their quantitative or statistical aspects. The broader question of the qualitative requirements or standards of graduate work in engineering and the problems incident thereto are omitted or at least touched upon only incidentally.

The following aspects of requirements for graduation are dealt with: Residence requirements; transfer of credits from other institutions; statement of requirements in quantitative terms; classification of graduate courses, together with the incidental matter of the admission of undergraduates to graduate courses and of the acceptance of undergraduate work in partial fulfillment of requirements for advanced degrees; and foreign language requirements. Under the head of "The Thesis" are considered such points as credit allowed, administration and supervision, and relationship to institutional research programs. Examination methods are treated briefly. The chapter concludes with a statistical summary of degree practices in graduate work.

TIME IN RESIDENCE FOR HIGHER DEGREES

Somewhat fewer than half of the institutions offering work for the master's degree set a maximum limit on the time which may elapse from first enrollment as a graduate student to acquirement of the degree, while more than half of the institutions set no such limit. The range of maximum time limits is from 2 to 8 years, with 5 years specified more frequently than any other one limit.

No institution permits earning of the master's degree in less than 1 year; this is virtually universal practice in the case of full-time work in residence. Two institutions (Yale and Johns Hopkins) report a minimum time limit of 2 years.

[1] Based on questions 9, 10, 11, and 12 of the questionnaire. See appendix.

When the time in residence is expressed in other units than the year, such as the term, semester, or week, requirements are found to be the equivalent of 1 year of work. In the case of programs of evening work leading to the master's degree the minimum time limit is 2 years, with longer periods mentioned as the average time required.

Apparently continuity of residence is not a problem of moment in connection with programs of work for the master's degree since only eight institutions mention that any requirements as to continuity of residence are enforced.

In the case of the program for the doctor's degree, continuity of residence has evidently received more consideration and is more definitely a problem because of transfer of students from one institution to another. Among 12 institutions that reported on the matter 6 require at least 1 year in residence and 2 of these indicate that this year must be the last year. Three other institutions indicate that at least 24 hours of work in course must be in continuous residence, while 2 institutions require 2 years of continuous residence.

TRANSFER OF CREDITS FROM OTHER INSTITUTIONS

In the case of work for the master's degree only 18 institutions out of a total of 82 reported any specific practices in the matter of transfer of credits from other institutions, though it is not certain that the number which would accept such transferred credits is limited to those who reported on the matter. The range of number of credits that will be accepted in this manner is from a minimum of 6, or approximately 20 percent of the total requirements, to a maximum of 24 out of 48, or half of the entire program. Six credits, or their equivalent in other units, is mentioned more frequently than any other one number.

As to transfer of credits for the doctor's degree only one institution indicated that no such transfers are permitted. In some instances arrangements for transfer of credits are made on the merits of each individual case, but in most cases restrictive regulations are enforced. In one case as much as 2 years of work in other institutions may be accepted; in another the limit is set at 30 semester-hours of work in course; in another the transferred credits must be acceptable on the

basis of evaluation in accordance with the standards of the accepting institution. Control of transfer of credits is vested in various individuals or groups. In general, transfer of credits is not permitted to decrease the minimum requirements for the degree, and usually 1 year in residence is stated definitely as the minimum requirement. It is the general practice to require that the doctoral thesis must be done in the institution that confers the degree.

GRADUATION REQUIREMENTS IN QUANTITATIVE TERMS

MASTER'S DEGREE

The following tabulation indicates the range of practice. Where necessary for uniformity of expression, requirements in other than semester-hour units have been expressed in the equivalents of that unit.

Requirement in semester hours	*Number of cases*
24	5
28	1
24, plus thesis	8
30	37
More than 30	12
Cases not susceptible of exact quantitative statement	13
Total number reporting	76

Since the modal requirement in undergraduate work is 32 semester-hours per year, it is observed that the requirement for the master's degree that prevails in a majority of cases—30 semester-hours or its equivalent—is less than the corresponding requirement in undergraduate work, doubtless a reflection of the fact that a greater amount of work is required per unit in graduate study.

DOCTOR'S DEGREE

While quantitative requirements of work for the doctor's degree are often stated and a tabulation of such requirements might be presented herein, it is believed that such a tabulation would not convey any information of value in addition to the basic fact that the requirement for the doctorate is almost universally 3 years of work in full-time residence after acquirement of the baccalaureate degree, and that

approximately 1 full year of the 3 must be spent on the preparation of the dissertation, whether this time be spent continuously or spread over parts of 2 years. Institutions differ in their practice as to the amount of work required in course and in research. They also differ in the units in which course work is expressed; for example, many institutions require a minimum of 60 semester-hours of work in course plus a thesis, while others state the same real requirement of work in terms of a stated number of 48 semester-hours plus a thesis; but it is apparent from information submitted that numerical statements of requirements for work beyond the master's degree are not of great significance.

CLASSIFICATION OF GRADUATE COURSES.

Three practices are followed in the classification of courses open to graduate students: (1) All graduate courses are grouped in a single category, these being open to graduate students only. The graduate student may not, in these cases offer any work done in courses open to undergraduates. (2) Courses are listed in two categories—those open to graduate students only and certain undergraduate courses which graduate students may pursue for credits. These are often called class A and class B courses. (3) Courses are grouped in three classes—often called 100 Courses, 200 Courses, and 300 Courses because of the numbering system used in the catalog. Courses in these three groups are open, respectively, to undergraduates only, to undergraduate or graduate students, and to graduate students only. A large majority of institutions—62 of 80 that gave definite answers—classify graduate courses in one or the other of the last-named manners, having certain courses or groups of courses that may be taken either by undergraduates or graduate students for credit toward their respective degrees. Only 18 institutions indicate definitely that they do not classify graduate courses in this way.

Practice differs greatly in the proportion of courses in the different classifications that may be taken by candidates for master's degrees. Two institutions indicate that all work offered in fulfillment of requirements for this degree must be taken from strictly graduate courses exclusively; 4 indicate that the proportion must be 75 percent or more; 15 indicate

that the proportion must be from 50 percent to 66⅔ percent; and the remaining institutions either indicate that the proportion may be less than 50 percent or do not answer the question. In one instance the prescription is that not more than 25 percent of work for the master's degree may be from subjects either offered primarily for undergraduates or open to them. In quite a number of cases there is no definite regulation, the matter being left to the discretion of the professor in charge of the student's major field of work or to that of the head of the department. A few other requirements may be quoted to indicate diversity of practice as follows:

> Major must include 16 hours of courses open to seniors and graduate students.
>
> At least 12 quarter credits out of 45 must be in courses exclusively for graduate students.
>
> Not more than 40 percent of work for the master's degree may be in courses open to seniors or may be "B" courses, and then only in use as minors.

Practice also differs widely in the matter of giving credit for undergraduate courses. Fifty-four of 82 institutions reporting permit the student to offer such work; 20 definitely do not. The proportion of these undergraduate courses that may be offered in satisfaction of the requirements for the master's degree varies widely. In certain cases the proportion is indicated by the use of such terms as "variable", "small", "limited", "very limited." In cases where practice is stated in percentages the figures range from 25 to 50.

An instance in which practice also varies greatly among institutions is the case in which a given subject is taught in an undergraduate course in one curriculum and as a graduate course in another. Courses in differential equations are sometimes taught in this way, i. e., they are required in the undergraduate curriculum in electrical engineering, but are available to graduate students in other fields. In 57 cases on which reports were received in this connection, graduate students of one curriculum are admitted to the undergraduate class in another curriculum; in four additional cases, the graduate students are taught in separate sections, though the content and level of the courses are substantially the

same in both groups. In only a few cases are graduate students who are required to take courses coming in this classification obliged to do so without receiving any credit toward the advanced degree. In 16 additional cases the graduate course in the subject is more extended and on a higher level than the undergraduate course. In one instance the remark is made that graduate students can attend undergraduate classes in a particular subject if no freshmen or sophomores are present. In certain instances graduate students are expected to achieve higher grades for credit in courses of the type herein referred to than are undergraduates pursuing the same courses.

The converse case to that just discussed is the admission of undergraduates to graduate courses. In 56 institutions this practice is permitted, subject to definite restrictions. In 17 institutions it is not permitted. The general practice is to require the undergraduate to have satisfied all undergraduate prerequisites, and, in some instances, the further limitation is imposed that the student must have nearly completed all the requirements for the baccalaureate degree.

Certain of the specific regulations that are made in this connection are the following:

> No credit for the graduate course is allowed until the bachelor's degree has been awarded.
> Undergraduates must be "honor" students.
> Undergraduates are not admitted to graduate courses unless within 15 units of graduation.
> Undergraduates are admitted to graduate courses only when working for two degrees simultaneously.

It is the general practice to permit enrollment of undergraduates in graduate courses only with the consent or upon the advice of the head of the department, the schedule adviser, or some other person authorized to grant the permission.

FOREIGN LANGUAGE REQUIREMENTS

MASTER'S DEGREE

In 65 of the 82 institutions reporting, no foreign language is required for the master's degree. In certain of those that do make the requirement it is left optional with the department or applies to particular departments only, such as

chemical engineering, where German is specified rather frequently. Eight institutions report that they definitely prescribe work in modern foreign languages as part of the requirements for the master's degree, while six additional institutions prescribe a stated amount of language work as a requirement for admission to graduate study; or they require the equivalent—a "reading knowledge" of one or more languages. The latter requirement is common when the program of work for the master's degree is considered to be a more or less integral part of the general program leading to the doctorate.

DOCTOR'S DEGREE

In 27 institutions offering work in engineering for the doctorate a reading knowledge of two foreign languages—virtually always French and German—is insisted upon. This requirement must be met before the student is accepted as a doctoral candidate in most instances. In only two cases among the institutions reporting in this survey is it specifically stated that a reading knowledge of a foreign language is not required. In one instance it is stated that the candidate must have a speaking knowledge as well as a reading knowledge of two modern foreign languages, the degree of proficiency being judged by a committee of the general university faculty.

VIEWS AS TO THE FOREIGN LANGUAGE REQUIREMENT

Only a limited number of correspondents indicated their views on this subject, and in certain instances those who did reply did not indicate clearly whether they intended their remarks to apply to the master's degree or to the doctor's degree. The following is a summary of the opinions that were expressed: In 24 instances foreign languages are deemed important in all graduate work. In 10 instances they were considered to be desirable but not indispensable, and in one of these cases it was the cultural rather than the utilitarian aspect of language work that was emphasized. In 26 institutions, in addition to those just mentioned, the foreign language requirement was emphasized as essential in work for the doctorate, and in 15 of these cases two languages were indicated. In nine of these German and French are believed to be necessary. In certain instances correspondents indi-

cated the belief that the language requirement depends to a certain extent upon the field of work or on the individual needs or inclinations of the student.

THE THESIS

Requirement of a thesis in partial fulfillment of requirements for the master's degree is almost universal practice in engineering colleges. In only a very few institutions is the thesis not required; in such instances it is usually optional, course work being substituted for it, often with the consent of a faculty adviser. In general, the intent is to place a good deal of the responsibility for initiating and conducting graduate theses on the student. Twenty-eight institutions indicate that the student is expected to make his own selection of a topic, though in certain instances a list of topics is supplied from which selections may be made. A conference with the professor in charge of a particular field of work is suggested and the student's final choice is subject to approval either by the thesis adviser or by the head of the department. In a few cases the professor or thesis adviser selects or assigns the topic; in such instances the student exercises little or no initiative and may even have no choice in the matter.

The allotment of credits for the master's thesis is represented in the following tabulation. In interpreting these figures it should be remembered that a total of 30 credits is the modal requirement for the master's degree.

Number of institutions	Number of semester-hour credits allowed to thesis
1	2 to 3.
2	3 to 6.
3	4.
5	4 to 8 or 10.
2	5 to 6.
1	5 to 10.
6	6.
8	6 to 9, to 12.
1	8.
1	9 to 12.
1	10.
3	13 or more.

In the administration and supervision of thesis work for the master's degree 33 institutions place the chief responsibility on the professor in immediate charge of the student's project. Among these institutions four assign some of the responsibility to the head of the department as well as to the professor in immediate charge of the work. In eight institutions responsibility for general supervision rests with

a committee, as is so commonly the case in work for the doctorate.

In a considerable number of institutions work on master's thesis is closely related to the institutional or departmental programs of research, particularly in those institutions having experiment stations. In a few instances special research projects of outside industries are assigned to students for thesis topics.

The general status of the doctoral thesis is so well understood and so much reduced to standard practice as not to require discussion at this point.

EXAMINATION METHODS

Replies to questions about examination methods in graduate work indicate a wide variety of practice. They do not, in general, make clear the distinction between the practice for the master's degree and for the doctor's degree. Consequently the statistics herein summarized may apply to either of these degrees.

With reference to examinations in formal courses, 43 institutions reported that the conventional written examination is required, while 6 reported that the written examination may be omitted at the option of the professor in charge. Two institutions indicated that a written report may be submitted in lieu of an examination. Three institutions reported the use of either a written or an oral examination; one that the examination may be waived in case the term record is B or better, and 27 made no reply. Apparently it is still the common practice to utilize the usual written examination in each course taken towards an advanced degree.

Answers to a question relating to examinations for admission to candidacy for a degree indicate a wide divergence in the interpretation of the question and in the practice among institutions. Some answers considered the question with reference to admission of the student to graduate courses, as indicated by the fact that 21 institutions reported no examination, 12 reported that an undergraduate record of high standing was required, and 4 indicated that an examination might be required for admission to graduate work.

Other institutions do not consider the student to be a candidate until he has demonstrated his ability to do graduate work successfully, as shown by the next group of answers. Two required satisfactory completion of a quarter's work for admission to candidacy for the degree. Four institutions reported both oral and written examinations required; three reported an oral; two, a written examination; five, admission to candidacy after passing the prescribed courses on the program; while four indicated the requirement of written examinations in modern languages and minors, and oral and written examinations in the field of the major. Three replies were scattering and 33 made no answer to this question.

Apparently it is a common practice to grant the master's degree upon completion of the prescribed program of studies without any comprehensive examination, although a few institutions do require both written and oral comprehensive examinations for the master's degree. For the doctorate, it is common practice to withhold approval of the thesis until oral or written examinations covering the major and minor fields as well as the language requirements are passed.

As to the use of comprehensive examinations: 30 reported an oral examination; 6 reported an oral examination on the thesis only; 15, an oral and a written examination; and 8 a "comprehensive." Twelve reported the use of either an oral or written examination or both; 1 indicated that the oral examination was considered of but little value; 7 reported no comprehensive examination; and 15 did not reply to the question. As the word "comprehensive" was not defined it is not certain whether the examinations were comprehensive in their covering of one subject or of a field. However, since many of the examinations covered the major, the minor, and the thesis, it is fair to assume that many of them apply to a comprehensive covering of the field.

Ten replies indicated that the oral examination extended from 1 to 3 hours, with 2 hours the most common time allowance.

Eighteen institutions reported that the examining committee was appointed in accordance with faculty rule; 16, that it was appointed by the dean; 8, reported appointment

by the head of the department; 3, by the president; 3, by the graduate committee; and 15 did not indicate the method of appointment of the examining committee.

The membership of the examining committee is indicated to be as follows: 23 institutions reported representatives of major and minor departments and the thesis supervisor; 7 reported each professor who had had the candidate in class; and 7 reported the major department, the thesis supervisor, and a representative of the graduate committee. Four reported the professors in major and minor courses, the thesis supervisor, and a representative of the graduate committee who had not had the student in class; 2 reported the graduate committee; 1 the committee in charge of student's program of studies; and 15 did not reply.

Sixteen reported the department head as chairman of the committee.

Six institutions reported that the examination was open to the public, and in one of these cases it was stated that any of those present could ask questions of the candidate but only the candidate's examining committee could vote on the recommendation for the degree.

Replies indicate that the oral comprehensive examination is common in graduate work, especially for the doctorate, and that the examining committee is made up of representatives of the departments involved. The practice of a few institutions in specifying at least one member of the committee who has not had the candidate in class seems a very desirable arrangement.

In conclusion it can be said (1) that the written examination is still widely used; (2) that there is considerable variation in the practice among institutions in rating a student as a candidate for a degree; and (3) that oral comprehensive examinations covering the field of graduate study are commonly used.

ADVANCED DEGREES IN ENGINEERING

The following tabulations summarize current practices. Virtually all of the institutions in the United States that offer graduate work in engineering are included. Honorary degrees are omitted from the tabulations, as are professional

degrees, such as civil engineer, that are offered as post-scholastic degrees on the basis of practical experience.

TABLE 8

MASTER'S DEGREE

Form of the degree	Number of institutions reporting
M. S.	22
M. S. with designation, as M. S. in C. E.	42
M. C. E., M. E. E., etc.	6
M. S. E.	2
M. S. and M. S. in C. E.	3
C. E. (for work in course)	3
M. S., M. S. E., or M. S. in C. E. (depending on nature of the program)	1
Total	79

DOCTOR'S DEGREE

Ph. D.	23
D. Sc.	4
Ph. D. or D. Sc. (depending on nature of the program or at the option of the student)	4
Ph. D. and D. C. E.	1
Ph. D. and D. Eng.	1
D. Eng.	1
D. Sc. and D. Eng.	1
D. Sc. in C. E.	1
Ph. D. in Eng.	1
Ph. D. in C. E.	1
Total	38

A glance at these data discloses that diversity of practice in advanced degrees is as great as it is in baccalaureate degrees. On but two points does there seem to be general agreement: (1) That the designation of the first advanced degree in engineering should include the word "master" and (2) that the second or highest degree should include the word "doctor." A considerable majority of institutions employ the word "engineering" in the designation of the first advanced degree, but in a considerable majority of cases this word does not appear in the designation of the doctorate. In the latter case the classical designation Ph. D. has been retained by about two-thirds of all the institutions that offer doctoral programs. This may be due in some measure to the fact that control of the granting of the

doctor's degree is vested in most instances in the graduate schools of our universities and only the single designation of all doctor's degrees has been retained.

In response to a question as to the preferred form of designation of advanced degrees in engineering a great majority of those who replied endorse the form employed in their own institution.

CHAPTER IX: RELATIONSHIP OF GRADUATE WORK TO UNDERGRADUATE WORK [1]

IT IS inconceivable that the rapid development of graduate work, with its attendant effects on teaching staffs, on institutional policies, and on other aspects of engineering education, as pictured in some measure in preceding chapters, could have taken place without having important effects on undergraduate work.

Before discussing this matter it should be noted that simultaneously with the rapid growth of graduate work, and even preceding it by a few years, a perceptible change was taking place, quite independently, in the nature of undergraduate work: Requirements for the bachelor's degree were being decreased; curricula were being simplified; emphasis was shifting from the more advanced technical courses and from purely descriptive work to the more deeply fundamental subjects; less time was devoted to the more mechanical types of work, and the time so released was devoted, in considerable measure, to humanistic studies.

As a part of this survey it was believed that some attempt should be made to appraise, at least in a general way, the influence of graduate work on undergraduate work, both in relation to the movement just mentioned and to effects that may have occurred independently of that movement. The following questions were therefore submitted to the several schools:

(1) Has there been any perceptible tendency, as work for advanced degrees in engineering has been developing during the past 2 decades, to transfer from the undergraduate curriculum any of the more advanced engineering courses to the graduate program?

(2) Has the development of graduate work in the past 2 decades had any other perceptible influence upon the content, purpose, scope, or other characteristics of undergraduate curricula?

It is unfortunate, perhaps, that the institutions were not asked whether the reverse of the tendency mentioned in the

[1] Based on question 17 of the questionnaire. See appendix.

first question had been observed. However, information on that point was given voluntarily in a number of replies.

In answer to the question as to the transfer of work from undergraduate curricula to the graduate field, 48 of 79 correspondents replying stated that no such tendency had been observed. Eighteen institutions reported that there had been such a tendency, and 10 volunteered the information that the tendency had been the reverse, namely, subject matters had been transferred from graduate to undergraduate curricula. Apparently there has been a good deal of difference in the trends in different institutions. Strangely enough, two schools of engineering in the same university report opposite tendencies. The whole matter is of so much interest and importance that a few replies may be quoted as indices of the general trend.

In relation to the transfer of work from undergraduate to graduate curricula one correspondent writes: "Yes, the tendency has been to stress fundamentals and humanistics in undergraduate work and to offer the more specialized topics in graduate courses." Another says: "Yes, due to increase in requirements in fundamental sciences, economics, and electives." These two replies are typical of several explicit statements indicating that the effects of the introduction of graduate work has been to cause greater stress to be laid on fundamentals and to cause the transfer of certain of the more advanced specialized engineering courses to the graduate field.

Another group of replies may be illustrated by the following typical answer: "No; but many new courses have been developed [in the graduate field]." Several others state that the contrary trend has prevailed, and that certain subjects, formerly considered as of graduate status, are now offered in the later years of the undergraduate program.

Replies indicate very clearly that the demands of graduate work are for a more fundamental and sounder training in the basic elements of engineering science. The program of graduate work appears, therefore, to have become something of a measuring stick by which the adequacy and effectiveness of undergraduate work may be evaluated.

Replies also indicate that the influence of graduate work is to direct undergraduate engineering education, by and

large, into the more scientific phases of the design and research functions of engineering, and less into the operation, administration, and sales functions. There can be no dissent from the aim of placing engineering education on the highest possible plane of quality and effectiveness, and it is probably correct to say that the influence of graduate work has been in that direction.

As to other influences of graduate work on undergraduate work, the following quotations are offered:

One correspondent writes: "The development of graduate work has naturally improved the character of undergraduate teaching." This is doubtless the most beneficial effect that graduate work could possibly have on the general character of engineering education. Another correspondent phrases the same general thought in the words: "It has improved undergraduate work and placed it on a higher plane." Another writes: "It has intensified the scientific character of the undergraduate program. Less emphasis is being placed on the practical." Another says: "It has reacted to increase emphasis on fundamentals and on the scientific subjects of undergraduate curricula. The tendency of undergraduate courses to be planned for the more highly specialized graduate courses has been emphasized." Another writes: "There has been more emphasis on the scientific basis of design and less on mere drawing and routine computations." Another notes: "Informational courses have been abandoned."

A trend differing from those just quoted is noted by one who writes: "Graduate work has helped to keep undergraduate work from becoming too technical, with too little humanities, etc. It has tended to make undergraduate work more general."

As to changes in methods of instruction, replies indicate several interesting changes in undergraduate work. One states: "More use is now being made of the conference and research methods of instruction." "It [graduate work] has been a great stimulus to scholarship. Small research projects have been introduced for seniors." Another says: "Time in class has been reduced and more out-of-class work has been required." Another summarizes the situation by

remarking: "It has raised the level of original and independent work throughout the institution."

As a concluding quotation, the following may be cited as indicative of the general leavening effect of graduate work through engineering education at large: "The effect of graduate work has been revolutionary, stimulating the faculty and the interest of the students in their work."

As a final effect, graduate work appears to have tended to fix 4 years as the normal length of the undergraduate program. No positive evidence of this influence can be adduced from the replies to its inquiries, but it is believed that the lengthening of the general program of engineering education through the widespread provision of a fifth year of work for the master's degree is tending to effect the lengthening of the normal period of engineering education that has been so often and so strongly advocated. That any considerable number of institutions will provide both the longer undergraduate curriculum and added years of graduate work for advanced degrees does not seem probable.

CHAPTER X: SUBSIDIZED GRADUATE WORK, SCHOLARSHIPS, FELLOWSHIPS, ETC.[1]

DATA ARE given in the following paragraphs relating to the number and type of subsidized opportunities for graduate work that are open to engineering students. The several statements are largely self-explanatory.

There was a gain in total funds provided throughout the country for this purpose from 1932–33 to 1933–34, though most of this increase was in a single institution—Massachusetts Institute of Technology.

It is also significant that as many as 249 teaching fellowships and assistantships are available, an average of 6 per institution reporting them. Many of these graduate fellows and scholars are assigned to work as laboratory supervisors, but a rather large proportion are assigned to regular classroom instruction. The practice of using graduate students as classroom teachers has been followed to a greater or less extent for a long while, but it has grown rapidly as a result of curtailed budgets and expansion of programs in the past 5 years. Attention is called to this situation as one deserving most careful consideration.

SCHOLARSHIPS AND FELLOWSHIPS CLASSIFIED ACCORDING TO TYPE

Fellowships and scholarships making no demands on the student's time:

Total number available, 426.

Stipends range from remission of tuition to as much as $1,500 per year. Most of the stipends are less than $500 per year. Many are from $200 to $300 per year.

Fellowships and assistantships requiring part-time service in research or testing:

Total number available, 124.

Stipends range from a small sum, such as $100 per year, plus remission of tuition and fees, to as much as $1,000 per year, without remission of tuition and fees. The modal tendency is toward $400 to $600 per year.

Time required in research or testing ranges from 6 to 8 hours per week to full time. Half time to the institution and half time for study is a common arrangement.

[1] Based on question 14 of the questionnaire. See appendix.

Teaching or laboratory assistantships requiring part-time service in instruction:

Total number available, 249.

Stipends range from remission of tuition and fees to as much as $1,200 per year, $400 to $600 per year being a common stipend.

Services to the institution range from 4 or 5 hours per week to half-time. The latter is a common arrangement.

Industrial fellowships:

Total number available, 50 in 25 institutions.

Stipends range from $400 to $1,800 per year, several being within the limits of $500 to $1,000 per year.

Half time service is usually required. Fellowships paying the largest stipends—$1,500 to $1,800 per year—require full-time services on research.

Miscellaneous:

In addition to the foregoing, 18 positions of miscellaneous types are open to graduate students. The compensation ranges from 35 cents per hour for occasional work to $540 per year for half-time duties. Work ranges from night librarian to power-plant operations.

A few institutions also permit graduates who are unemployed and cannot afford to pay the fees to attend graduate classes without charge.

Total funds available as stipends for scholarships and fellowships open to advanced students of engineering were $261,854 in 1932–33 and $293,078 in 1933–34, a gain of 12 percent. Most of this gain occurred in one institution—Massachusetts Institute of Technology. A majority (34) of those reporting a change in connection with fellowships and scholarships stated that there had been a reduction in number available, or in stipends, or in both. A few institutions (10) reported gains in these particulars.

In certain instances the numbers of scholarships and fellowships reported above are open to graduate students of the institution at large. Most of the positions, however, are open to engineering students only.

CHAPTER XI: IMPROVEMENT OF GRADUATE WORK IN ENGINEERING[1]

AS A conclusion to the questionnaire on which this survey is based those from whom information was sought were invited to state their views as to appropriate ways and means through which graduate work in engineering may be improved and also as to their views on the general principles and policies under which it should be conducted. Replies to this question proved to be extremely interesting and valuable. Almost all could be quoted to advantage; limitations of space alone have dictated a choice from among those submitted. The following selections have been chosen chiefly with the idea of covering the general range of suggestions; those that were found in several replies have not been repeated. The general matter of principles and of policies relating to graduate work is divided into two sections in the material which follows: The first is a compilation of statements of a general nature. The second section relates to a more specific aspect of the matter having to do with regional planning of research work and of graduate study and of cooperation therein with a view to development without needless and expensive duplication of effort and scattering of resources.

VIEWS OF CORRESPONDENTS AS TO GENERAL POLICIES AND METHODS

1. The graduate faculty of engineering should be largely relieved of all duties of undergraduate instruction, save perhaps where a teacher gives one course in the senior undergraduate year. The time of the graduate faculty should be divided evenly between instruction and experimental research or other form of creative activity contributing to the advance of the state of the art in the respective fields. In this institution, and I believe in most others, the faculty giving graduate instruction is overburdened with duties of undergraduate instruction.

2. It will produce disaster and chaos for institutions in a common territory to campaign by subsidizing prospective

[1] Based on questions 18 and 19 of the questionnaire. See appendix.

graduate students and becoming rivals in this respect at the expense of the State.

3. Too many students have been taking graduate work during the past 4 years because they could not find satisfactory positions in industry. In many schools this has meant simply a continuation of their undergraduate study. The same methods, the same type of studies, and the same laboratory equipment have been used as when they were undergraduates. Graduate work in engineering ought to be for the minority who can profit by it. The incentive for creative work should be the test. I do not favor the restrictive laboratory research followed at many schools. That is, where a school by reason of its location is isolated from industry and where research facilities are restricted to certain laboratory equipment, there is too much tendency to assign graduate research to trivial problems which may be solved by means of the particular laboratory equipment available. Graduate engineering research should be broader than this.

4. We should like to see greater emphasis on research in the graduate program and corresponding reduction in course work. We believe the examinations of graduate students should be completely overhauled along the lines of the typical comprehensive examination.

5. In a study of catalogs of Nation-wide selection one is impressed by the low percentage of engineering faculty members who have done graduate study and, in particular, those who hold earned doctor's degrees. In my mind those who give graduate courses should not only have done substantial graduate study but should also have published substantial papers of a scientific and not trade-journal caliber.

6. I believe that what is most needed in engineering instruction in this country is an elevation of the entire undergraduate curriculum in most schools. Our entrance requirements as a rule are too low. Good graduate work can really be done where and when the foundation is substantial.

7. I believe there is a real need for the development of graduate work in engineering on a part-time basis in urban institutions. This would provide many engineers an opportunity to carry their education beyond the undergraduate level without the expense of additional years of residence in school.

8. We have insisted that work for the M. S. degree shall be a distinctive and advanced educational process requiring a considerable degree of individual and semi-independent work—with a discipleship relation between the student and some senior member of our staff. We question the propriety of giving an advanced degree for a mere prolongation of the undergraduate program.

9. Graduate work in engineering is a proper and natural correlative of the 4-year undergraduate course. However, the 4-year course is naturally a "completion course" for the vast majority of young engineers, and as such it is not the best preparation for the small percentage who go on to graduate study.

10. In the 168 or more institutions in the United States giving engineering training, about 160 of them are trying to put 6 years into 4 years' time. The result is a deficiency in the student's foundation. By cramming a lot of professional courses into the undergraduate years they have to leave out needed language, literature, history, science, and economics. We build a proper foundation first and then put 2 years of graduate professional work on a good foundation.

COOPERATION AMONG INSTITUTIONS IN THE DEVELOPMENT OF GRADUATE WORK IN ENGINEERING

It appears from an analysis of answers to this phase of the inquiry that the large majority of engineering schools favor some form of rational development of graduate work in relation to State, regional, or national needs. There is considerable diversity of opinion as to the best way of obtaining such development.

Several schools believe that a series of conferences of representatives of institutions would be helpful; others recommended that the Society for the Promotion of Engineering Education, the professional engineering societies, or the Engineers' Council for Professional Development would be the best integrating agencies in developing and coordinating a long-time program of graduate study and research. The American Council on Education, the Association of Land-Grant Colleges and Universities, and the National Research Council are also mentioned in this connection. A thought that recurs in several replies is that individual institutions should not be prevented but should be encouraged to develop along their own lines.

Nearly 20 institutions expressed approval of the general idea of a broad program of cooperation but stated that this should be in harmony with the needs of regional industries. It is natural that engineering schools located in the midst of mining, petroleum, aeronautical, and other highly specialized industries would properly find their programs in connection with such industries.

Replies from 10 institutions stated that the general control of research as indicated in the topic cannot be accomplished, or even if it were possible that it would be undesirable. A few are willing to have some control exercised in certain specialized fields only.

A few specific statements of opinion are given herewith:

1. It is doubted whether graduate work (at present anyhow) can judiciously or wisely be "guided." It will necessarily grow out of local talent, facilities, and interests of students. The professional or national needs should predominate over local considerations as a controlling principle.

2. An engineering school in an industrial center can, with cooperation with neighboring industries, offer a type of program impossible for the isolated school. Engineering research on actual industrial problems using the facilities of both the school and industry opens a field without limit.

3. Graduate students flow to institutions where the outstanding leader in his field resides. Graduate offerings will reflect regional and State needs rather than national needs.

4. Institutions should be permitted to develop their graduate work free from all regional, State, or national control. Naturally they will cooperate with the several kinds of authority as far as possible.

5. Graduate work should be developed so as to make proper opportunities available in each locality or region. Duplication of facilities in adjacent schools seems unnecessary and expensive. A cooperative agreement or a code of practice might be worked out for the entire country.

6. The general economies of the situation may demand a certain degree of specialization in certain institutions and the avoidance of too much duplication of staff and equipment. Some institutions have already developed certain branches more than others. It would be better to emphasize these rather than to spread out.

7. There should be recognition of work done in certain engineering fields by a limited number of proper geographical distributions. Other institutions in a given geographic area should not parallel the work.

8. Engineering graduate work should be permanently (*a*) to train men for research work in industry; (*b*) to supply a higher grade of engineering teachers. With these objectives as fundamental no national, regional, or State guidance is necessary.

9. It would be good to have meetings of deans or professors of specific departments at a regional conference to discuss and assign specific problems to at least two institutions having professors and equipment best fitted to carry out the work.

10. There should be at least a well-organized and effective clearing house for research and graduate work, both as to personnel and equipment of the different institutions in this country. There is too much pseudo-research and graduate work in many of our institutions, developed under administrative pressure from "higher up" to secure greater publicity when adequate facilities are not provided for the work in question.

Honesty and integrity in graduate work and research are similar to the problem of honest and clean intercollegiate sports; it rests with the conscience of the individual institution more than anything else.

CHAPTER XII: INDUSTRY AND THE GRADUATE OF ADVANCED COURSES

THE QUESTION is frequently raised whether the engineering student with an advanced degree gets employment more readily and of how his advancement compares with the man with a bachelor's degree.

Since 1930 there have been lamentations about the scarcity of positions for college graduates. It is difficult to obtain a position, but several studies indicate that engineering graduates through persistence have been able to find jobs. It has been found in a recent study that engineering college graduates of the classes of 1931, 1932, and 1933 are rather consistently placed to the extent of approximately 60 percent. Later studies indicate that more than 57 percent of the electrical engineering graduates of 1934 are satisfactorily placed. A study by Purdue University of their graduates from 1928 to 1934, inclusive, revealed that in 1929, 20 percent found employment before graduation; an additional 60 percent within 2 weeks; and approximately 15 percent more within 3 months. For the whole period 9.9 percent found employment before graduation; 39.5 percent more within 2 weeks after graduation; and 23.7 percent within 3 months after graduation. In other words, while in 1929 more than 95 percent found first employment within 3 months after graduation, the average over the years 1928–34 was 73.3 percent finding employment within 3 months after graduation. In the fall of 1934 when the study was made 91.3 percent of the graduates of the classes of 1928–34, inclusive, were employed. This indicates that engineering graduates are overcoming difficulties and are finding employment. Employers looking for men tell me it is difficult to find first-class applicants from the so-called depression-year classes. Professor Leutweiler of Illinois had a request for some of his recent mechanical engineering graduates. He wrote the graduates of the recent classes and not finding enough prospects, he wrote to all his graduates from 1922–34, inclusive. Less than 6 percent replied that they were

unemployed. As there were prospects of employment, it seemed to him reasonable to draw the conclusion that all those unemployed and wanting work would reply. Of those replying, 62 percent were employed and satisfied; 31 percent were not fully satisfied with present positions and opportunities. These facts are given (in regard to the employment status of recent engineering graduates) as a background in considering the question if postgraduate training in engineering is an asset in getting placed and in future progress.

Letters were written to the deans or placement officers of the 20 engineering schools and universities which granted the largest number of master's and doctor's degrees in engineering in 1934. Replies were received from 17, representing close to 60 percent of the master's degree group and more than 95 percent of the doctor's degree group. Recognizing the impracticability of getting statistical data, the letter of inquiry requested that the reply give such information as was available along lines of a submitted series of questions which were considered as merely suggestive. The replies were, on the whole, to the questions as submitted, so this discussion will deal with the questions asked although it is recognized that they did not adequately cover the subject.

The first questions were: "Do engineering students with postgraduate degrees get employment more readily than those with bachelor's degrees? Is the same thing true for the various branches of engineering such as chemical engineering, civil engineering, electrical engineering, aeronautical engineering, etc.?"

The replies varied from the extremes of "Unquestionably, yes" to "In most cases, no." Two out of three replies reported that their experience showed that the postgraduate degree group has found employment more readily. Emphasis was placed upon graduate work being especially advantageous for teaching positions, for research, and for distinctly engineering work. A number of replies stated that those with advanced degrees probably found employment more readily. Some qualifying statements were "Practically no difference for those with M. S. only"; "Past experience indicated yes, but case was completely reversed this year"; "98 percent advanced degree men placed as compared with 83 percent bachelors."

The consensus of opinion was that graduate work in engineering is advantageous in obtaining employment for all branches of engineering. There was unanimity of opinion that it was of value in getting a position in chemical engineering and metallurgical and ceramic lines. The majority felt it was so in electrical and mechanical engineering, while the most doubt was expressed in the case of civil engineering graduates.

The second group of questions were: "Are the men with graduate degrees accepting positions formerly filled by men with bachelor's degrees? In other words, are they accepting positions in which there is no need or occasion to use the technical material and methods studied in the postgraduate years? If so, would the men continue to be happy on that type of work when industrial conditions improve?"

There was considerable feeling that the postgraduate degree man is accepting the type of position filled by the bachelor degree man in former years. It was felt that this will not produce a problem for the future because being better qualified he will make better progress. One reply stated that employment standards are rising and another that some of the jobs were formerly filled by men with bachelor's degrees because of the shortage of men with graduate degrees. Still another reply raised the question whether in the adjustment to new conditions the individual might not have to find his ego satisfaction in his avocation.

The third set of questions were: "Is there any indication that the graduate group has been diluted in ability by increases in registration resulting from inability to get employment? If so, is there any indication that this lower ability group improve their chances of getting a position by taking graduate work?"

About half the replies indicated that there has been dilution in ability along with the increase in registration since 1930. This dilution appears to be much less now than in 1931 and 1932. It was felt that even in those cases where there was dilution, those of lesser native capacity improved their employment chances by taking graduate work.

The question was raised "How does the engineering graduate with a B. S. degree who returns for further study in other undergraduate engineering courses or who takes some

graduate studies without completing the requirements for an advanced degree fare in obtaining a position as compared with the man who has his B. S. degree only and with the man who has a graduate degree?" The replies showed that very few B. S. men have returned for undergraduate courses in other departments and that those who took graduate courses but did not fulfill the requirements for an advanced degree, did not improve their employment prospects appreciably.

There was nothing to show that any particular type of industry is especially active in employment. It is recognized that the larger industries are taking few men compared with the years previous to 1930. Government projects are employing quite a number of engineering graduates, especially civil engineers. The others are finding employment in smaller diversified industries. Starting rates have continued to decrease from 1929 until reaching a low in 1932, and have increased slightly since then. The increments in starting salaries between men with bachelor's, master's, and doctor's degrees have also decreased. Estimates give the starting salary for a man with a master's degree in the neighborhood of $100 to $125 a year more than for the man with a bachelor's degree. Starting salaries for men with their doctor's degrees are less standardized, but vary from $300 to $500 a year up more than for the bachelor's degree group. While these starting salaries are higher than for men with bachelor's degrees, the classmates of the advanced degree men who accepted employment at the time of receiving their B. S. degrees have usually advanced to a higher salary than the starting salary for the advanced degree classmate.

While the preponderance of opinion is that men with graduate degrees obtain positions more readily than those with bachelor's degrees, the replies emphasized that it must not be forgotten that success in life depends primarily on character, personality, and native ability and that too much weight must not be placed on graduate study as being the major reason for advanced degree men getting placed more readily. It was pointed out that men taking graduate work are in general of superior qualifications and that they are more mature. One reply placed considerable weight on the fact that the faculty members are better acquainted with the graduate students and accordingly take a greater personal

interest in them, resulting in their coming to mind more quickly when asked to recommend someone for a position. Apparently some new types of positions have been created in some industries calling for men with graduate engineering training.

Contact was also made with a number of industrial concerns. The consensus of opinion was that graduate work in engineering is an asset for research, design, and highly technical positions, but that it is not of measurable value in strictly operational, production, and commercial positions. A greater percentage felt that the graduate group has been diluted in ability and that greater care must be exercised in selection. There is general agreement that the men who return to college after getting their bachelor's degree are better prospects for employment than the men who accept nonengineering employment until conditions pick up. The majority of men accepting nonengineering employment forget their engineering principles and are at a disadvantage when openings do come up.

As for future progress, there is some statistical evidence that men with graduate training make better salary progress in the creative branches of engineering but on the whole their progress in operational, production, and commercial work is of the same order as that of men with bachelor's degrees. Men in the analytical and creative types of work who continue their studies rank in rate of progress with the men who received their graduate degrees before employment. Professor White, of the chemical engineering department of the University of Michigan, gave some definite data in a paper he presented at Atlantic City in December 1931. The table showed that at the end of 10 years after receiving their first degrees, the median salary for men with the bachelor's degree was in the neighborhood of $3,800; for men with 1 year of graduate work in the neighborhood of $4,600; and for men with 2 years of graduate work in the neighborhood of $5,400 in the research field. There also appears to be less turnover for men with graduate degrees. This is true for production and operation forces as well as for the research and development positions.

It appears that men with graduate engineering degrees are finding positions at higher starting compensation than men

with bachelor's degrees. These starting rates in a given company are generally less than the current rate of engineers who received their bachelor's degrees at the same time but accepted employment instead of returning for further study. In work of a creative nature the men with graduate work appear to have made more rapid progress than the men with bachelor's degrees who did not carry on continuing study programs. There are no data to support the theory that men with graduate degrees made more rapid progress in engineering work of the operational and productive type. However, the rate of turnover for men with graduate degrees has been lower than for men with bachelor's degrees. Will these same things be true for the advanced degree men who are being graduated now in increasing numbers and are entering different kinds of employment? Only time will tell.

CHAPTER XIII: INTERPRETATION OF THE SURVEY BY THE COMMITTEE

FROM A position of minor importance, graduate work in engineering has advanced to one of great significance during the brief period of the past 20 years. Such rapid development could not have taken place without intensifying certain existing problems, as well as creating new ones. In many ways these problems have been made more difficult by the fact that the most recent stages of the growth of graduate work have taken place during the most severe and long-continued financial depression that has occurred since engineering education reached its majority. The situation thus produced calls for study based upon wide and accurate knowledge of all the relevant facts. It has been the purpose of the present survey to assemble such facts. These have been presented in the preceding chapters of this report. This concluding chapter embodies the discussion of those facts, as well as conclusions relating to certain of the broader aspects of graduate work, by the Committee on Graduate Study of the Society for the Promotion of Engineering Education at whose instance the survey was undertaken. The statements and discussions contained herein are tentative; they are essentially the opinions of the committee and are intended chiefly to provoke further thought in certain directions. It is probable that no final judgment can be reached at this time as to many of the problems under consideration. Time will be required for movements now in progress to take definite directions and for thought concerning them to mature. The time is appropriate, however, for widespread discussion. It is this that we hope to evoke.

GRADUATE WORK IN THE GENERAL PROGRAM OF ENGINEERING EDUCATION

It is basic, we believe, that the broader aspects of graduate work be considered in relation to the field of engineering education as a whole. The following fundamental questions to which results of the survey direct attention may therefore

be stated: Should graduate work be considered essentially as a continuation of the ordinary collegiate program of engineering instruction forming part of a definitely integrated program with no sharp differentiation as to type of work or methods of instruction; or should it be considered as a rather uniquely different stage of work specially adapted to the needs and abilities of the gifted minority and intended to fit them for distinctive places in science and industry? Is the problem essentially one of increasing the duration of the normal program of engineering education so as to provide a broader, more liberal, and less crowded program with sufficient time to do thoroughly all that is attempted; or is it one of providing a program of two fairly distinct stages of essentially different characteristics? Should the offering of programs of advanced work be widespread; or should they be concentrated largely in those institutions possessing exceptional staffs and facilities? Study of the results of the survey confirm the general observation that this issue exists, and though it may not be as clearly or sharply defined as the alternatives suggested by the wording of these questions would seem to indicate, it seems clear that it would be in the general interest of engineering education if it could be clarified. The problem is closely associated, of course, with the question of the length of the undergraduate curriculum. Programs of graduate work following 5 years of undergraduate study would differ to an important extent from those following 4 such preparatory years. The situation is also complicated by the problem of the undergraduate curriculum of junior and senior stages, as adopted in a few institutions, and by the rapid growth in numbers of junior colleges. This whole matter has so many ramifications that a thorough-going discussion of it would lead far beyond the scope of the present report. We would remark, however, that the effect of the growth of graduate work—doubtless the most important recent development in engineering education—will probably be in the direction of causing 4 years to be retained as the normal period of undergraduate work. It seems unlikely that many institutions will move toward the provision of 5-year undergraduate curricula while at the same time devoting their energies

and resources to the development of their programs of graduate study.

While advancing no conclusive answer to the question of the definiteness of distinction between undergraduate and graduate stages of engineering education, your committee believes that developments are likely to be in the direction of graduate work of a fairly distinctive nature. It is quite possible that the termination of the conventional 4-year course marks a point of diminishing returns in the education of many of our students, and that a distinct advantage is to be gained from a clearly marked termination of one stage of the program with subsequent reentry to the higher phases of work on the basis of selective admissions.

As to the importance and magnitude of the place that graduate work is to occupy in the general scheme of engineering education, evidence already at hand indicates clearly that it is to be one of great and fundamental significance. It should be one of corresponding soundness. In this connection we venture to express the view that it might be just as well to consolidate and strengthen the position already achieved by the recent advance into the field of work for the master's degree before any further widespread movement is made into the still more advanced stage of work for the doctorate.

GENERAL CHARACTERISTICS OF GRADUATE WORK

We present two aspects of this matter: First, fundamental characteristics of graduate study; and, second, content and methods of instruction.

Fundamental characteristics.—Two distinctive features should, we believe, characterize a program of genuine graduate study: Concentration in a somewhat limited and a fairly well-defined field of study; and a rapidly increasing degree of initiative and self-motivation on the part of the student as he progresses in his work. The former characteristic implies a high degree of attainment and of mastery on the part of the student and requires a correspondingly more profound mastery of his field of work on the part of the teacher. Fortunate indeed is the institution that can number among its faculty any considerable number of men

having such mastery in a variety of fields so as to provide rich and varied opportunities for its advanced students, and who can also so direct their students as to develop in them qualities of initiative and resourcefulness. It is the attainment of the goals expressed in these statements that constitute, in our opinion, the core of the problem of graduate work.

Data gathered in the course of this survey indicate clearly that programs of graduate work, in comparison with undergraduate programs, place emphasis to a marked degree on the more highly scientific and technical phases of engineering, that comparatively little weight is given to economic factors, and that almost no time is devoted to what are commonly called the liberal or humanistic elements. The trend appears to be strongly toward the design and research functions of engineering as the aim of graduate instruction, with little emphasis upon the administrative function. It seems to be expressly or tacitly assumed by many that this is the chief if not the sole aim of graduate instruction. If this assumption is, indeed, generally held, there would seem to be need for careful study of this aspect of graduate work; consideration should be given to the possibilities of functional differentiation in the graduate field, similar to that effected in undergraduate work by the introduction of courses and curricula emphasizing the economic and administrative elements of engineering activities. While the attainment of deeper and broader knowledge of the basic physical and mathematical sciences throughout engineering education is an end of unquestionable soundness, it must be remembered that engineering undertakings always have an economic aim and motive, and that they are the product of coordinated human endeavor. It is seriously to be questioned, therefore, whether development of and emphasis upon mathematical and physical science in graduate work, without proportionate development of the economic and administrative element would, in the end, be in accord with the fundamental aim of education for the broad field of industry and engineering.

Language requirements.—In work for the doctorate, a reading knowledge of two modern foreign languages is required almost universally. Apparently the traditional

requirements of work in pure science, the classics, and philosophy have been adopted in engineering without much consideration of their relevancy. It is of some significance, perhaps, that in programs of work for the master's degree, which have developed in closer relationship to undergraduate work in engineering and often under the direct guidance and control of the engineering faculty, language requirements are usually not imposed. Further study might well be given to this whole matter.

Methods of instruction and guidance.—The effects of the relationship of graduate study to the customary standards and practices of the graduate school on the one hand, and to the undergraduate work of the engineering college on the other, are exhibited also in the methods of instruction and of supervision and guidance of work that are employed. In doctoral programs, after the stage of attainment of the master's degree has been reached, there is a minimum of formal class instruction, more use is made of the seminar, and much greater emphasis is given to the doctoral thesis wherein the student consults with his adviser individually. These methods are employed almost universally throughout the university graduate school, and are so well understood and so widely endorsed as to call for no further comment. In work for the master's degree, however, there is greater diversity of practice, and in many instances methods approximate more closely to those of the upper undergraduate years: Formal class instruction is common; practice in the use of the seminar varies widely; and there is even a good deal of diversity in the degree of independence and of initiative permitted to the student in the selection of the topic of his thesis and to his work thereon. Furthermore, as will be discussed later, in many instances graduate students are permitted to accumulate credits in a certain number of undergraduate courses where the customary methods of formal class instruction are employed. On the average, about one-fourth to one-eighth of the credit requirements for the master's degree are allotted to the thesis, in which really individual self-motivated work is done, while the remaining units are usually in regular course work in which methods of instruction approximate closely those of undergraduate work. It is a little hazardous, perhaps, to attempt

thus to characterize the methods of instruction employed in work for the master's degree in terms of a general average, but a careful study of all the data submitted in the course of the survey indicates that the general trend is about as indicated, even though exceptions and deviations are fairly numerous. Apparently the belief is held rather widely that there cannot or should not be any abrupt change in methods of instruction as the student begins his advanced study. Probably, also, limitations produced by the present general situation tend to impose a continuation of the methods of undergraduate work into the first year of graduate study. In this connection we would reiterate our belief, expressed in an earlier section of this report, that genuine graduate work should be characterized by a rapidly increasing degree of self-direction and of guidance rather than by formal instruction. It is for this reason, in part, that we have sounded a note of caution as to the rapidity of further expansion of graduate programs in the immediate future, or until present restrictions, so widely felt in engineering education, can be removed.

ADMISSION AND GRADUATION REQUIREMENTS

Admission requirements.—Aside from requiring applicants to have attained the baccalaureate degree, most institutions impose more or less restrictive limitations aiming to admit only "properly qualified" students. These usually take the form of restricting admission to graduates of institutions of "recognized standing", of requiring students from other institutions to make up "prerequisite courses" not included in their undergraduate curricula, and of admitting only those having "superior" undergraduate records. Restrictions of the latter sort seem to be imposed more strictly on students coming from other institutions than they are on graduates of the same institution, the presumption being, apparently, that the institution is under some obligation to admit its own graduates.

The principle of selective admissions to graduate work is, we believe, one of prime importance. There appears to be opportunity and need for the more widespread establishment of requirements of high scholastic ability as well as qualities of originality and self-reliance. The student's undergraduate

record will doubtless have to be relied upon chiefly for evidence of scholastic ability, but more weight might be given to endorsement by his instructors in the form of explicit statements as to his qualifications for original and self-motivated work. Possibly less weight might be given in some instances to the minutae of the student's undergraduate curriculum. Apparently an excellent opportunity for further selective measures in the master's program is being generally overlooked in the possibility of imposing a requirement for formal admission to candidacy for an advanced degree after a probationary period of advanced study—in the case of the master's program, a term or semester. This requirement, common in doctoral programs, is in effect also as to work for the master's in some institutions. In view of the fact that qualifications for work that is, or should be, to a considerable degree self-motivated are judged far better during the pursuit of such work than they are by the examination of a record of grades in undergraduate work, the more widespread adoption of this means of selection might be given consideration.

As to the admission to the doctoral program, whether the master's degree is or is not achieved en route, procedures are more nearly uniform and standardized, showing the influence of the university graduate school. The stages of admissions procedure just mentioned, i. e., preliminary admission to study with later formal admission to candidacy, are well-nigh universal. The practice has stood the test of long-continued usage.

Graduation requirements.—As measured by credits, requirements for the master's degree range from 24 to 36 semester hours, this unit being defined in the same way as in undergraduate work. One year of residence is required except in the case of two institutions which require a minimum of 2 years. The thesis is usually weighted at from 4 to 8 units,[1] or about 20 percent of the total, the proportionate amount of research as compared to course work being about the same. Work for the master's degree in engineering is planned almost universally as a terminal program, even if it is anticipated that some students will later go on for their doctorates. (Its general nature is indicated in a way by the term "little doctorate" that is sometimes

[1] There are important deviations from the practice represented by these average figures.

applied to it.) This is in contrast with certain other divisions of science in which it has become rather common to discourage students aiming at the highest degree from acquiring the master's degree en route, the purpose being to have them concentrate on a single piece of research, after completing the course requirements, instead of undertaking two projects, one in the master's program and the other in the doctor's.

Requirements for the doctor's degree are not usually expressed in terms of units or credits, but simply in terms of years of residence; 3 years after attainment of the baccalaureate degree being universal so far as we have been able to learn. Work for the doctorate is essentially a research type of program following closely the traditional pattern set by the classics and pure science. It is adapted almost solely to the needs of the design and research function of engineering, especially the latter. Programs of this type appear to have been tacitly accepted in engineering education and no serious question appears ever to have been raised as to the validity of their aim and purpose, a point touched upon earlier in this report.

We call attention at this point to one specific aspect of graduation requirements, namely, the practice of classifying courses that may be pursued in satisfaction of requirements for advanced degrees in two or more groups, variously designated "A" and "B", or as "100", "200", and "300." It is common practice to permit students to submit credits up to a specified maximum in the lower, or even the lowest, of these categories, such courses being either advanced courses open to both graduate and undergraduate students, or regular "out-of-department" undergraduate courses. Restrictions imposed in connection with the pursuit of such courses differ: In some instances only undergraduates having exceptional records are admitted to "B" courses. In others the proportion of graduate programs that may be comprised of courses of this type is strictly limited. In a good many instances only such courses may be offered as are needed as prerequisites for advanced work. There appears to be some danger in this connection, however, of padding graduate programs by the inclusion of too much work of purely undergraduate content and nature.

It may be noted in this connection that there would seem to be no reason why graduate students should not be permitted to pursue certain undergraduate courses needed in the pursuit of their graduate programs without counting them as credits toward an advanced degree.

PROBLEMS OF ADMINISTRATION

Forms of administrative organization under which graduate work is conducted vary with and are dependent upon the types of institutions which offer engineering programs. These range in size and complexity from the small separately organized schools of technology to the largest universities, and include the entire range of institutions of higher learning. Except in the largest of the separate schools of technology, graduate and undergraduate work are commonly administered under the same unit of organization, though often a special committee of the faculty is placed in charge of certain administrative matters, such as passing upon applications for admission, and the like. General policies are usually formulated, however, by the officers and faculty of the institution as a whole. In the universities it is common practice to place control of the administration, and, to a certain extent, the actual conduct of graduate work in a separate administrative unit, known as the graduate school, which cuts across all lines of institutional and departmental organization. This school is commonly presided over by a dean and its work is in charge of a faculty which comprises the senior professors who actually conduct graduate work. A more complete statement as to methods of administering graduate work will be found in *Proceedings*, Society for the Promotion of Engineering Education, vol. XL, (1932), page 84.

Aside from expressing the opinion that the simpler the form of administrative organization, consistent with the complexity of the local situation, the better, we would call attention to one specific problem with relation to administrative organization, namely, the question of whether work for the master's degree, particularly in the institutions in which it is closely integrated with undergraduate work (the bachelor's degree being conferred as a more or less incidental

award at the end of the first 4 years of a longer program), would not be more advantageously administered under the engineering school or division rather than by the graduate school of the entire institution. Administration by the engineering school may, on the one hand, aid in providing programs of more definite purpose and more coherent content; while, on the other hand, administration under the graduate school may bring the benefit of broader institutional standards and policies. Local circumstances and the nature of the program will dictate the solution of this problem.

Supervision of the student.—In many institutions methods of supervision of candidates for masters' degrees do not differ essentially from those of undergraduates, though there is commonly the closer association afforded by the relatively smaller groups of students and teachers. In one or two instances plans for the provision of a closer relationship between teacher and student have been instituted in a sort of "discipleship", one or two graduate students being assigned to individual members of the faculty who serve as their adviser and direct their program of work. The student works continually in close association with this individual teacher. Where faculties are not large and where the graduate students are relatively few this arrangement would seem to be an excellent one.

In doctoral programs the student is assigned, almost invariably, to a small committee comprising the professor under whom he is to do his thesis and two or three teachers from his minor fields. This arrangement is so common as not to require further comment.

PROBLEMS OF THE TEACHING STAFF

It is in relation to faculties that the most serious problems incident to the rapid growth of graduate work have arisen. Even if the recent expansion had occurred in normal times, the problem of meeting the need for increased staffs would have been a serious one. Coming during a period of financial limitations, the problem has been acute in many institutions. During the past 2 years it has been intensified still further by the resumption of the growth in undergraduate enrollments. Information gathered in this survey indicates that

the additional load of instruction has been carried in most cases simply by adding it to the loads already carried by members of the teaching staffs. So far as can be discerned, standards of undergraduate work have not suffered thus far by reason of these increases; teachers have simply buckled down to the increased loads. There is some evidence, however, that there has been a substantial increase in the assignment of teaching to graduate assistants and fellows. This does not constitute the whole problem, however. Another and more important element is the fact that teachers of graduate work—the abler and more productive men—have had less freedom to follow lines of individual scientific interest and research; they have, in general, been forced to carry on their work under a state of greatly increased stress—a condition that promises to continue. The seriousness of this situation can scarcely be overstated.

SELECTION OF TEACHERS

Evidence gathered in the survey indicates that there is an increasing tendency to choose new teachers largely on the basis of the duration of their academic preparation. It has become the common practice to appoint to teaching posts only those holding at least the master's degree, and in a good many institutions to promote to professorships only those holding the doctor's degree. There is some evidence that insistence upon possession of higher degrees is at the expense of a corresponding period of experience in engineering practice. There can be little question that the trend toward the requirement of more extended scholastic training is resulting in a more highly qualified group of teachers of junior rank. We are led to observe, indeed, that the brightest aspect of the future of engineering education today is the quality and training of the young teachers who are coming in to fill the junior ranks in our staffs. We are inclined, however, to raise one question in this connection: Whether the need for experience in professional practice is not as great as it ever was, and whether this should not be insisted upon? Engineering graduates must deal with actual engineering enterprises, and their academic training must be a nicely balanced combination of theoretical and practical elements. Teachers likewise must possess both ability in

theory and practical insight into its application lest their teaching become purely scholastic and sterile, and lest both graduate and undergraduate work be cast into purely academic molds.

In this general connection we would remark that the tendency to require the holding of an advanced degree as a condition precedent to promotion to the higher faculty ranks, as prescribed by some institutions, needs to be administered with judgment and latitude in the case of engineering faculties. Many instances of teachers possessing the very highest professional attainments without benefit of formal advanced training could be cited in support of this statement.

SUBSIDIZED GRADUATE WORK IN RELATION TO TEACHING

Mention has already been made of the fact that the rapid growth of graduate work in recent years has led to a considerable increase in the employment of graduate students as part-time teaching assistants. A considerable percentage of the graduate students enrolled in engineering are subsidized through scholarships or some other form of award. We are not able to state the exact ratio of subsidized graduate students to the total enrollment, since not all of the graduate fellowships are filled by graduate students of engineering (in some institutions some of the opportunities so listed are filled by students of other branches of science). Some idea of the extent to which subsidized opportunities are available can be obtained, however, from the fact that in the year 1934–35 there were more than 850 such opportunities—nearly one-third as many as the entire enrollment of graduate students of engineering.

Approximately 250 of these positions are listed as requiring part-time services in classroom or laboratory teaching. This is approximately one-tenth of the total number of graduate students of engineering. While the aggregate of the teaching done by these graduate students is not a large fraction of all the teaching done in engineering colleges, it is a factor of some importance in the institutions where the practice is followed since this is a minority of all the institutions. These figures represent that portion of the practice over which the engineering colleges

themselves have control. In universities having engineering divisions, instruction of all undergraduate students, including engineering students, is commonly given in the college of liberal arts in such fundamental subjects as English, mathematics, physics, and chemistry. The proportion of teaching done by graduate assistants in such cases is larger than it is in engineering colleges. In the aggregate the practice is a fairly prevalent one.

The type of work done and of responsibility assigned to graduate students in their capacity as assistants in instruction varies from the handling of the chores of laboratory routines and paper work, with some incidental supervision of laboratory squads, at one extreme, to acting as virtually full-fledged (though part-time) instructors, at the other. A common arrangement is to use the graduate assistant to relieve the regular teacher of some of the load of laboratory instruction and of the work incident to laboratory operation. This would seem to be a suitable arrangement provided the interests of the graduate student are safeguarded and he is not called upon for more than a stipulated fraction of his time.

To use the graduate student under a small stipend as a part-time teacher giving regular classroom instruction, as a measure of economy, is a practice that at the least is open to the danger of lowering educational standards. It may also be questioned whether the division of interests of the graduate student between his own advanced work, on which he should be concentrating his best energies, and the intensive preparation that should precede classroom instruction when it is a wholly new experience is in the best interests of the graduate student himself. There are undoubtedly exceptions to any rule in this connection, and some graduate students, by reason of inherent aptitude for teaching as well as insight from their own recent experiences into the problems and difficulties of undergraduates, may make acceptable instructors. On the whole, however, we regard the use of graduate students as classroom teachers, except, perhaps, in the case of mature individuals with previous teaching experience, as an undesirable practice. The fairly widespread prevalence of the practice leads us to call attention to its dangers.

COOPERATION AMONG INSTITUTIONS

Two aspects of this general subject are presented for consideration: (1) Specialization among institutions in the development of particular fields of advanced study and research; and (2) cooperation in the offering of complementary programs of advanced study.

(1) Much has been said and written as to the benefits that would accrue from the avoidance of needless duplication in advanced work on the part of institutions in the same vicinity that deal with much the same student and industrial clientele. Two points of view on this matter are expressed; they exist, in fact, among the members of this committee: One, that measures should be sought looking to the development of noncompetitive lines of advanced work, where such competition is clearly undesirable; and the other, the realistic attitude that specialization in graduate work and research is likely to be a matter of natural development rather than of planned restriction, or limitation, or of more or less formal agreement among institutions, however much avoidance of duplication may be desirable, ideally. It is the view of the majority of the committee that institutions desiring to achieve an important place in advanced work and research will do so by taking advantage of opportunities afforded by resources or environment or special abilities of members of the faculty, to build up distinctive programs of work. Illustrations of the accomplishment of this aim are increasing in number. Among them may be cited certain of the courses and conferences specially adapted to the needs of engineering teachers that are offered by several institutions; special programs of graduate study afforded in several cities for the benefit of young employed engineers; distinctive research programs of a considerable number of engineering experiment stations; and so on. The development of centers of research of the continental type seems without question to be one of the ends most to be desired in engineering education. Recent developments in graduate study have given impetus to this movement. It is to be hoped that available resources will permit its further development.

(2) Cooperation among institutions in exchange of credits and in facilitating the movement of graduate students from institution to institution so that they may take advantage of noteworthy offerings in particular fields appears to be a distinctly promising means of promoting cooperation among institutions in the general field of advanced study. We feel that this is not only possible of accomplishment but that active steps might well be taken to insure it. We therefore suggest that a conference of administrative officers be held with a view to determining the general principles in accordance with which cooperative arrangements may be effected as well as to adopting administrative procedures needed to carry such principles into effect. Such a program might include special provision for teachers who desire to do their work for advanced degrees in more than one institution.

CONCLUSION

In bringing this report to its conclusion we would reiterate our introductory remark that our discussions of the results of the survey are not intended as specific recommendations. As the study has progressed it has become increasingly apparent that the development of graduate work in engineering is in such a formative state that it would be premature to attempt to draw up a comprehensive set of definitive conclusions and recommendations at this time. We believe, however, that it may be appropriate to present the following summary of some of the more important issues and problems that have become apparent as the survey has progressed as a means of focusing thought and discussion upon them:

(1) There is apparent need for clarification of the issue between the extension of the undergraduate program into a fifth year, and of the 2-stage program of 4 undergraduate years followed by advanced work of genuine graduate nature.

(2) There is need for recognition of the fact that many of the procedures as well as the content and method of graduate work have been the result of adopting the forms of the older fields of philosophy and pure science without regard to the special attributes or needs of engineering. Herein, distinctive features of graduate work seem likely to evolve. The question is how fast we should pioneer.

(3) A problem is before us in connection with the functional aim of graduate work: Should it be directed almost solely to preparation for the design and research function of the profession—with incidental values as preparation for teaching; or should there be proportionate development of the administrative function?

(4) The extent to which the characteristic methods of undergraduate instruction should be carried over into the graduate field seems to be something of a problem; it is not clear that original and self-motivated work on the part of the student is a basic idea in the operation of many graduate programs, particularly for the master's degree. In this connection it would seem that consideration might be given to the adoption of the honors group plan of work for gifted undergraduates of the junior and senior years as a means of promoting original and self-motivated work in the graduate school.

(5) There are evidently problems of administrative supervision and control of graduate work in engineering, particularly where the engineering division is part of a larger institution. These problems differ, even in the same institution, as to work for the master's degree and for the doctor's degree.

(6) Most pressing at present is the problem of selection and of development of teaching staffs in the graduate field, a condition aggravated by the rapidity of the growth of graduate work and by financial conditions.

(7) Consideration should be given to the possibilities of cooperation among institutions in the development of complementary programs of graduate work and in promoting transfer of students from institution to institution.

(8) Finally, there are many specific problems relating to various aspects and details of graduate programs. Among these the following may be listed, though, of course, the list is not complete:

(*a*) Language requirements in the master's and the doctor's programs.
(*b*) Use of the subsidized graduate student as a part-time teacher.
(*c*) Admission standards and procedures, with particular reference to progressive selection.
(*d*) Examination methods, with particular reference to oral examinations in the master's program and to comprehensive examinations.
(*e*) Degree practice, with particular reference to the use of the Ph. D. in engineering.
(*f*) Practice in the matter of conferring advanced degrees on members of the institution's own staff.

(*g*) Teaching loads and evaluation of graduate instruction and supervision of research in connection therewith.

Committee on Graduate Work,
Society for the Promotion of Engineering Education,
T. R. Agg
Edward Bennett
Dexter S. Kimball
Parke R. Kolbe
Thorndike Saville
George B. Thomas
Carlton E. Tucker
H. P. Hammond, *Chairman.*

APPENDIX

This appendix includes a copy of the letter of the Acting Commissioner of Education to officials of higher institutions of learning that offer courses in engineering, transmitting the questionnaire on which the survey was based; also a copy of the questionnaire itself.

UNITED STATES DEPARTMENT OF THE INTERIOR,
OFFICE OF EDUCATION,
Washington, October 15, 1934.

To Presidents or Deans of Engineering of Colleges and Universities offering courses in engineering:

The Office of Education and the Society for the Promotion of Engineering Education are cooperating in a study of the status and trends of graduate work in engineering. A part of the study will be based upon data and opinions of engineering educators. The facts thus obtained will be compiled and the results published for the information of those concerned with this important and rapidly developing field of instruction in education.

The questionnaire which accompanies this letter has been prepared by this Office and the committee on graduate study of the S. P. E. E. and is sent to all colleges and universities that offer courses in engineering. Your aid is therefore invited by supplying as fully as possible the information requested. If your institution does not offer graduate work in engineering, it is suggested that the questionnaire be returned with an answer to the first question. At the same time the Office will be glad to have your views on questions which are of interest to you.

Three copies of the questionnaire are being supplied. Will you kindly return at your earliest convenience one, with the requested information. One copy can remain for your files and the third may be used as a work sheet.

A penalty label, which requires no postage, is enclosed for your use.

Sincerely yours.

BESS GOODYKOONTZ,
Acting Commissioner.

74062°—36——8

COPY OF QUESTIONNAIRE

UNITED STATES DEPARTMENT OF INTERIOR,
OFFICE OF EDUCATION,
Washington, D. C., October 15, 1934.

SURVEY OF GRADUATE WORK IN ENGINEERING EDUCATION

Name of institution ---------- Post office address ----------

(Name and title of individual to whom communications relating to this form should be addressed.)

---

1. Does your institution offer graduate work in engineering? Yes_____ No_____.

If the answer to this question is "no", kindly return this form without further entries.

Certain of the questions on this form may be answered by supplying facts and figures. Spaces are provided for the tabulation of such replies. Others request opinions, or general descriptions. In such instances the spaces provided may not be sufficient. In that event, please use additional sheets, indicating thereon the item of the questionnaire to which the additional comments relate.

It is recognized that certain of the data requested can be supplied, if at all, only with considerable difficulty by some institutions. There is no desire unduly to burden anyone with the preparation of such data. It is merely hoped that replies will be as complete as is reasonably possible. Where answers can be given most readily by reference to published documents, such as catalogs, excerpts from such documents may be pasted either on this form or on additional sheets, indicating the item of the questionnaire to which the excerpts relate.

Information is desired as to engineering work only, and unless specifically indicated to the contrary, each question refers to your college of engineering. Architecture, pure science, and other fields, though related to engineering, are not intended to be covered by the study, even though such work is conducted in the engineering college. In some instances it may be difficult definitely to differentiate between work in engineering and work in science. In that case the judgment of the individual supplying the information must determine whether or not the work in question is to be included. In case work properly to be considered as lying within the field of engineering is administered by the general graduate school or division of the institution,

such work is to be considered as coming within the scope of the study. Graduate work conducted by the institution on a part-time basis in cooperation with industries is also to be considered as coming within its scope, if the degree or credit for work done is conferred by the institution.

Where the word "Administration" is used it refers to registration and classification of graduate students, appointments to the graduate faculty, approval of courses, and the clerical work of recording credits, checking time in residence, and similar matters. Where the term "supervision" of graduate work is used, it means, in general, activities connected with the actual teaching side of graduate work as distinguished from the clerical. Where the word "college" is used, it refers to the engineering college or division. Where the word "institution" is used, it refers to the educational institution of which the college of engineering is a part.

2. Please enumerate fields of work (as chemical engineering, civil engineering, etc.) in which graduate work is provided. (Abbreviations, as C. E., may be used.)
   (*a*) For the master's degree_____
   (*b*) For the doctor's degree_____
3. Enrollments and degrees conferred. Please supply figures as indicated by the following table:
   (*a*) Enrollments in work leading to master's, or equivalent, degree, second semester or second quarter, 1933–34.[1]

Field	Full-time resident students	Part-time resident students (teaching fellows, etc.)	Cooperative students	Evening students	Others (please specify types)			Number of master's degrees conferred 1933–34 [1]
Chemical engineering								
Civil engineering								
Electrical engineering								
Mechanical engineering								
Mining engineering								
Metallurgical engineering								
Total								

[1] Do not include any degrees conferred for practical experience as "postscholastic" degrees. Include such degrees under (*c*) only. Do not duplicate any enrollments under both (*a*) and (*b*).

3. Enrollments and degrees conferred—Continued.

(*b*) Enrollments in work leading to the doctor's, or equivalent, degree, second semester or second quarter, 1933–34.[1] (If it is impracticable to classify such students, or degrees, by divisions of work, merely give totals.)

Field	Full-time resident students	Part-time resident students (teaching fellows, etc.)	Cooperative students	Evening students	Others (please specify types)			Number of doctor's degrees conferred 1933–34[1]
Chemical engineering								
Civil engineering								
Electrical engineering								
Mechanical engineering								
Mining engineering								
Metallurgical engineering								
Total								

[1] Do not include any degrees conferred for practical experience as "postscholastic" degrees. Include such degrees under (*c*) only. Do not duplicate any enrollments under both (*a*) and (*b*).

(*c*) Number of engineer's degrees, such as civil engineer, conferred in 1933–34 for practical experience, as postscholastic degrees, or otherwise, except for work in course. _____

(*d*) Please state the year in which the first master's degree in engineering was conferred by your institution. _____

Similarly, please state the year in which the first doctor's degree in engineering was conferred. _____

4. Administration of graduate work in engineering. Please check type of administrative organization in spaces provided below, or, if no appropriate designation is given, please describe the form of administrative organization in your institution. If work for the master's degree is administered differently from work for the doctor's degree, please so indicate.

(*a*) *General administrative control by*—	*Master's degree*	*Doctor's degree*
College or division of engineering		
Graduate school distinct from college of engineering		
Special committee of engineering faculty		
Other arrangement (please describe)		
_____		

4. Aministration of graduate work in engineering—Continued.

(b) *Individual in immediate responsible charge*—

	Master's degree	*Doctor's degree*
President		
Dean of engineering		
Dean of graduate school		
Chairman of committee		
Other supervisor (please specify)		

(c) Please describe, briefly, the form of the departmental organization of your engineering college for directing graduate work; in particular, please state any differences between departmental organization as to undergraduate and graduate work

(d) Please explain the general relationship of administration and supervision of graduate work in engineering to other graduate work in the institution, particularly in science, and especially in physics, chemistry, geology, metallurgy, and other fields closely related to engineering

(e) Please state your views as to the most desirable form of administrative and supervisory organization of graduate work in an institution of the same general type as your own

(f) Do you offer engineering graduate courses in the summer term? Yes..... No.....

If so, please tabulate the enrollments by courses (subjects of instruction) during the summer of 1934.

Courses	Enrollments of teachers		Enrollments of others than teachers
	From same institution	From other institutions	

5. Faculty.

(*a*) To what extent do you relieve those teaching graduate students from the teaching of undergraduates? Specifically, in adjusting teaching loads, what relative weight is given to graduate teaching as compared with undergraduate teaching? If a definite policy is pursued, please outline it.....

.....

.....

(*b*) Is special or additional remuneration allowed for graduate teaching? If so, please outline your plan briefly.....

.....

.....

(*c*) Have you had any experience in relation to visiting and exchange professors? Yes.... No....., or

Do you at present have any definite plan for employing them? Yes..... No..... If so, please outline briefly....

.....

.....

(*d*) Have you any definite plan for the encouragement of younger members of your staff to pursue graduate work? Yes..... No..... In your own institution? Yes..... No..... Or elsewhere? Yes..... No.....

Are sabbatical leaves granted for this purpose? Yes..... No.....

Please indicate the extent to which your teachers have availed themselves of such opportunities by filling in the following spaces:

Number and percentage of your engineering staff now pursuing graduate work. Number..... Percentage.....

Number and percentage of your engineering teaching staff who earned graduate degrees in the years 1928 to 1934 inclusive. Number..... Percentage.....

(*e*) What percentage of your staff engages in teaching graduate work? ..... What percentage engages in directing research? .....

(*f*) In choosing new members of your teaching staff, what weight is given to possession of advanced degrees by applicants?....

.....

.....

Similarly, what weight is given to possession of practical experience?.....

.....

Do you require the holding of a degree beyond the baccalaureate by new applicants? .....

Has there been any change in this situation in recent years?

.....

If your institution has a definite policy in this connection, please state it.....

.....

5. Faculty—Continued.

(g) Please outline the practice of your institution in conferring advanced degrees, for work in course, upon members of your own staff. Is there any limitation as to the rank (or title) of teachers upon which you will confer such degrees? _____

_____

_____

6. Basic nature of graduate work.

(a) Please state the practice of your engineering college and your personal views as to the relative emphasis upon and time to be devoted to pure science, engineering, and "humanistic" work in graduate study in comparison with undergraduate study.

(1) For the master's degree_____

_____

(2) For the doctor's degree_____

_____

(b) Please state your views as to the place which study of economics and of economic factors in engineering should occupy in graduate work leading to advanced degrees in engineering.

(1) For the master's degree_____

_____

(2) For the doctor's degree_____

_____

7. Nature of programs of graduate work.

(a) What percentage of your requirements must be satisfied by work in course, and what percentage by research—

	Work in course, including seminars	*Research, including thesis*
For the master's degree	_____	_____
For the doctor's degree	_____	_____

(b) To what extent do you use the seminar type of work in graduate courses:

For the master's degree_____

For the doctor's degree_____

(c) Have you a definite plan of prescribed "majors" and "minors"? If so, please outline it as regards work for the—

Master's degree_____

_____

Doctor's degree_____

_____

(d) Please state your requirements as to time in residence for the

	Maximum time permitted	*Minimum time permited*
Master's degree	_____	_____
Doctor's degree	_____	_____

(e) Please outline your requirements and practice as to continuity of residence, transfer of credits from other institutions, and like matters_____

_____

_____

8. Admission requirements.

(a) Are specifications imposed as to the quality of undergraduate records of applicants for admission to graduate work? Yes_____ No_____

If so, how are they expressed? _____

_____

(b) Please outline your procedure as to admission of graduates of nonengineering curricula. Have you any system of prerequisites in this connection? _____

_____

(c) Please outline your requirements and procedure as to the admission of a graduate of one engineering curriculum who desires to work for an advanced degree in another field. Have you any system of prerequisites in this connection?_____

_____

_____

(d) On what basis are credentials of graduates of other institutions evaluated?

As to specific courses pursued? _____

_____

On the general standing of the institution? _____

_____

On the quality of the undergraduate record of the applicant?

_____

Please explain your policy and methods. _____

_____

(e) Are examinations for admission to graduate courses given (aside from those required for formal admission to candidacy for a degree)? Yes_____ No_____.

If so, what is their nature? Oral? _____ Written? _____ In specific subjects of instruction? _____ Or comprehensive examinations? _____

_____

_____

(f) How are admission procedures administered? By an individual? _____ By a committee? _____

_____

_____

(g) Please outline your requirements and procedure as to formal admission to candidacy for—

The master's degree_____

_____

The doctor's degree_____

_____

(If your catalog outlines such requirements accurately and completely, answers may be supplied by pasting excerpts on this or on an attached sheet.)

6. Admission requirements—Continued.

(h) What is your foreign language requirement for—

The master's degree_____

_____

The doctor's degree_____

_____

What is your view, in general, as to the requirement of modern foreign languages for advanced degrees in engineering? _____

_____

9. Graduation requirements.

(a) Please state your requirements, in semester hours or in other terms in accordance with the practice of your institution, for the award of—

The master's degree_____

The doctor's degree_____

(b) Do you classify graduate courses in categories, such as "class A", and "class B", or those that may be taken only by graduate students and those that may also be taken by undergraduates, etc.? Yes_____ No_____.

If so, please state the basis of classification_____

_____

What proportion of each type is required for an advanced degree? _____

_____

Are undergraduate courses not taken by the student as an undergraduate accepted as partial fulfillment of requirements for an advanced degree? Yes_____ No_____.

If so, in what proportion? _____

Under what conditions?_____

_____

If certain subjects, such as differential equations, are required in some undergraduate curricula but not in others, and if graduate students may offer such courses in satisfaction of the requirements for an advanced degree, are such students admitted to the undergraduate classes, or is the subject taught separately for the graduate students? If so, is there any difference in subject matter and method of presentation?_____

_____

_____

Are undergraduates admitted to any graduate courses?_____

If so, what conditions are imposed?_____

_____

_____

10. The thesis.

Please outline your methods of conducting thesis work and your requirements therein under the following heads: (1) Selection of topics; (2) time required and maximum time permitted; (3) credit given (please state your views as well as your practice); (4) methods of administration and of supervision; (5) relationship to institutional and departmental research programs; (6) other aspects of importance in your institution.

Please supply answers on separate sheets as to—

(*a*) The master's degree.

(*b*) The doctor's degree.

11. Examinations.

Please outline your methods as to (1) examinations in prescribed and other formal courses; (2) examinations for admission to candidacy for a degree; (3) Final (comprehensive) examinations. In particular please state the extent to which the oral examination and the combination of oral and written examination are employed and, in instances where the oral examination is employed, the manner in which the examiners are chosen.

(Please use additional sheets for this discussion.)

12. Degrees.

Please state the form of degrees conferred by your institution for work in course—

(*a*) The master's degree (as M. S., M. S. in C. E., M. C. E., etc.)

(*b*) The doctor's degree (as Ph. D., D. Sc., D. Eng., D. C. E., etc.)

(*c*) Please state your views as to appropriate forms for degrees for advanced work—

In engineering

In science

---

13. Costs.

(*a*) Please state how the cost of graduate work is budgeted. Under what major items? How is cost of research budgeted? Is cost of engineering graduate work budgeted separately from work in science and in other fields?

(If a sample form of budget can be supplied please attach two copies, omitting amounts if desired.)

(*b*) Please state the fees charged for graduate work and the basis of such charges, i. e., whether the charge is made per course unit, a single charge per year, a stipulated minimum total for the degree, etc

---

---

13. Costs—Continued.

(c) If such data *can be readily given* please state the costs of graduate work in your institution in terms of dollars per full-time student per year, or in terms of cost per course unit, or in such other units of expression as you may employ. If costs of graduate work in engineering are kept separately, please give data both as to costs in engineering and as to costs in related fields. Please state explicitly the basis upon which unit costs are computed_____
_____
_____

14. Fellowships, scholarships, and teaching assistantships.

Please give the following information for the academic year ending June 1934.

(a) Number of institutional fellowships or scholarships filled by engineering students which make no demand on students for assistance of any kind_____
Stipend per school year for each type (fellowships, scholarships)_____

(b) Number of institutional (including experiment station) fellowships or assistantships available to graduate engineering students. requiring part-time work on assigned research or testing_____
Stipend per school year for each type_____
Hours of service required per week_____

(c) Number of teaching or laboratory assistantships available to graduate engineering students, requiring part-time assistance in the conduct of class (quiz) or laboratory sections_____
Stipend per school year for each type_____
Hours of service required per week_____

(d) Number of industrial fellowships available to graduate engineering students, requiring part-time work on projects of interest to the industry_____
Stipend per school or calendar year for each type (underscore which)_____
Hours of service required per week_____

(e) Please give similar information relative to other fellowships or awards in support of graduate work in engineering which do not fall under any of the above groupings_____
_____
_____

(f) If there has been any marked change as to number of fellowships and scholarships available, or any material change in stipends, during the past 2 or 3 years, please describe briefly
_____
_____

June 1934—Continued.

(g) Total value of stipends available to graduate engineering students in all departments:

During the year 1932–33 ---------- $----------

During the year 1933–34 ---------- $----------

15. Cooperation.

(a) Has your institution any cooperative arrangement for interchange of facilities or credits in graduate work with any other institution? If so, please describe the essential features of the arrangement. Please state the extent to which it is used. Please also give your general experience in this connection------

---

(b) Has your institution any arrangement with industries for the offering of post-graduate work for employees either on a part-time or on a full-time basis? If so, please outline the arrangement and discuss your experience----------

---

---

16. Facilities for graduate work.

Please state the funds allotted in 1933–34 for extension of and for maintenance of facilities for graduate work in engineering, and for research. If possible, please give separate figures for laboratory facilities and for the library.

	For laboratories	*For the library*
For maintenance	$----------	$----------
For extension (new accessions)	$----------	$----------

How does your situation in this respect in 1933–34 compare with that in 1929–30? Please give answers in as explicit terms as possible

---

---

17. Relationship of graduate to undergraduate work.

(a) Has there been any perceptible tendency, as work for advanced degrees in engineering has been developing during the past 2 decades, to transfer from the undergraduate curriculum any of the more advanced engineering courses to the graduate program?----------

---

(b) Has the development of graduate work in the past 2 decades had any other perceptible influence upon the content, purpose, scope, or other characteristics of undergraduate curricula? If so, please describe the situation in this connection in your institution----------

---

---

17. Relationship of graduate to undergraduate work—Continued.
(c) If longer curricula, as of 5 or 6 years, are offered for the first degree in engineering in your institution, what is the relationship of such programs to programs for advanced degrees? Please state as explicitly as possible, in terms of types of undergraduate and of graduate programs, credits toward advanced degrees for work in the longer undergraduate programs, transfers from other institutions having 4-year undergraduate programs, and similar matters.....
.....
.....

18. Please state your experience and your views as to any other aspects of graduate work in engineering that would be helpful to the Office of Education and to the committee either in appraising the existing status of graduate work or in considering means by which it may be strengthened. If, in particular, there are any specific problems relating to graduate work in your institution not covered by the foregoing questions, please outline them.....
.....
.....

19. Do you believe that graduate work in engineering should be guided in its development by State, regional, or national needs? If so, how may institutional practices be kept in line with those needs?.....
.....
.....

INDEX

Administration of graduate work in engineering, 10–17; most desirable form, 15–17; nature of control, 10, 11; official in charge, 11; problems of, 90; relation to other graduate work, 13–15.
Admission to candidacy for degrees: 49; master's degree, 50; doctor's, 51.
Adjustment of teaching loads, 20, 21.
Admission to graduate study in engineering, 45–51; admission of graduates of non-engineering and engineering curricula other than the proposed field, 46, 47; requirements, 87, 88; specifications as to quality of undergraduate records of applicants, 45; procedures, 48, 49.
Advanced degrees conferred in engineering, historical, 1–4; summary table, 3; types classified, 63.
Appendix: 99–111.

Candidacy, admission to, 49, 50; master's degree, 50; doctor's degree, 51.
Classification of graduate courses, 55–57.
Committee on Graduate Study of the Society for the Promotion of Engineering Education: Cooperative efforts, VII, IX, XI; introductory statement, XII; acknowledgement, XIII; names of committee members, XIII; interpretation of survey, 82–98.
Conclusion, 96–98.
Cooperation among institutions, 73, 95–96; arrangements, 18, 19; cooperative and part-time graduate work, 39–44.

Degrees, advanced, 62–64; form of master's and doctor's degrees, 63; conferring advanced degrees on members of the institutions' own staff, 24, 25.
Departmental organization, nature of, 11–13.

Engineers' Council for Professional Development: Advocacy of post-academic training, 4.
Enrollments in graduate work, 2–4; summary and table, 5–8.
Evaluation of credentials, 47, 48; of graduates of other institutions, 47; according to standing of institution, 48; according to undergraduate record of applicant, 48; policies and methods pursued, 48.
Examination, methods of, 60–62; comprehensive type, 61.

Fellowships, classification, 69, 70.
Foreign-language requirements, 57–59; for master's degree, 57–58; for doctor's degree, 58; views as to these requirements, 58–59.
Forms of administrative organization, 15–17, 90, 91.

Graduate courses, 55–57. Classification of types, 55; proportion of types that may be taken, 55–57.
Graduation requirements: In semester-hour credits, for master's degree, 54, 88, 89; for doctor's degree, 54, 89, 90; time in residence 52; transfer of credits for degrees, 53.
Graduate work: Cooperation in development of, 73–75; general characteristics, 84–86; improvement of, 71; in general program of engineering education, 82–84; in summer term, 17; relation to graduate work, 65–68; views of correspondents as to policies and methods, 71.

Improvement of graduate work in engineering, 71–75.
Industry and the graduate of advanced courses, 76–81.
Institutions included in survey, IX–XI.
Instruction, methods of instruction and guidance, 86.
Interpretation of the Survey, 82–98.

Language requirements, 85. *See* foreign-language requirements.
Letter of Assistant Commissioner of Education to engineering school officials, 99.

Majors and minors, plan of, 26; master's degree, 34–38.
Master's degree in engineering, the first: 1.
Methods of instruction and guidance, 86, 87.
Method of the survey, IX.

Opinions as to place of economics and economic factors in programs of study, 29, 30.
Opinions as to improvement of graduate work in engineering, 71–75.

Part-time graduate work, 39–44.
Ph. D., first in engineering, 1.
Program of graduate work in engineering, 26–38; economics and economic factors, 26; general characteristics, 26; proportion of required work in principal fields, for master's degree, 27; for doctor's degree, 28.
Purpose of the survey, IX.

Questionnaire, 100–111.

Ratio of graduate students in engineering to seniors, 3.
Recruitment and training of teachers, 22, 23.
Relationship of graduate work to undergraduate work, 65–68.

Selection of teachers, 21, 22, 92.
Seminar, use of, 26; master's degree, 33; doctor's degree, 34.
Scholarships, classification, 69, 70 (also fellowships).
Standards of instruction, 23; advanced studies taken, 23; improvement through summer sessions, 23.
Student supervision, 91.
Subsidized graduate work, 69, 70; in relation to teaching, 93, 94.
Summer term, graduate work in engineering, 17.

Teaching loads, adjustment, 20; and extra compensation, 21.
Teaching staff, problems, 91–92; selection, 92–93.
Thesis, credits allotted, 59.
Time in residence for higher degrees, 53.
Training of teachers, degrees required, 22; self-advancement, 23.
Transfer of credits: 53, 54.

Visiting and exchange professors, 21.

Work in course and work in research, their relations, master's degree, 31; doctor's degree, 32.