EMPLOYMENT OUTLOOK FOR
ENGINEERS

UNITED STATES DEPARTMENT OF LABOR • BUREAU OF LABOR STATISTICS

Maurice J. Tobin, Secretary

Ewan Clague, Commissioner

OCCUPATIONAL OUTLOOK SERIES • BULLETIN No. 968

Engineers discussing a problem in connection with construction activities at Grand Coulee Dam, Columbia Basin Project.

[This report is based in part on information from a survey made by the Bureau of Labor Statistics in cooperation with the Engineers Joint Council and with the National Roster of Scientific and Specialized Personnel, United States Employment Service.]

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ENGINEERS

Employment Trends and Outlook

Earnings

Occupational Mobility

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LETTER OF TRANSMITTAL

United States Department of Labor,
Bureau of Labor Statistics,
Washington, D. C., May 12, 1949.

The Secretary of Labor:

I have the honor to transmit herewith a report on the employment outlook for engineers. This is one of a series of occupational studies prepared in the Bureau's Occupational Outlook Branch for use in schools, colleges, local offices of the State employment services affiliated with the United States Employment Service, and other agencies engaged in vocational counseling of veterans, young people in schools, and others considering the choice of an occupation.

The report was prepared under the supervision of Harold Goldstein. The three major sections—Employment Trends and Outlook, Earnings, and Occupational Mobility—were prepared by Robert W. Cain, Cora E. Taylor, and Chester F. Schimmel, respectively. The 1946 Survey of the Economic Status of Engineers was made by the Bureau in cooperation with the Economic Survey Committee of the Engineers Joint Council, and with the National Roster of Scientific and Specialized Personnel, United States Employment Service.

The Bureau wishes to acknowledge the cooperation of the 25,000 engineers who participated in the survey and the many members of the engineering profession, including officials of engineering societies and of engineering colleges, and engineers in industry, who discussed trends in the profession with the Bureau's representatives and commented upon a preliminary draft of the report.

Ewan Clague, *Commissioner.*

Hon. Maurice J. Tobin,
Secretary of Labor.

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EMPLOYMENT OUTLOOK FOR ENGINEERS

Introduction

Engineering is one of our largest professional occupations, outranked in size only by teaching and nursing; for men it is the largest profession. Perhaps more than any other occupation it is identified with our present-day technological civilization. Engineers give technical leadership in industry; they develop new products, machines, or processes; they design many types of structures; they devise the most efficient way to manufacture a product, lay out a system of highways, arrange the work processes in a factory, or bring minerals out of the depths of the earth. The third of a million engineers contribute greatly to planning the work of, and designing the machines and buildings used by, a major part of the 60 million people employed in the United States.

As a field of employment, engineering has much to offer. Opportunities are numerous in this rapidly growing profession, and the employment outlook is good in the long run for those who succeed in entering the field, particularly for well-trained men. Engineering positions are to be found in every State, in small cities as well as large; and the profession often offers opportunities for travel and for employment overseas. While the incomes of engineers vary widely, depending on many factors, average earnings rise fairly sharply with increasing experience. Moreover, there are many opportunities for engineers to advance to administrative positions. While primarily an occupation for men the profession also offers a limited number of opportunities to women.[1] Engineering work appeals to those who are interested in applied science and its methodology and who have a practical bent; it offers a challenge to the ingenuity, and often an opportunity to do creative thinking and to see the results emerge step by step from the drafting board to actuality.

Those who are considering this field, however, must not forget that the engineering profession is a difficult discipline, requiring marked ability to think abstractly and in mathematical terms, to remember a mass of details and visualize complex problems, to study and work with great persistence, and to continue studying and learning throughout their professional life. Moreover, the competition in entering the profession will probably be greater than in many other occupations in the years ahead.

Engineering has been described as "the art of applying the laws of the natural sciences to the utilization of the materials and forces of nature for the benefit of mankind and the art of organizing the human effort required in connection therewith."[2] An emphasis on efficiency, which is related to cost, is one of the main factors distinguishing the work of the engineer from that of the research scientist. A chemist may create a new compound or a geologist may discover an oil field; it is the job of the engineer to figure out how the compound can be manufactured or the oil extracted at a cost that will enable it to be sold on the market. In building a skyscraper it might be possible to ensure safety by making the walls of solid masonry twenty feet thick, but it is much less expensive to hire an engineer who will closely calculate just how much weight the walls have to bear, what forces will affect them, and what factors of safety to allow. The engineer must decide which building material would be the cheapest to use, considering the relative strength, the quantities of materials needed, and the cost of labor required. The mechanical engineer designing a crankshaft or the electrical engineer laying out a circuit does the same kind of job. The engineer, then, uses scientific principles in devising methods of doing things most efficiently.

[1] Opportunities for women in engineering are discussed in the following publication: U. S. Department of Labor's Women's Bureau, *The Outlook for Women in Architecture and Engineering*, Bulletin No. 223-5, Superintendent of Documents, Washington 25, D. C., 1948. Price 25 cents.

[2] Stewart, Lowell O., *Career in Engineering*, Iowa State College Press, Ames, Iowa, 1947.

Engineers are employed in many different ways in addition to their function as designers. Their skill is used in administration and management, particularly in industries in which engineering methods are important. Many engineers supervise construction, or the operation of plants or mines. Others are engaged in research and in the development of products and methods of manufacture on the basis of research findings. Some, particularly younger engineers, do drafting or analysis and testing, much of which is routine work. A sizable number are employed as independent consultants, who advise their clients on engineering matters and prepare designs or plans. Many companies employ engineers in selling their products, particularly when the buyer is a business firm, and when the salesman has to be able to discuss the product technically and advise engineers as to its installation and use. The teaching of engineering in colleges and technical schools is also a field in which significant numbers of engineers are employed.

The profession has within it men of widely varying levels of ability and training. Educational attainments of engineers range from the most advanced training of the relatively few with the doctor's degree in engineering to very little formal education. The bachelor's, or first professional degree, long considered the standard preparation for engineers, is held by a great majority of those in the field. Levels of ability range from that possessed by the creative genius doing outstanding research, design, or administration to that found on the borderline of professional attainments, in which the work is merely routine computing, drafting, or testing. New entrants customarily enter in the more routine jobs and move up the scale to positions of greater responsibility. Some, however, spend most of their working lives in the entry positions.

There are many varied fields of specialization in the engineering profession. These divisions became necessary over a period of many years owing to the great expansion of scientific knowledge. The engineering field is usually divided into the following major groups: civil, mechanical, electrical, chemical, and mining and metallurgical. Within the several general fields many specialized areas of activity are recognized in practice and in engineering school courses. Descriptive material on the profession of engineering may be found in many publications.[3]

Generally speaking, despite these major divisions, engineering is one basic field. It is characterized by a common approach to the solution of practical problems on the basis of scientific knowledge. Usually, the first 2 years of all engineering curricula contain the same core of subjects—mathematics, chemistry, physics, and basic engineering courses, as well as English, the humanities, and the social sciences. As a rule the curricula diverge only in the last 2 years as the particular professional specialties are developed. In actual practice many an engineer is required to use a knowledge of more than one broad field in solving a particular problem. Moreover, persons educated or experienced in one branch frequently move into others. That many men did this in recent years is shown in a later section of this report.

Transferability among fields is facilitated because engineers generally specialize in one or another of the functions of the profession such as research, design, development, or sales. Often an engineer who has performed one of these functions in a particular field may transfer and carry on the same function in another field.

Persons interested in engineering as a career should also look into employment possibilities in related occupations. One source of such information is the *Occupational Outlook Handbook*, issued by the Bureau of Labor Statistics in cooperation with the Veterans Administration.[4] This volume contains reports on the following major engineering fields: civil, electrical, mechanical, chemical, mining and metallurgical, industrial, and ceramic; it also deals with related occupations such as chemist, architect, industrial designer, tool designer, draftsman, meteorologist, radio operator, foundry technician, and electronic and radar technician. The handbook covers a total of 288 occupations and gives information on methods of entry, training and qualifications required, earnings, and employment outlook.

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[3] For example, U. S. Department of Labor's U. S. Employment Service, *Descriptions of Professions Series*, Pamphlet Number 2, Washington 25, D. C., price 15 cents; Stewart, Lowell O., *Career in Engineering*, Iowa State College Press, Ames, Iowa, 1947; and Engineers Council for Professional Development, *Engineering as a Career*, New York, N. Y., 1942; also see suggested reading list, p. 116.

[4] U. S. Department of Labor's Bureau of Labor Statistics, *Occupational Outlook Handbook*, Bulletin No. 940, Superintendent of Documents, Washington 25, D. C., 1949. Price $1.75.

The present report consists of three major sections. In the first, the employment trends and outlook in the profession are analyzed, beginning with the trends in demand for engineers and then going on to the trends in the supply of persons qualified for work in the profession. Comparison of the prospective demand and probable future supply leads to a conclusion on the employment outlook for those who are now in engineering schools, and estimates of future training needs. The second major part of the report describes the earnings of engineers and the factors affecting them, and traces the effect of changing economic conditions upon earnings. In the third major section, the occupational mobility of engineers is discussed.

A large part of the report is based on information from the 1946 Survey of the Economic Status of Engineers, made by the Bureau of Labor Statistics in cooperation with the Economic Survey Committee of the Engineers Joint Council and with the National Roster of Scientific and Specialized Personnel, United States Employment Service.[5]

Summary of Conclusions

Employment Trends and Outlook

Engineering is one of the most rapidly growing professions in the United States; moreover it is expected to continue to grow substantially in the future, although at a slower rate than in the past. The number of engineers in the United States increased nearly tenfold between 1890 and 1940, rising from 27,000 to around 260,000. By early 1948, the number had risen to about 350,000—an increase of almost 100,000.

The report concludes that in the long run the demand for engineers will continue to grow. Upon the basis of past trends and the growing use of engineers by industry, it may be inferred that by 1960 the number of engineers may well increase by another 100,000 to a total of about 450,000. Such an increase would amount to about 8,000 jobs a year, on the average, between 1948 and 1960. (See pp. 7 to 13.) In addition, the demand for new engineers resulting from losses to the professions (deaths, retirements, and transfer to other occupations) is expected to increase from about 9,000 or 10,000 a year in 1948 to over 13,000 a year by 1960. (See pp. 42 to 45.) Thus the total demand for new engineers for the next few years may be estimated at approximately 17,000 to 18,000 a year. By 1960 the demand may well rise to around 21,000 or 22,000 a year. Mechanical engineering is the largest branch and is growing rapidly. Electrical engineering, after failing to grow in the thirties, is again expanding, as is chemical engineering. Mining and metallurgical engineering have experienced a steady growth over the past several decades. Civil engineering, though a large field, is growing more slowly. (See pp. 13 to 33).

The number graduated by the engineering schools has been increasing. The number of men receiving the bachelor degree in engineering rose from an average of 7,000 a year in the twenties to about 10,000 a year in the thirties. Total engineering graduations for the decade 1940 to 1950 can be estimated at over 190,000—an average of 19,000 a year. The number of persons in training is at record levels and the number of graduates expected from these enrollments should more than supply the demands for engineers in the next several years. In the academic year 1947–48, some 32,000 engineering students were graduated; in the year ending June 1949, 44,000. It was estimated that on the basis of 1948–49 enrollments about 47,000 will be graduated in the year 1949–50; about 36,000 in the year 1950–51; and nearly 29,000 in the year 1951–52. (See pp. 33 to 40.) Actually, graduations in these years may be somewhat higher for several reasons. (See p. 38.)

It is of course impossible to estimate graduations more than 4 years in advance. Nevertheless, it is of interest to illustrate what the level of engineering graduations may be, solely on the assumption that past trends will continue. These trends indicate that the number of engineering degrees awarded may decrease from the peak in 1949–50 to not less than 18,000 in 1956 and then rise gradually to at least 25,000 around 1964. (See p. 40.)

A comparison of the estimated supply of and demand for engineering graduates, leads to several conclusions. In the next few years the num-

[5] See appendix C, p. 89.

ber of graduates will greatly exceed the demand for graduate engineers. After that, if the past trend in enrollments should continue, the annual demand for graduates and the supply of new graduates would roughly be in balance.

Although it is likely that during the next few years the total number of engineering graduates will be greater than the number of engineering positions available, the employment situation will vary greatly among types of engineering positions and among the various fields of engineering. Even when competition becomes stiffer, it is likely that a demand for men with special abilities or training in such work as research and design will still exist. Comparisons of the estimated supply and demand in the various fields suggest that a surplus will occur earlier and be larger in some branches of engineering than in others. (See pp. 46 and 47.) The differences in employment outlook among the fields of engineering are likely to be reduced to some extent by the ability of some engineering graduates to obtain employment in engineering fields other than those in which they were trained. (See section on occupational mobility, pp. 69 to 81.)

To the engineering student, it should be pointed out that the best training obtainable will help to meet the expected intense competition.

For the high-school student who has to look ahead 4 or 5 years to opportunities in the profession when he graduates from college, the outlook is more difficult to evaluate. If those graduates of the next few years who cannot get jobs in engineering find satisfactory employment in other types of work, and if engineering enrollments return to levels suggested by past trends, opportunities for engineering graduates 5 or more years hence are likely to be better than for those in the immediate future. On the other hand, if many engineering graduates of the next few years who do not get engineering employment continue to seek such work, opportunities for new graduates may be less promising.

To the engineering schools, the estimates presented here may suggest that over the long run there will be a demand for roughly twice as many graduates as were turned out annually in the decade before the war and that facilities and instructional staff will have to be provided. The great interest in engineering also suggests that there is both the opportunity and the need for a careful selection of students. Progress has been made along these lines If the standards of entry into engineering schools were raised and if more exacting selection methods were used, it is evident that schools could admit even fewer students and still provide an adequate supply of engineering personnel.

In applying these conclusions to the guidance of individuals, counselors in high schools, colleges, and other agencies will want to keep in mind that the increasingly competitive situation expected for the next few years should give pause to the marginal student, but should not be allowed to deter those with real aptitude and realistic interest in engineering.

Earnings of Engineers

In choosing a career, expected monetary returns are always of interest and importance. Earnings in engineering, as in other professions, vary considerably and are affected by many factors. The section of this report on earnings (see pp. 49 to 68) analyzes a survey of engineers made by the Bureau of Labor Statistics in 1946 and discusses some of these factors, such as length of experience, amount of education, kind of work done, type of employer, and economic conditions. The conclusions in brief are given below.

Length of experience is one of the most significant factors affecting earnings. For most engineers, earning capacity increases with added years of experience. In general, the greatest rise in earnings occurs in the first 10 years of experience; in 1946, the annual increase for each year of experience averaged $120 to $240. After about 30 years of experience average salaries tend to level off. (See pp. 50 to 53.) Entrance salaries in 1946 in all fields of engineering were much the same, ranging from an average of $226 to $247 a month. However, there were great differences by field in the amount of increase in earnings with years of experience. Median earnings of chemical engineers showed an increase of about $440 a month, or 185 percent during the working span; median earnings of civil engineers increased by only 85 percent; other types of engineers had increases of 140 percent to 165 percent.

Earnings of engineers, like those of other workers, vary with business conditions. During the depression year 1934, engineers with 10 years of experience received approximately $100 less per month than similarly experienced engineers in 1929—a drop of 30 percent in average salaries. In most fields it was a decade or more before salaries of engineers having 10 years of experience had returned to the 1929 average. Earnings increased considerably during and after World War II, until by 1946 they averaged 50 percent higher than 7 years earlier. Further increases took place after 1946. (See pp. 63 to 67.)

Top salaries in all the major fields of engineering are earned by engineers in administration-management jobs. These positions are usually attained only after many years of experience. Earnings considered in relation to length of experience show that jobs in research and sales, as well as administration, generally pay more than such work as inspection, analysis and testing, operation, and college teaching. (See pp. 53 to 55.)

By and large, earnings are highest for engineers with the greatest amount of formal education. In most fields, holders of the master's degree average slightly more than those with the bachelor's degree, and men with the doctor's degree earn considerably more than those in either of the other groups. (See pp. 55 to 58.)

Engineers employed by private firms and by the Federal Government have comparable average earnings when length of experience is taken into account. Engineers employed by State and local governments generally have lower earnings. (See pp. 59 and 60.)

Income from fees, bonuses, and other sources is an important factor in engineers' earnings, especially for older men. When overtime is paid, the least experienced engineers generally profit more than the older men. (See pp. 60 to 62.)

Historical information is useful in showing what the average person may expect by way of remuneration in the engineering profession, but caution should be exercised in applying such findings to individual cases. Some engineers never advance beyond the earnings level of the average factory worker or clerk. It is possible to gain an engineering degree without having the capacity to advance far up the professional ladder; moreover experience tends to increase earning capacity, but it does not do so for all people. The section of this report which deals with earnings reveals that the highest-paid 10 percent of the engineers with 5 years' experience or less had higher median earnings than the lowest 10 percent of the group with 30 years or more of experience. (See chart 10.) Young people considering engineering as a career should carefully weigh their own interests and abilities in relation to the competition in this field. For those who can successfully meet competition, the top of the profession is so well rewarded, both in remuneration and job satisfaction, that it is well worth sacrifice and struggle to attain.

Occupational Mobility

The extent to which engineers are able to change jobs interests young people entering the occupation, educators in the field, and those responsible for recruitment and employment of technical personnel. How many move from one State to another? From one industry to another? Between private and Government employment? From one major branch of engineering to another? How many are educated in one branch of engineering but find employment in another branch? The Bureau's 1946 Survey of the Engineering Profession provides some information on these points. (See pp. 69 to 81.)

A greater proportion of engineers—about 30 percent—changed their employment location from one State to another between 1939 and 1946, than were involved in any of the other types of change analyzed. The majority of those who moved from their 1939 employment location did so by 1943. (See pp. 78 and 79.)

At least 25 percent of the engineers changed their industry fields between 1939 and 1946; these changes appear to reflect the high wartime demands for engineers in the "heavy" or durable-goods industries. (See pp. 76 to 78.)

Changes made by engineers among the major types of employment—approximately 22 percent made such changes—indicate to some extent the principal sources of employment for engineers during the war and postwar years. Between 1939 and 1943, employment in private firms and in the Federal Government increased chiefly at the expense of employment by State and local governments and self-employment. From 1943 to 1946, relatively more engineers transferred from public employment to private industry than vice versa. (See pp. 74 to 76.)

The close relationship among all the branches of the profession, and the similarity of basic engineering training, make it possible for engineers to shift from one branch to another. From 8 to 14 percent of the engineers who were in each of the five major branches of the profession in 1939 were in some other branch 7 years later. The greatest percentage of those who shifted fields went into mechanical engineering; civil engineering lost the greatest proportion. (See pp. 71 to 74.) Close relationship among engineering fields is also reflected in the fact that in 1946 more than 20 percent were employed in a branch of engineering other than that in which they had been educated. (See chart 14.) The proportion employed in each branch of the profession whose education had been in another branch ranged from 10 percent of those employed in chemical engineering to 36 percent of those employed in mining and metallurgical engineering. (See pp. 69 and 70.)

Thus it appears that the engineering profession is a flexible one, offering opportunities to transfer among fields of specialization, industries, employers, and locations. In order to equip himself to adjust more easily to changing conditions or to advance his career, the young person contemplating entering the engineering profession may wish to acquire the broadest possible educational preparation consistent with an adequate background for the specialty he intends to follow. At the same time, however, he is faced with the conflicting trend toward a high degree of specialization in each field, accompanied by the demand for more graduate education.

Employment Trends and Outlook

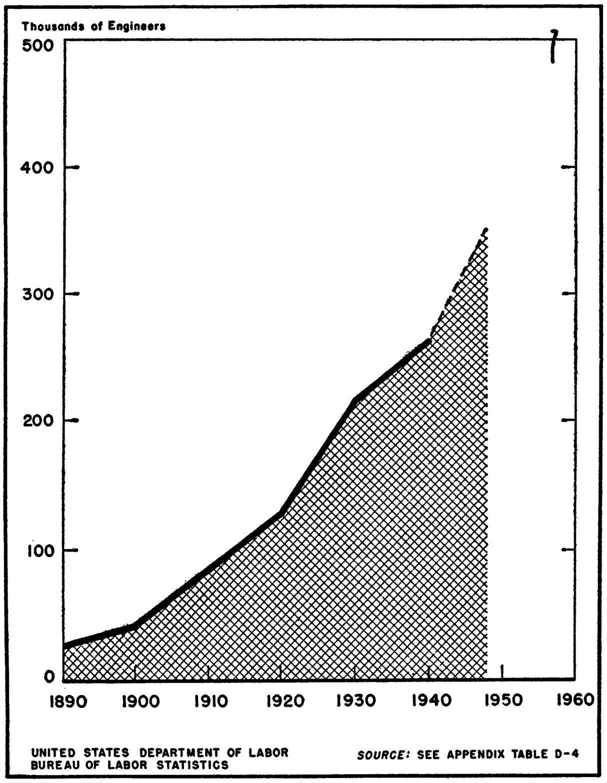
Employment Trends

In analyzing the employment outlook for engineers it is necessary to evaluate the demand for engineers and engineering services, and to compare prospective demand with the supply of trained engineers that is likely to be available. This first section reviews the past trends in employment of engineers with a view to determining the major factors which have created a demand for their services. Upon what appears to be reasonable assumptions as to how these factors may operate in the future, an approximation of the prospective demand for engineers is then suggested. A review of past trends is first presented for the profession as a whole; then the trends in each major field of engineering are discussed.

GENERAL TRENDS IN THE PROFESSION

Engineering is one of the most dynamic and rapidly growing professions. Its striking growth since 1890, when there were only about 27,000 engineers in the United States, is shown on chart 1. The number of engineers was 10 times greater in 1940 than in 1890 although the total number of workers in all occupations only doubled in this 50-year period. Though the rate of growth shows signs of diminishing, the numerical increase has been large in recent decades. Even over the depression decade of the thirties, employment in engineering expanded. There are few large occupations in the United States that can match this record of rapid and persistent growth.

Chart 1.—Growth of the Engineering Profession, 1890–1948

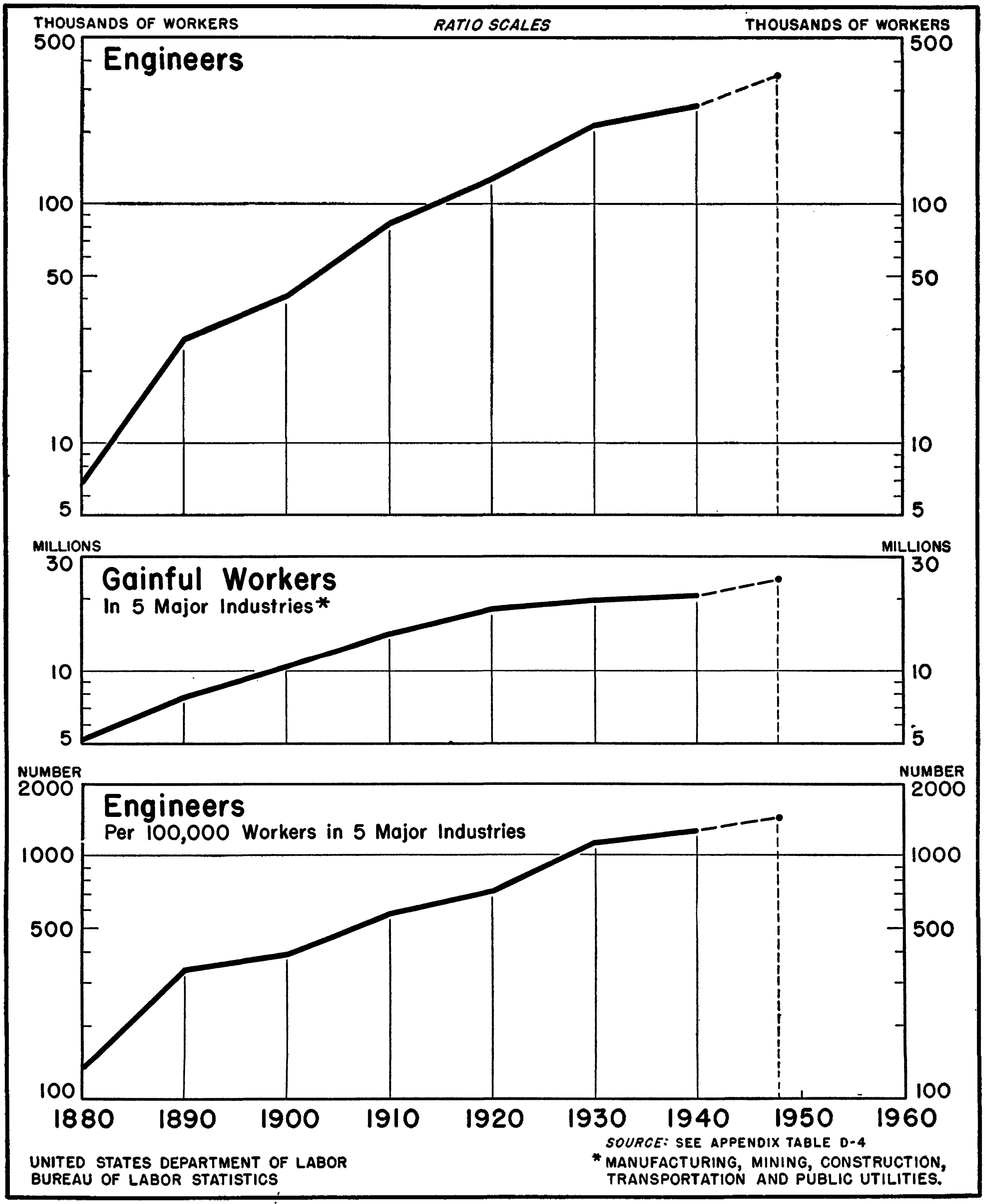


The profession's growth was the result of two principal factors: the rapid expansion in this period of the types of industrial activity which use engineers; and the increasing degree of utilization of engineers for many different functions within these industries. In assessing the prospective trends in the demand for engineers it is necessary to find out to what extent these factors have affected employment of engineers in the past, and to judge what effect they may have in the future.

Growth of Industries Using Engineers

Primarily a rural, agricultural country at the close of the Civil War, the United States had become a predominantly urban, industrial Nation by the beginning of World War II. This transformation was reflected in a decline in employment in agriculture and a sharp increase in employment in the five basic commodity-producing and transporting activities—manufacturing, mining, construction, transportation, and public utilities. The

Chart 2.—Growth of the Engineering Profession and Major Industries Employing Engineers, 1890–1948



number of workers attached to these industries almost tripled from 1890 to 1940, as compared to a twofold increase in the total number of gainful workers in the United States, although the rate of growth slowed down markedly after 1920, as shown in chart 2 and appendix table D-4. The war and postwar periods witnessed a large additional increase in employment in these industries, and in the spring of 1948 the number of workers attached to them was 19 percent more than in 1940.

They comprise the major sphere of activity of engineers, employing three out of four members of the profession. Furthermore, the work of most of the engineers employed in other industries is directly related to business activity in these five industries. For example, large numbers of the civil engineers employed in Federal, State, or local governments are engaged in work connected with construction activity, including design and supervision of public construction projects and approval of plans for private construction; in the same way, large numbers of the engineers employed in "professional and related services" in independent consulting firms are engaged in consulting work for the five major industry divisions listed above. Trends in business activity in these industries are therefore a major factor affecting the employment of engineers.

Future trends in business activity in these major industries are, of course, difficult to anticipate. Two major areas of uncertainty are the general level of business activity—the "business cycle"—and the international situation. In analyzing the outlook for engineers in this report, however, it is assumed that high levels of general business activity will be maintained unless otherwise indicated. Exploration of the implications of such a situation for the engineering profession provides a bench mark by which the possible effects of lower levels of business activity may be judged. A second general assumption which will be made is that the United States will not be engaged in a major war within the next decade; if there should be a war, the need for engineers would, of course, increase. The following discussion will thus suggest an outlook for the engineering profession that will be somewhere between the extremes of the range of possibilities.

If there is to be "full employment" in the United States, the total number of persons employed would have to increase moderately over the next decade in view of the expected growth of population and consequently of the labor force. The total labor force will increase by about 7½ million in the period 1948 to 1960, according to estimates made on the basis of trends in the size of the adult population and trends in participation in the labor force on the part of men and women, and older and younger persons. After allowing for a peacetime military establishment, a minimum amount of "frictional" unemployment (mostly people temporarily unemployed while moving from one job to another), and an agricultural employment level in line with long-term trends, we may have an increase in nonagricultural employment of about 7 million over this period, or about 13 percent.

The five major industries using engineers are not likely to expand as rapidly as this, however. Since the end of World War I, they have declined in relative position as a source of employment among American industries. They included about 60 percent of the total employed in nonagricultural industries in 1920, about 55 percent in 1930, about 50 percent in 1940, and about 45 percent in the spring of 1948. Trade, services, and Government as a group have gained while the commodity-producing industries have declined in relative importance. In view of this trend, it seems reasonable to expect that full employment would be achieved with a gain of less than 13 percent in employment in the commodity-producing industries. Assuming a gain of about 10 percent, total employment in these industries would amount to around 26½ million by 1960. This general conclusion is supported by analysis of the prospects for each of the major industries employing engineers, which is presented in other publications in the Bureaus' Occupational Outlook Series.[1]

In summary, then, a moderate expansion is likely in the long run in the types of industrial activity which make the most use of engineers' services. The long-term growth of employment in these industries will be slowing down—partly because of the success of engineers themselves in introducing new processes, machines, and production methods which make it possible to increase the average output per worker.

[1] See pp. 116 to 118 for a list of these publications.

Increasing Use of Engineers

A much more significant factor affecting the growth of the engineering profession has been the increasing degree of utilization of engineers for many different functions in industry. If, in the five industries referred to previously, the services of engineers were utilized to the same extent today as in 1890, their number would have increased at the same rate as total employment in these industries, or about threefold over the five decades. Actually the number of engineers increased tenfold from 1890 to 1940, or more than three times as much as would be accounted for by the growth of these industries. This reflects the fact that engineers are being employed more widely and for an increasing number of functions.

The advance of scientific knowledge and its practical application in industrial operations has affected the demand for engineers in two ways: the new applications of scientific findings required additional engineers to put them into effect; and the growing complexity of technology created the need for greater specialization, which resulted in the development first of the major branches of engineering and then of the specialties within these branches.

New applications of engineering methods are continually being developed. The value of engineering training for administrative jobs in production has been recognized. Engineers are used in sales work where a technical knowledge of the product and its uses is necessary. The expansion of research work in industry has required many engineers. The whole field of production methods of engineering, or industrial engineering, has developed. Quality control has also required trained engineers. All of these developments underlie the extension of industry's use of engineers.

Also, there has been a great increase in the employment of engineers by the Federal Government in research and development work connected with national defense and other Federal activities. In 1938, the Federal Government employed about 20,000 engineers; in July 1947, some 35,000 were employed, or about 75 percent more, according to records of the United States Civil Service Commission. This growth resulted largely from wartime and postwar conditions, and employment of engineers by the Federal Government will probably not continue to increase at this rate. Nevertheless, any substantial future increase in the employment of engineers by the Federal Government would tend to increase the number of engineers in the country relative to employment in the five industries listed.

The use of engineers in industrial research has been increasing rapidly as scientific advances open up new possibilities for commercial development. A comparison of the data from the 1946 directory of industrial research laboratories [2] with that from the 1940 edition shows an increase in the employment of engineers from 12,711 to 20,637 between 1940 and 1946 or about 62 percent.

The increased use of engineers may be illustrated by computing the ratio of the number of engineers in the United States to the number of workers in the basic commodity-producing and transporting industries listed above over the past five decades. In 1890 there were 344 engineers in the United States for every 100,000 workers in these industries; in 1940 there were 1,282 per 100,000—a fourfold increase [3] (chart 2). The ratio increased by an average of a third in each decade, although there were wide variations around this average.

Looking at the figure in another way, the number of workers per engineer has, of course, been decreasing over the same period (chart 3). This ratio dropped from about 290 workers per engineer in 1890 to 78 per engineer in 1940—a little over a fourth of that in the former period. The ratio has been decreasing more slowly in recent decades, however.

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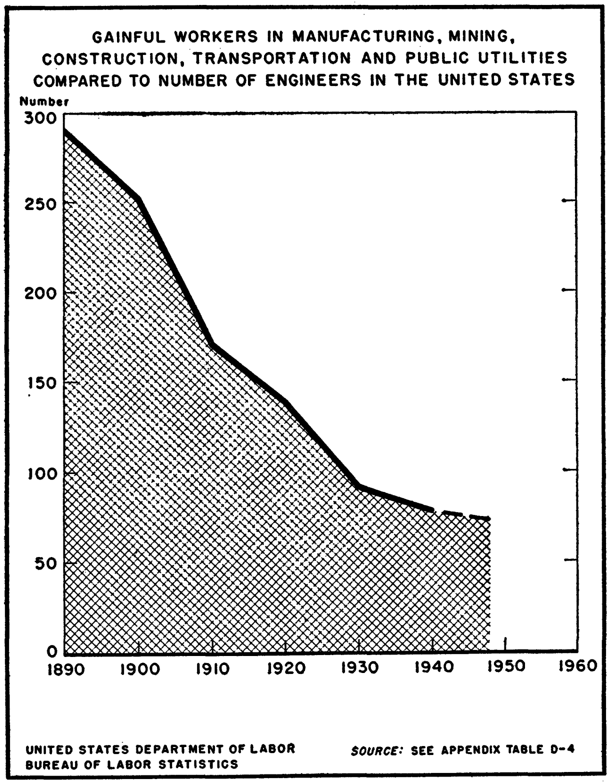
[2] National Research Council, *Industrial Research Laboratories of the United States*, Eighth edition, 1946, Washington, D. C.

[3] The figures in chart 2 on engineers and on number of workers attached to the major industries using engineers are based on the number of gainful workers who reported that they were customarily employed in these industries, rather than those actually so employed at the time of the census. This method made it possible to show the normal trend, rather than one influenced by a distorted ratio of engineers to the total number of workers in 1940, which was caused by the fact that in the depression many firms which had severely reduced their employment had retained a nucleus of skilled workers, foremen, managers, and engineers. As pointed out in the Compton report to the Society for the Promotion of Engineering Education (*Journal of Engineering Education*, September 1946, pp. 25–49), this enabled industry to make tremendous advances in production and employment during the war without adding proportionately to their engineering staffs. When the ratio of engineers employed to total number of workers actually employed in 1940 was plotted, it jumped far above the trend line. This suggests that the method adopted gives a more accurate representation of the underlying trend.

Chart 3.—Number of Workers Per Engineer, 1890–1948



During the war, when some 60,000 engineers were in military service, the ratio of engineers to total employment in these industries dropped, and there were widespread shortages of engineers. After the end of the war the long-term trend in the use of engineers was resumed, stimulated by the great wartime dependence on technology, by the expansion of research activity in industry and in the Federal Government, and by the desire of industry to make practical use of recent technological developments. By the spring of 1948, the engineering profession may have numbered around 350,000—an increase of around 34 percent since 1940 (appendix table D–2). This increase was almost twice as great as the 19-percent rise in the total number of workers attached to the five major industries.

The ratio of engineers to the total labor force of these industries has therefore gained somewhat. A check on this tremendous growth of about 100,000 engineers between 1940 and 1948 is made by examination of a recent survey of employment of engineers made by the Engineers Joint Council.[4] Though the sample was relatively small and the figures provide only a rough check, the data show an increase of about the same proportions since 1940—the ratio in the spring of 1948 being one-eighth above that in 1940. It is, however, not as high as would have been expected at this time on the basis of past trends, perhaps partly because of shortages of engineers. On the other hand, the number of workers per engineer declined from 78 to 1 in 1940 to 69 to 1 in 1948.

Summarizing, there are several factors therefore which tend to keep the ratio of engineers to total employment rising and to create an increasing demand for engineers: the continually increasing complexity of technology; the effect of wartime experiences which demonstrated the value of engineering services; the increase in use of engineers by governmental agencies; the increased use of research by industry; and the tendency for engineers to develop new processes and inventions which in turn often create demands for additional engineers and technicians. From these past trends, and from the rapid strides that are now being made in science, it seems probable that the use of engineers in industry relative to other workers will continue to increase. How rapidly this will take place is of course a matter of conjecture.

On the other hand, there are several factors which suggest that the ratio of engineers in the United States to total employment in these industries may not continue to increase as rapidly as in the past. Technical progress is cumulative, and the extension of the frontiers of scientific knowledge in its application to industrial problems could continue at a good rate—perhaps at an accelerating rate—even if the number of engineers were to reach a plateau at some future time and remain constant. As scientific and engineering techniques improve, many of the day-to-day engineering problems in industry may be solved more readily.

Moreover, there has been a great development of the use of larger numbers of semiprofessional assistants to engineers and other scientific workers, particularly during the war. A survey of leading

[4] *1949 Employment Programs for Engineering Graduates*, a survey conducted by the General Survey Committee of the Engineers Joint Council, New York, N. Y. (Mimeographed.)

industrial research laboratories showed, for example, that between 1940 and 1946 the ratio of professional workers (more than a third were engineers) to total research personnel decreased from 53 percent to 40 percent.[5] If this trend continues, it will make possible the use of fewer engineers than would otherwise be the case. While this development resulted in part from the wartime shortages of engineers, it also reflected a long-term trend toward the greater use of semiprofessional workers.

One factor underlying the growth of the engineering profession in the past has been the increasing employment of engineers in administrative positions. Over the past several decades, however, the number of people receiving formal training for administrative and management positions in industry has been growing rapidly. This may be seen in enrollments in university schools of business administration, as well as in the growth of in-service executive training programs in industry. From 1920 to 1940, while the number of baccalaureate and first professional degrees awarded in engineering increased from 4,716 to 14,348, the number awarded in business administration and commerce increased from 1,560 to 19,036, according to reports of the United States Office of Education. Engineers will no longer be almost the only persons in industry available for executive jobs who have had advanced training applicable to industry.

Examination of the trends in the use of engineers in each industry, described in the sections of this report dealing with the major branches of engineering, confirms the judgment that the number of engineers employed should continue to increase relative to other workers in industry. Even if the ratio of engineers to other employees should rise more slowly in the future than in the past, it is likely to increase substantially in the remainder of the 1940–50 decade and through the next decade. As mentioned above, the ratio has increased by about one-eighth in the 8 years since 1940. If it continues to rise at this pace, the total increase over the entire decade may amount to about 15 percent, or one-half the average increase in each of the previous five decades. For purposes of illustration of the future possibilities, perhaps an increase of similar magnitude in the 1950–60 decade may be assumed; this would bring the ratio to about 1,700 engineers per 100,000 workers.

Summary—Prospective Demand for Engineers

The preceding section has traced the growth of the engineering profession and has suggested that the two major factors underlying this growth will continue to operate in the future. A moderate further expansion of the major types of industrial activity which use engineers' services is in prospect for at least the next decade, under the assumption of full employment in the American economy. An increase of about 10 percent would bring the total number of workers engaged in these industries to some 26½ million by 1960.

The growing utilization of engineers, caused by the advance of science and its application to industry, is also likely to continue. If the ratio of engineers to the total number of workers attached to these industries should increase as much in the next decade as in the present one, it would reach the figure of approximately 1,700 per 100,000 workers by 1960.

Under these circumstances total engineering employment would amount to roughly 450,000 or some 100,000 more than in 1948. These figures are given, not as a forecast, but only to suggest in rough quantitative terms the implications of the past trends for the future growth of the profession.

An increase in employment of this magnitude would be very great in view of the present size and recent growth of the profession. Actually, it would mean that the number of employed engineers would have increased by over 80 percent in only two decades—a remarkable rise even for this occupation and much larger than the increase expected in most occupations of comparable size. A survey of the hiring plans of a number of large firms (see footnote 4, p. 11) employing engineers reveals that these firms did plan to hire a significant number of engineers in 1949 although somewhat fewer than in 1948.

The method used in this study to estimate the possible future growth in employment of engineers is of course but one of the approaches that might be used. For several reasons the ratio of engineers

[5] U. S. Employment Service, National Roster of Scientific and Specialized Personnel, *Industrial Research Personnel in the United States*, Washington, D. C., 1947. (Unpublished.)

to the number of workers engaged in the five major industries using engineering services may not present the entire picture. Several other approaches were used, but they did not prove as satisfactory as the one finally adopted. In some cases the data available did not show any definite trends, indicating a lack of relationship; in others the data were not available for early years. One measure of the ratio of the growth of the profession to a type of economic activity was more fully explored—namely, the ratio of the number of engineers to the number of horsepower-hours of energy output in industry—which did show a definite relationship. When the trend in this ratio was projected to 1960, on the basis of estimates of future energy consumption, the results obtained were fairly close to those obtained by the method used in this report.

From the above review of the past trends in the growth of the engineering profession as a whole within the framework of the industrial economy of the United States this picture emerges: the occupation has grown rapidly in the past; there is an indication that the rate of growth is diminishing, but no indication that the pattern is being reversed; and therefore, on the basis of the general trends considered, there is every likelihood that the profession will continue to grow for some time. In the following sections, the development of each of the major fields of engineering will be reviewed in order to determine whether some are growing more rapidly than others, to provide the detail underlying the general conclusions summarized above, and to give other information on each field.

CIVIL ENGINEERS

Civil engineering is the oldest of the branches of the broad field of engineering; it is the main trunk from which nearly all other fields developed as technical knowledge expanded and industry became more complex. Formerly, there were only two main branches of engineering—"military" and "civil." Today, civil engineering is recognized as only one of the specialized branches of the profession.

Civil engineers are concerned with the design and construction of such facilities as roads, buildings, bridges, dams, tunnels, water-supply and sewerage systems, transportation projects, and many other structures for public, industrial, or commercial use. Such areas of activity as structural, sanitary, architectural, hydraulic, and highway engineering are in this main field.

About half the civil engineers work for a governmental agency, either Federal, State, or local. About one-quarter are employed by the construction industry. Nearly 6 percent are employed in the transportation industries and slightly more than 4 percent in the utilities industries. The distribution of civil engineers by industry fields may be seen in the accompanying tabulation.

The reason so many civil engineers are employed by Federal, State, and local governments is partly the nature, cost, and size of the projects with which civil engineers work. While the major part of all construction work is privately built, a large proportion of the projects requiring engineering work—the large projects—are built for the public, such as highways, dams, sewerage systems, etc. In addition, civil engineers occupy such positions as administrators of water and sanitary departments and street and highway divisions.

Industry field	*Percentage distribution*
Total	100.0
Construction	26.6
Manufacturing	8.1
Petroleum and coal products	1.4
Iron, steel, and nonferrous metals and their products	2.9
Other manufacturing industries	3.8
Transportation	5.8
Utilities	4.1
Government	50.8
Other industries	4.6

Generally speaking, a greater proportion of civil engineers are in positions dealing directly with the administration or management of an enterprise than is true in any other field of engineering (appendix table D–8). On the other hand, a relatively small proportion of civil engineers are found in either research, design, and develop ment positions or in such jobs as production, operation, maintenance, inspection, and installation.

In the construction industry itself—one of the major employers—almost half the civil engineers are engaged in administrative, management or supervisory positions. (See table 1.) These positions range from that of an official of a large construction firm to that of site supervisor of a construction gang. Slightly more than a quarter are employed in the general field of design, development, and drafting. The job of designing a bridge, for example, involves the planning and selection of a type of structure and estimating of costs of the various parts, such as the superstructure, piers, or abutments. Civil engineers also are responsible for many individual jobs on the construction project itself. The equipment must be selected and the flow of materials and supplies must be ensured. Other engineers are also found in many varied positions including the estimating of costs of new projects or the inspection and maintenance of highways and bridges.

TABLE 1.—*Percentage distribution of civil engineers, by occupational status in selected industry fields, 1946*

Occupational status	All industries [1]	Construction	Transportation
Total	100.0	100.0	100.0
Administration-management	47.5	51.5	42.6
Administration-management, nontechnical	2.4	2.2	1.2
Administration-management, technical	27.2	26.6	29.1
Construction supervision	17.9	22.7	12.3
Consulting	8.4	8.9	2.7
Consulting, independent	5.2	6.2	.8
Consulting, as employee of private firm	3.2	2.7	1.9
Operation and maintenance	7.6	5.8	25.3
Inspection	2.1	2.4	1.2
Installation	.2	.2	----------
Maintenance	3.4	2.4	20.7
Operation	1.2	.4	2.3
Production	.4	.1	.4
Safety engineering	.3	.3	.8
Design, development, and research	29.6	30.7	26.2
Design	19.9	21.9	17.3
Development	2.0	2.0	.8
Analysis and testing	1.0	.9	----------
Drafting	2.4	2.5	3.1
Research and basic science	.3	.1	----------
Research, applied	1.3	.7	.8
Estimating	2.7	2.6	4.2
Sales	1.2	.3	.4
Other	5.7	2.8	2.7
Editing and writing	.7	.5	.4
Retired	.1	.1	.4
Student	.1	.1	----------
Teaching, college or university	2.3	.2	----------
Any occupational status not specified	2.5	1.9	1.9

[1] See appendix table D-9 for list.

Many civil engineers employed in industries other than construction are actually engaged in work connected with new construction or the repair of old structures. Some civil engineers work for building materials manufacturers or in private consulting firms which advise on technical problems.

In the transportation industries, there is a slightly wider distribution of functions than in construction. Here, about two-fifths of the civil engineers are in administrative or management jobs, such as executive in a railroad company or section supervisor of a surveying crew. About one-quarter find employment as division engineers in charge of maintenance of the tracks, yards, and structures, or in the construction office estimating maintenance costs for equipment and tracks. Others are found in such jobs as design engineer planning the location and construction of roadbeds, tunnels, grade separations, etc., or drafting foreman in a divisional office.

The functional distribution in the utilities industries is somewhat similar to that in the construction industry. Nearly half are in some type of administrative or supervisory work such as engineer in charge of construction. Another sizable group is found in such positions as head of the drafting department, or planning or design engineer responsible for location of power plants and distribution lines.

The development of the profession is closely related to the history of the construction industry. As long as houses and other relatively small buildings were the principal types of structures built, there was no great need for engineers to design them and supervise their construction. Traditional building methods were used—methods developed after centuries of experience—and carpenters, masons, and other building craftsmen were able to put them up without an engineer's design or supervision. This is still the way most private homes, farm buildings, and other small structures are built.

Although several experimental (horse-drawn) railroads were in use earlier, the industry did not really begin to develop until after 1830; at about this time the profession of civil engineer also began to expand. The railroad industry grew slowly until the end of the Civil War; then it expanded rapidly, extending into the West and South. Railroad construction (miles of track) reached its peak in the 1880's when the civil engineers were still few in numbers—the Census of 1890 showed fewer than 27,000 in all fields.

The civil engineer was now branching out in many directions. In addition to construction needed for the expanding railroad industry, the need for better roads and bridges was felt. Civil engineers were also active in the building of waterways, harbors, and canals to keep pace with the Nation's growing trade and commerce. Water supply and sewer systems were built extensively in the large cities and even in small towns.

In addition, a more intensive use of engineers was made in types of construction work which before had been planned by craftsmen as they went along. New materials and ways of building were introduced such as all-steel frame construction and fireproofing. Larger buildings called for engineering design. Another factor affecting employment of engineers was the development of local laws to protect the public against unsafe construction in buildings. Most of these regulations required approval of building plans by qualified engineers.

The development of the automobile next opened a great vista of opportunity for the civil engineer. Although the first internal combustion motor car was built as early as 1885, the automobile did not gain real public acceptance until the First World War. Then, during the twenties and on into the thirties many thousands of miles of highways were built for motor vehicles. The number of miles of improved roads, including such projects as grade crossing eliminations and super highways, has continued to expand after the period of rapid development, and increasing traffic will call for continued expansion and improvement in the future.

The decade of the twenties also witnessed a boom in new construction activity, reaching a peak in physical volume in 1927. Construction of commercial buildings, public utility facilities, public buildings, and houses as well as highways hit a new high during this decade. The profession grew from between 45,000 and 50,000 in 1910 to nearly 60,000 in 1920 and then increased by almost 50 percent to a total of about 88,000 by 1930. (See Appendix table D–1.)

The decade of the thirties witnessed no increase for the civil engineering branch of the profession. Employment in the profession is greatly affected by changes in the general level of business activity. The private construction industry, particularly with respect to residential, commercial, and industrial building, varies greatly in its volume of activity with severe curtailment during depression periods. In fact, the volume of new construction activity in 1933 was only 29 percent of that in 1929.[6] Public construction, including reclamation projects, public buildings, and transportation facilities (mainly highways), has held up better during depressions, and some types of public works have been emphasized in the past when private construction was lagging.

The effects of the business depression on civil engineers are illustrated by unemployment figures for this branch of engineering. In 1932, many civil engineers were unemployed or were working in subprofessional jobs. In addition, civil engineering was about the only field which had not recovered somewhat by 1934, and in that year had the highest unemployment rate of all fields. Of the new graduates, entering the field between 1930 and 1934, between 55 and 60 percent had periods of unemployment at some time during that period. Furthermore, civil engineers in the higher age groups as well showed the greatest unemployment rate among all fields of engineering.[7]

Civil engineering recovered somewhat from the effects of the depression as new construction activity more than doubled from 1933 to 1940. Nevertheless, in 1940, nearly 10 percent of the civil engineers were still unemployed and in the allied occupation of surveying almost 20 percent were unemployed.

Large numbers of civil engineers left the profession during the 1930 to 1940 decade. The numbers in the field showed almost no increase in this period in contrast to the rapid growth of the twenties. The growth of this branch of the profession is shown in chart 4.

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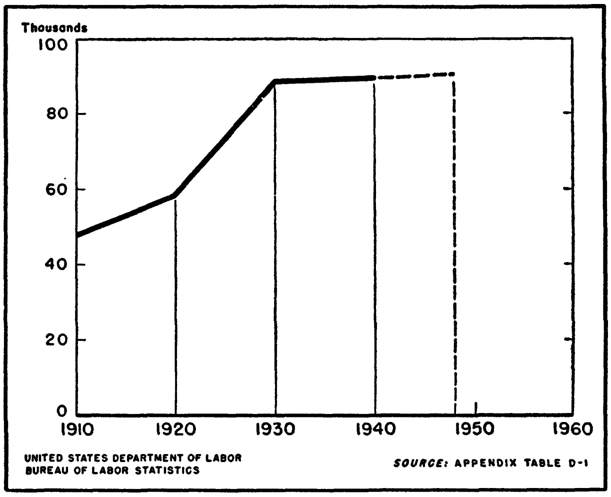
[6] U. S. Department of Labor's Bureau of Labor Statistics, *Probable Volume of Postwar Construction,* Bulletin No. 825, Superintendent of Documents, Washington 25, D. C., 1945. Price 10 cents. See also *Employment Outlook in the Building Trades,* Bulletin No. 967, Superintendent of Documents, Washington 25, D. C., 1949. Price 50 cents.

[7] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934.* Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

Chart 4.—Number of Civil Engineers, 1910–48.



With the advent of the war in Europe, the defense program provided many opportunities for civil engineers. The volume of new construction reached a peak in 1942—even higher than the 1927 record. New army training camps and other defense facilities were built, but most types of nonmilitary construction decreased during the war period. Even military construction reached its peak early in the war and then decreased very rapidly. Many civil engineers entered the armed forces and many transferred to other fields of engineering, such as mechanical, in which personnel were in great demand. (The extent of these movements is discussed in greater detail in the section on occupational mobility; see pp. 69 to 81.)

The country entered the postwar period with a backlog of residential, commercial, and highway construction needs created not only by a decade of depression but also by the war. Construction volume had already started to expand in the first postwar year, 1946. In 1947, it climbed even higher and toward the end of 1948 it appeared that near record levels were to be reached. A great deal of emphasis is being placed on residential construction, a field in which comparatively few civil engineers are engaged in proportion to the total dollar volume of construction. Some types of construction programs have yet to get under way. Many State governments have embarked on highway expansion programs and they may be expected to emphasize these programs for a number of years. In 1946, about 17 percent of all civil engineers were employed in highway construction, and an additional 6 percent in bridge construction. A recent survey of engineering schools [8] showed that many State highway departments are having great difficulty in recruiting civil engineering graduates. This is due in part to the comparatively low salaries paid in these positions. The 1946 survey of the engineering profession revealed this same condition. (See table 14.)

Expansion of the public works program of conservation and development has in general lagged behind that of most other types of construction, but currently is proceeding at a rate at least comparable with those of earlier periods of high activity. Short-range changes in the level of activity are controlled by governmental appropriations, and are not easily predictable; but greatly increased public consciousness of the importance of this work makes a long-range increase seem likely.

Despite the failure to increase in numbers to any degree in the last two decades, there has been a moderate upward trend in the ratio of civil engineers to total construction employment and to total construction volume. It is likely that this trend will continue in the future.

While there are signs that some types of construction expansion may not continue without interruption, the long-range potentiality of a very large construction market seems to be at present beyond any question. This market includes the types of construction to which engineers are most essential. Demand for civil engineers will therefore probably continue at a high level for several years and then ease off somewhat. In the long run a slow additional expansion seems likely; perhaps this branch of engineering will number around 105,000 by 1960, which means an average of over 1,200 additional jobs each year. It must be remembered, however, that the construction industry and therefore civil engineering is extremely sensitive to the level of general business activity and any serious decline would probably lead to unemployment in this branch of the profession. This would be mitigated to the extent that civil engineers were needed for expanded public works programs.

[8] J. A. Anderson, *Shortage of Highway Engineers Starts in College,* American Highways, April 1948, pp. 6–7.

Geographical Location

Civil engineers may be found in nearly all parts of our Nation, both in or near large cities or in remote rural areas. They are more evenly distributed geographically than the members of any other field of engineering as may be seen by appendix table D-10. A great many civil engineers are required to move from one construction project to another although working for the same employer. Many large consulting firms and contracting firms have offices in several States, and advise companies in several parts of the country. The engineer employed by one of the consulting or contracting firms may be required to move, for example, from a bridge project in Salt Lake City to a grade crossing project in Los Angeles. The largest proportion of the profession is concentrated in dense population centers, where the bulk of industrial and commercial activity is located.

MECHANICAL ENGINEERS

Mechanical engineers are responsible for designing, testing, construction, and operation of machinery that produces power, transmits power, consumes power, or utilizes heat energy. These engineers also design machinery, tools, and equipment, and plants or mills which require special construction to accommodate power-producing or transmitting machinery. Mechanical engineering covers several distinct areas of work, among which are: aeronautical; marine engineering and naval architecture; automotive; railroad equipment, heating, ventilating, and air conditioning; and general power production. Industrial engineering is frequently regarded as a branch of mechanical.

Mechanical engineering began to emerge as a separate field following the expansion in the use of power machinery in the eighteenth and particularly in the nineteenth centuries. The evolution of power machinery and the profession of mechanical engineering are closely associated. Mechanical engineers have developed new machines for power utilization and this new equipment in turn has provided opportunities for other engineers.

This particular branch of engineering is related to all types of industrial operation. Though dealing primarily with power and machinery, it includes activities ranging from instrument making to the design and construction of equipment for huge power plants.

Employment trends in the profession can best be understood in the light of the past trends and the outlook for the metalworking industries. Even though mechanical engineers are employed in many industries, as may be seen by the following tabulation of their distribution in 1946, about half are found in the following manufacturing industry groups: Machinery (including electrical), transportation equipment, and basic metals and their products (including iron and steel and nonferrous metals).

Industry field	*Percentage distribution*
Total	100.0
Construction	2.5
Manufacturing	67.6
Food and textiles	2.5
Lumber, furniture, and paper	2.1
Chemicals and allied products	3.2
Petroleum and coal products	2.9
Rubber, and stone, clay, and glass	1.9
Iron, steel, and nonferrous metals and their products	8.7
Machinery	19.5
Transportation equipment	20.4
Other manufacturing industries	6.4
Transportation	1.7
Communication	1.5
Utilities	3.5
Government	10.5
Other industries	12.7

Manufacture of Basic Metals and Their Products

The iron and steel industry grew rapidly when a cheap form of steel was made possible after the Civil War by the introduction of the Bessemer process, combined with the exploitation of the rich ore deposits of the Great Lakes region and a good supply of coal. The industry received tremendous impetus from World War I and grew steadily in the twenties. After a sharp contraction during the depression, production rose to record heights during World War II. In the postwar period, activity has remained very high and, with heavy demand for construction and durable goods, and because of the foreign aid program and military needs, will probably continue high for several years. The long-term trend is slowly upward.

In 1946, about 1 out of every 14 mechanical engineers was employed in making iron and steel and their products. In general, engineering employment in this industry has been comparatively static in recent years compared to the growth in other industries, although engineers were responsible for many of the technological changes in the past. It is not likely that employment of mechanical engineers in basic metals production will rise very much because the industry itself will probably tend to remain near present levels.

Mechanical engineers have contributed greatly to the development of the nonferrous metals industries which include copper, aluminum, zinc, lead, tin, tungsten, nickel, and others. These industries expanded greatly as a result of the First World War and the general growth of the economy during the twenties. After the depression during the thirties, the advent of World War II brought about a tremendous demand for all types of metals. The aluminum industry in particular increased production to record peaks because of the demand for the metal in aircraft manufacturing. Production has been high in the postwar period, and will probably remain this way for several years, owing to the backlog of demand for civilian uses as well as the military aircraft production program.

The number of mechanical engineers employed in all metal industries, although increasing considerably over early periods, has not expanded as rapidly as in either the machinery or transportation equipment manufacturing industries.

Nearly half of the mechanical engineers in basic metals industries are found in administration, management, or similar functions (see table 2), either in top positions such as vice president in charge of production or engineering, or as heads of separate departments or sections within a firm. About 28 percent are engaged in research, design, or development. In these positions, the engineer may be working at a variety of tasks such as research on methods to be used in the production of the basic metal. The design of a blast furnace is the result of long hours of planning and development by many engineers. Around 8 percent of the mechanical engineers are in sales work while the rest are in other jobs such as consulting, production, operation, and maintenance. The small proportion of mechanical engineers in research, design, and developmental fields in these industries probably has resulted from the fact that some of these functions are performed by metallurgists or metallurgical engineers.

TABLE 2.—*Percentage distribution of mechanical engineers, by occupational status in selected industry fields, 1946*

Occupational status	All industries [1]	Iron, steel, and nonferrous metals and their products (manufacturing)	Machinery (manufacturing)	Transportation equipment (manufacturing)
Total	100.0	100.0	100.0	100.0
Administration and management	34.3	47.6	35.7	27.7
Administration-management, nontechnical	2.5	4.0	2.8	1.5
Administration-management, technical	29.5	40.7	31.6	25.4
Construction supervision	1.9	1.6	1.1	.7
Personnel-labor problems	.4	1.3	.2	.1
Consulting	5.7	3.9	5.0	2.2
Consulting, independent	2.0	1.6	1.8	.4
Consulting, as employee of private firm	3.7	2.3	3.2	1.8
Manufacturing and production	10.2	12.3	9.3	6.1
Estimating	1.1	1.4	1.7	.7
Inspection	1.0	.9	1.0	1.0
Installation	.8	.4	1.4	.5
Maintenance	2.2	3.1	.5	.9
Operation	1.8	2.2	.5	.7
Production	3.0	4.3	4.1	2.2
Safety engineering	.3	----------	.1	.1
Design, development, and research	39.0	27.9	36.9	58.9
Design	19.1	16.9	21.9	23.8
Development	7.7	5.4	8.7	11.2
Analysis and testing	3.3	.9	.5	10.0
Drafting	1.8	2.3	1.6	2.5
Patents	.4	.4	.3	.4
Research in basic science	.9	----------	.2	1.2
Research, applied	5.8	2.0	3.7	9.8
Sales	5.7	7.6	10.1	2.8
Other	5.1	.7	3.0	2.3
Editing and writing	.4	----------	.7	.4
Library and information service	.1	----------	.1	.1
Retired	.1	----------	.1	----------
Student	.3	----------	.6	.3
Teaching, college or university	2.6	----------	----------	.4
Teaching, other	.1	----------	.1	.1
Occupational status not specified	1.5	.7	1.4	1.0

[1] See appendix table D-9 for list of industries.

Machinery Manufacturing

The textile machinery industry was perhaps one of the first branches of machinery manufacturing to develop. The growth in the production of agricultural machinery came somewhat later. The use of other types of machinery, including machine tools and their accessories, pump and pumping equipment, electrical machinery, engines and turbines, business machines, domestic machines (sewing machines, washing machines, refrigerators, etc.), and general machinery and machine shop products, has grown rapidly in the last 80 years.

The machinery manufacturing industry has of course grown as the general level of industrial production has risen. Both World Wars have created an enormous demand for all types of machinery. During World War II, the machinery manufacturing industry reached unprecedented heights of production and employment. Most of the activity was directed towards war needs. Consequently demand was created for machinery products such as agricultural equipment, food products, textiles, paper, printing, and many others not directly connected with the war effort. Now the machinery industry is engaged in satisfying this backlog of demand. However, even after this has been accomplished, activity is expected to remain high owing to the long-run trend toward greater mechanization of industry and other factors.[9]

Around a fifth of all mechanical engineers were found in the machinery manufacturing industry in 1946—a slightly smaller proportion than in 1940. However, the actual number of mechanical engineers so employed increased during this period by about 18 percent.

In this field about a third of the mechanical engineers occupy administrative, management, or similar positions. Slightly more are engaged in research, design, and development—working, for example, on the design and development of a machine, improving its efficiency or lowering its cost of production. The evolution of one particular milling machine or drill press is the result of many hours of work by trained design or development engineers. About 10 percent of the mechanical engineers in the machinery industry are in sales positions; less than 10 percent in jobs relating to production, operation, installation, and similar functions. Therefore, a direct expansion or depression in activity or production will not necessarily bring about a corresponding change in employment of mechanical engineers.

Transportation Equipment Manufacturing

The earliest transportation equipment manufacturing industries, although originally responsible for much of the growth of mechanical engineering, are not now the major employers. During the early years in the shipbuilding industry, before the steam engine was used and before the use of metal for ship construction, mechanical engineers as we know them today were not used to any great extent. Later, after the Civil War, the function of mechanical engineering in the ship- and boatbuilding industry began to expand. Peaks of production have, as might be expected, occurred during both World Wars. In World War II, activity reached an unprecedented peak—close to 2 million persons were employed in 1943 and thousands of units were built. After VJ-day, the industry completed the downward trend in production started late in the war. In the spring of 1949, total employment in the industry, although higher than prewar levels, was considerably below the wartime peak and the majority of activity was directed towards repair work rather than new construction.

After original development several decades earlier, the railroad industry began to expand rapidly after the Civil War. Engineers began to be needed in ever increasing numbers for technological improvements in railway equipment. New types of locomotives, freight and passenger cars, and other equipment were devised. Since the start of the First World War the locomotive- and carbuilding industry has developed at a somewhat slower rate. During both the depression period of the thirties and the recent war, the railroad industry was unable to replace equipment as it deteriorated or became obsolete. As a result railroads today are faced with a problem of obtaining new rolling stock of all types (particularly freight). The demand for engineering services will probably remain at a high level for some time with the continuing need for modernization and upkeep of structures, roadways, and stock. The trend toward Diesel power is also expected to continue. All these factors point to a high level of activity in railway equipment building, lasting for a number of years.[10]

The beginning of the twentieth century saw the start of two industries, which were to challenge the railroads' leadership in transportation—first

[9] U. S. Department of Labor's Bureau of Labor Statistics, *Employment Outlook in Machine Shop Occupations*, Bulletin No. 895, Superintendent of Documents, Washington 25, D. C., 1947. Price 20 cents.

[10] U. S. Department of Labor's Bureau of Labor Statistics, *Employment Outlook in Railroad Occupations*, Bulletin No. 961, Superintendent of Documents, Washington 25, D. C. 1949. Price 30 cents.

the automobile industry and later the aviation industry. From 1900 to 1910 the number of cars and trucks produced annually had risen from about 4,000 to around 187,000. By 1916, annual production was nearly a million; mass production of automobiles had arrived. Several factors have contributed toward this mass production—including the large market for automobiles, the continued creation of demand by improvement of models, and such industry practices as the division of labor, standardization of parts, and finally the system of moving assembly lines. Engineering research and development contributed greatly to the progress made along these lines. The Society of Automotive Engineers, formed in 1904, has been largely responsible for effecting standardization of parts, measurements, and materials in the automobile industry.

As everyone knows, the automobile industry stopped production of civilian passenger cars and trucks during the recent war. Consequently an immense backlog of demand for motor vehicles was built up. In addition, with a greatly increased population and a higher level of income, the demand for both cars and trucks is expected to remain high. Also, as the industry is highly competitive, research, design, and development activities will probably continue at a high rate. In 1946, only 4 percent of all mechanical engineers were employed in automobile manufacture; however, the prospects are for continued growth in their use by this industry.

Although the aircraft manufacturing industry was the last of the transportation group to develop, it is now the largest single employer of mechanical engineers. Its greatest impetus has been as the result of war needs. Although the airplane was invented much earlier, industrial production and commercial utilization did not reach a rapid rate of increase until the First World War. With the end of the war came the cancellation of war orders and serious deflation nearly wrecked the industry. There was some expansion in the twenties and a serious setback in the thirties. With the advent of the war in Europe in 1939, the industry again received stimulus from war needs. The number of engineers required by the industry was far greater than ever before, because of the need to develop revolutionary types of aircraft for war purposes. After VE-day, production fell off greatly, reaching a low point with the end of the war in September 1945. The immediate postwar period was one of great readjustment for the aircraft industry. With increased defense appropriations, production of aircraft has increased a great deal and will expand even more during the next few years. In addition, aeronautical research, particularly in the military field, will probably continue to be emphasized for some time.

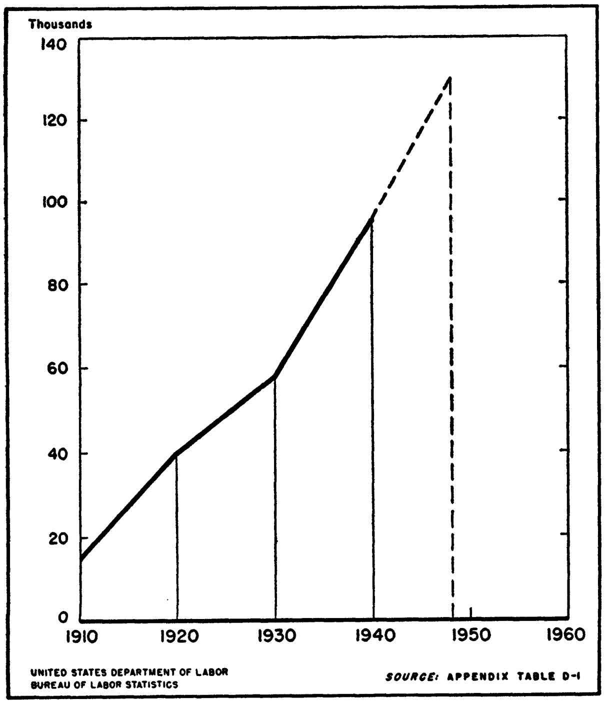
In 1946, about 1 out of every 6 mechanical engineers (including aeronautical engineers) was employed in the aircraft and parts manufacturing industry compared with about 1 in every 20 in 1940. The aeronautical engineers work mainly on the aeronautical and mechanical design of the structure of the aircraft (although for advanced research many mathematicians and physicists are employed); other types of mechanical engineers work on the engines, other mechanical parts, and on production problems; electrical engineers are increasingly being used in connection with electrical and electronic installations.

Among all mechanical engineers employed in the transportation equipment manufacturing industry in 1946, very few (6 percent) were engaged in direct manufacturing or production jobs, such as department supervisors or shift superintendents. Owing to the constantly changing technology of the industry and intense competition, particularly in aircraft and automobiles, over half of the mechanical engineers were in research, design, or development functions. In an aircraft plant, for example, research and design engineers are constantly experimenting with new models, testing various parts, such as the wing assembly, for resistance to stress and for aerodynamic efficiency. The field of aerodynamics is still comparatively young, and new and improved techniques are being devised all the time. The new fields of guided missiles and supersonic aircraft demand a large research and design staff. In the automobile industry, engineers work continually on the improvement of the total product and parts are constantly being improved. Improvement of this industry's mass production system was worked out by planning engineers. Mechanical engineers are also employed in sales, consulting, or other jobs.

Industrial Engineers

Another field of engineering—industrial—has developed primarily out of mechanical engineering. Today, this branch cuts across all fields of engineering and all industries in which engineers are found. Separate curricula for industrial engineering have been established in many schools but many persons trained in mechanical, electrical, chemical, and other fields of engineering enter the field. The industrial engineer is concerned primarily with the efficient use of labor, machines, and materials in industry. He designs factory layout so that the work flows efficiently from one step in the process to the next step; he designs machines so that the worker's efficiency in using them is improved; he devises records and controls so that the plant manager will have all the information he needs at his fingertips. From the first techniques developed by Frederick W. Taylor, this field of engineering has developed into a very specialized branch. Necessity for the establishment of this field was recognized as a result of the increasing complexity of industrial production. Trained personnel are needed to deal with the factors which affect cost, quantity, and quality of output. In 1940, the Census Bureau reported nearly 10,000 in

Chart 5.—Number of Mechanical Engineers, 1910–48

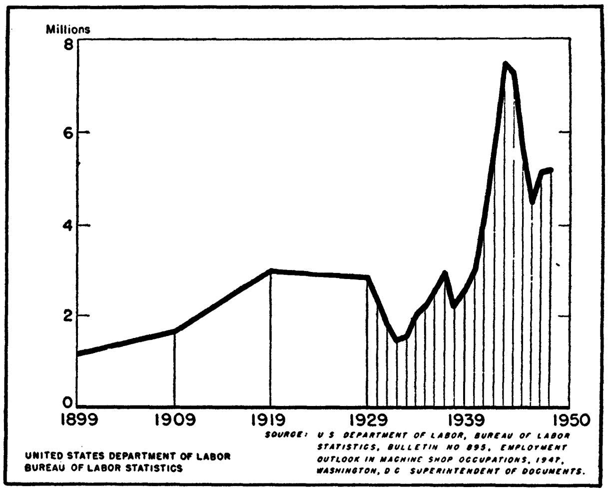


the field with about 5 percent unemployed. Since that time, owing primarily to war needs for greater production, the field has grown considerably. Scientific management and industrial engineering will become more important, with emphasis on higher productivity, greater mechanization, and better cost control.

Summary

Thus, the profession of mechanical engineering and all its subdivisions has expanded along with the general growth of the industries in which the majority of its members are concentrated. The greatest expansion has taken place in this century, when employment rose from about 15,000 in 1910 to over 95,000 in 1940 (including industrial engineers) and somewhere near 130,000 in 1948. (See appendix table D–1.) The growth of the profession and employment in metalworking industries in this period are shown on charts 5 and 6.

Chart 6.—Employment in Metalworking Industries, 1899–1948



Over the past several decades, there has been an upward trend in the ratio of mechanical engineers to employment in the metalworking industries, which should continue in the future. It is now the largest single branch of the whole engineering profession and, even with the tremendous growth in the past several decades, stands on the threshold of still further development and progress. The growth in the future will be based largely on advances in the major industries in which mechanical engineers are now concentrated. In addition, recent developments in such fields as atomic energy and jet propulsion, plus the expected expansion in research by both private industry and government agencies should add to the demand for technical personnel and provide jobs for additional mechanical engineers.

Therefore, the field of mechanical engineering is expected to grow, both over the next several years and over the long run, but the rate of increase will probably decline to some extent after a number of years. The trends discussed above point to the possibility that the mechanical engineering profession will have grown to around 175,000 by 1960—an average growth of over 3,700 jobs a year following 1948.

Geographical Location

Mechanical engineers are employed in all States. However, owing to the concentration of the industries where most are employed, about 70 percent are found in the following eight States: New York, Ohio, California, Pennsylvania, Illinois, New Jersey, Indiana, and Massachusetts. A more detailed tabulation of geographical distribution is shown in appendix table D–10.

ELECTRICAL ENGINEERS

Electrical engineers deal with the generation, transmission, and utilization of electricity. There are several broad areas of work, including power, illumination, wire communication, electronics (including radio, television, and other applications), transportation, and electrical machinery and equipment manufacturing.

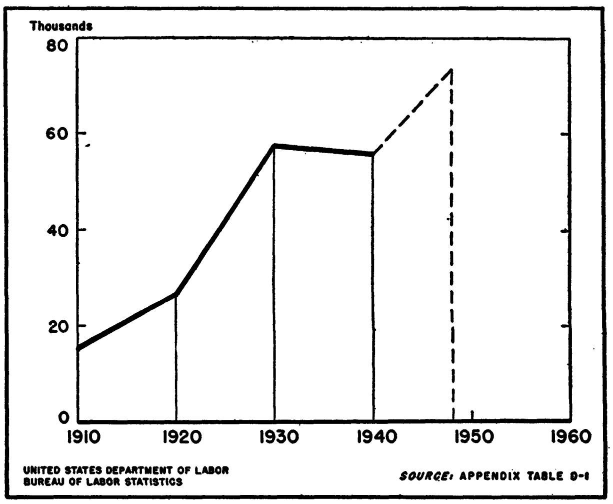
While the presence of electrical energy was known centuries before Benjamin Franklin's famous experiment, for the most part the commercial use of electricity has developed within the last 100 years. In 1831, Faraday demonstrated the first dynamo by which electricity could be generated by mechanical power instead of the chemical means used up to that time. Many developments followed, including Edison's carbon filament lamp and the inventions of George Westinghouse. The first central station for power generation was put into operation in New York City in 1882. Many new applications and uses of electrical energy followed, including new means of generation, different type of motors, converters, transformers, and radio.

Nearly all of the early inventions and developments concerning electrical energy were made not by men who had the conventional academic training of electrical engineer, but by inventors, mechanics, and other technical people. Furthermore, most of the progress in the beginning came as the result of isolated discoveries. Gradually, a store of information and engineering techniques was built up and specialized knowledge became necessary for work in the field.

Thus, the separate field of electrical engineering began to emerge toward the end of the nineteenth century. Unlike some of the other fields of engineering—such as civil or mechanical—the profession of electrical engineering grew up at the same time as the industries it serves. Engineering and research are responsible for much of the phenomenal growth of electrical industries.

In 1884, when the American Institute of Electrical Engineers was formed, there were probably not more than a thousand or so men in the field, since the census for 1880 reported fewer than 7,000 engineers in all fields. The profession then expanded rapidly until there were about 15,000 in 1910. The number in the field rose to nearly 27,000 in 1920 and then more than doubled to over 57,000 in 1930. (See chart 7.)

Chart 7.—Number of Electrical Engineers, 1910–48



Over the decade of the thirties the growth of the profession was interrupted. The number of electrical engineers showed no increase for this period (the census, which was not exactly comparable from 1930 to 1940, actually reports a decrease, from over 57,000 to 55,700 in 1940, of whom about 2,700 were unemployed). Many left the profession in this decade, as shown by the fact that, in addition, at least 3,000 persons employed in some other occupations reported that their usual occupation was electrical engineer.[11] Many of those graduated during the depression period were unable to find jobs; for the most part openings occurred only because of death and retirement. Research and development programs were drastically reduced in the thirties and many employers were unwilling to keep up the overhead costs of engineering research personnel. In fact, in 1932, about 10 percent of all electrical engineers were unemployed; even though unemployment dropped to around 7.5 percent in 1934, many were still on work relief.[12] Altogether, approximately 12 percent of the men in the profession were on work relief at some time between 1930 and 1934. The profession did recover substantially from the effects of the depression after 1934; even so, the advent of World War II saw many trained electrical engineers not active in their chosen field.

Industry field	*Percentage distribution in 1946*
Total	100.0
Construction	2.5
Manufacturing	36.7
Chemicals and allied products	1.1
Iron, steel, and nonferrous metals and their products	1.6
Machinery (including electrical machinery)	26.5
Transportation equipment	2.6
Other manufacturing industries	4.9
Transportation	1.5
Communication	19.7
Utilities	16.7
Government	14.3
Other industry fields	8.6

[11] U. S. Bureau of the Census, *Sixteenth Census of the United States, 1940: Population, The Labor Force, Usual Occupation.*

[12] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934*, Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

The outlook for electrical engineers is largely dependent on the growth of the three major industries in which electrical engineers are used—electrical machinery and equipment manufacturing, electric light and power, and communications. Electrical engineers are employed in many varied industries as shown in the preceding tabulation of their distribution in 1946.

Electrical Machinery and Equipment Manufacturing

The electrical machinery and equipment manufacturing industry, while a very large one today, has developed only within the past 50 years. The industry in the beginning concentrated on lighting equipment and industrial electrical apparatus. The three major divisions now are the plants making electrical equipment, communications equipment, and radio and television sets and phonographs. Though there were many small companies at first, today the majority of the business is in the hands of a few large corporations who employ a large number of engineers for research and development projects and for selling. Nevertheless, there are thousands of small manufacturers, many of whom employ engineers.

The tremendous expansion of the electric light and power industry during the twenties with its demands on the electrical machinery and equipment manufacturing industry parallels the growth of the electrical engineering profession in this period. Great strides were made in the extension of use of industrial electrical equipment. Even in the thirties, when practically all industry was hit by the depression, the use of electrical energy did not decline in the same proportion. Its use in metallurgical processes such as steel making and aluminum refining was expanding. Industry in general was also using more electrically powered machinery and control equipment.

Beginning in the twenties, public demand for domestic electrical equipment such as toasters, irons, radios, washing machines, and refrigerators increased rapidly. From this time and on into the thirties, the increase in the production of domestic appliances was phenomenal, creating a great demand for fractional horsepower motors. But like most other manufacturing industries, the entire electrical machinery and equipment industry experienced a sharp decline in the depression period (despite the increasing production of domestic appliances), followed by a gradual recovery. The failure of the electrical engineering profession to expand during the 1930's is related in part to the effect of the depression upon this industry.

During the war employment in the industry increased sharply. The production of motor generators, fractional horsepower motors, welding equipment, and other products expanded. Also the war stimulated the development of new applications of electronics in such devices as radar and industrial control equipment.

In the postwar period, employment in the industry has been somewhat lower than at the wartime peak, but more than twice as high as in 1939. The long-term prospects for the electrical machinery and equipment manufacturing industries are good. Electric power is being more widely used, and a large expansion is foreseen in consumption and generating capacity; [13] this means not only that more generating and distributing equipment will be purchased by utilities, but also that there will be more consumers and that they will purchase more electrical equipment per capita. There will doubtless be continued research and development of new products, including air-conditioning equipment, radios, television, radar and similar devices, and industrial measuring instruments. Much pioneer research work is going on in the electronics field. In the manufacture of equipment for power generation and distribution, there appears to be a prospect for moderate growth in research and development, and in the need for engineers. The electrical manufacturing companies are still occupied with the backlog of demand for industrial electric equipment. After this demand for products has been satisfied to some degree, activity will tend to level off somewhat. However, employment of electrical engineers should continue at a high level, as most of them are found in activities not directly involved in production but rather in those dealing with research, design, or development, although the trend has been toward the use of more engineers in production.

As would be expected, the major use of engineers in electrical machinery and equipment manufacturing is in research, design of products, and development of research findings into practical uses. Over 40 percent were in this type of work in 1946, one quarter were in administration, management, or similar functions, which range from an executive position in a manufacturing company to chief engineer in charge of maintenance; and only about 6 percent were in jobs more closely related to factory operations such as production engineer supervising the manufacture of a particular product. Nearly 17 percent of the electrical engineers in electrical machinery and equipment manufacturing were in sales positions—a much higher proportion than of the engineers in communications or electric light and power. These sales engineers work closely with the firms purchasing electrical machinery and equipment and with design engineers of their own firms in developing equipment to meet the needs of the users.

Electric Light and Power Industry

In the period since 1900 another industry—electric light and power—has had a very great effect on the growth of electrical engineering. Installed capacity of electric utility generating plants rose from about 2 million kilowatts in 1902 to over 56 million in 1948. A large share of the improvements and technological changes which have taken place during the industry's development was made possible only through the skill and knowledge of electrical engineers.

Following the great boom of the twenties, when capacity and production more than doubled, this industry, like most others, was hit by the depression of the thirties. Output of current declined very little, but generating capacity increased very slowly until the late 1930's. Capacity then increased tremendously during World War II when demand expanded rapidly. During the war, the production of electric current increased at a much faster rate than did capacity, forcing the industry to improve existing operating procedures and devise new ones. After a sharp drop in consumption of energy with the end of the war, output then increased above the wartime peak to a new high of over 282 billion kilowatt-hours in 1948.

Conservative estimates of future power requirements point to a substantial increase in the total electrical energy that must be produced. Several studies made by different industry groups support

[13] U. S. Department of Labor's Bureau of Labor Statistics, *Employment Outlook in Electric Light and Power Occupations*, Bulletin No. 944, Superintendent of Documents, Washington 25, D. C., 1949. Price 30 cents.

this conclusion. Nearly all major users of electrical power will increase their power demands—including industrial and commercial as well as farm and home users. If present trends continue it is likely that within 10 years utility generation of current will reach between 360 and 400 billion kilowatt-hours. Generating capacity consequently will have to be increased in order to meet this demand.[14]

TABLE 3.—*Percentage distribution of electrical engineers, by occupational status in selected industry fields, 1946*

Occupational status	All industries [1]	Machinery (manufacturing)	Communications	Utilities
Total	100.0	100.0	100.0	100.0
Administration and management	31.9	26.1	36.3	43.9
Administration-management, nontechnical.	2.0	2.3	2.2	2.6
Administration-management, technical.	26.4	22.7	32.0	34.6
Construction supervision	3.4	1.1	1.9	6.4
Personnel-labor problems	.1	--------	.2	.3
Consulting	5.7	6.2	3.8	5.8
Consulting, independent	1.4	.9	1.2	.9
Consulting, as employee of private firm	4.3	5.3	2.6	4.9
Design, development, and research	38.3	42.4	41.3	24.7
Design	16.4	21.3	10.2	16.4
Development	11.0	13.3	18.7	2.3
Analysis and testing	2.7	2.8	2.3	3.7
Patents	.5	.3	.6	--------
Research in basic science	.6	.3	.8	.1
Research, applied	6.2	4.0	8.4	1.1
Drafting	.9	.4	.3	1.1
Operations	12.2	6.2	13.2	20.1
Estimating	1.5	.9	1.6	2.9
Inspection	1.2	1.0	1.2	1.2
Installation	1.4	1.2	1.7	.8
Maintenance	3.3	1.0	3.3	4.6
Operation	3.7	.2	4.7	10.2
Production	.9	1.8	.7	--------
Safety engineering	.2	.1	--------	.4
Sales	6.3	16.8	1.5	3.0
Other	5.6	2.3	3.9	2.5
Editing and writing	.8	.5	1.4	.2
Library and information service	(2)	.1	--------	--------
Retired	(2)	--------	.1	--------
Student	.3	.4	.5	.1
Teaching, college and university	2.7	.1	.5	--------
Teaching, other	.3	--------	.4	--------
Occupational status not specified	1.5	1.2	1.0	2.2

[1] See appendix table D-9 for list of industries.
[2] Less than 0.05 percent.

Employment of electrical engineers in utility systems is expected to expand somewhat, but much less than production and capacity. Many of the additional engineers will be needed in the planning and construction of the new facilities and in the expansion of certain engineering activities, such as sales development. Most systems will, however, be able to construct and operate their additional capacity without a proportionate increase in their electrical engineering staffs. The average age of electrical engineers in utilities is high however, and many openings will arise both in engineering and administrative positions in the next decade to replace older men who will die or retire.

Electrical engineers in utilities (both privately and publicly owned) are engaged primarily in administrative, management, and similar positions, such as chief system development engineer or engineer in charge of industrial sales department. (See table 3.) A lesser number are in such jobs as general operating superintendent or test engineer. Nearly one quarter are found in research, design, development, and allied positions. Here, for example, electrical engineers work in an engineering department, designing new substations and new distribution lines or improving techniques of power distribution. Other electrical engineers in utilities are engaged in the service department as customer consultants or in other positions.

Communication Industries

The communication industries today consist of three major subdivisions—telephone, telegraph, and radio. The telegraph industry was the first to develop, reaching its peak rate of expansion of facilities before 1900. It has continued to grow and many improvements have been added, including the multiplex system, which permits the sending of many messages at the same time; the teleprinter; automatic relaying; and finally automatic telegraphy. The telegraph industry is still very important, as it carries a large share of today's communication traffic. Comparatively few electrical engineers are employed in this industry—and those mainly on research and development projects and to some extent in maintenance.

The telephone industry developed rapidly between 1890 and 1900 and has grown greatly since that time. This growth is characterized by many technological improvements, largely developed by the electrical engineering profession. Again in this industry we find that engineers are not used to a great extent in the operation of the system itself. Generally, their major functions are research and development and, to a lesser extent, the

[14] U. S. Department of Labor's Bureau of Labor Statistics, *Employment Outlook in Electric Light and Power Occupations*, Bulletin No. 944, Superintendent of Documents, Washington 25, D. C., 1948. Price 30 cents.

solving of problems concerning expansion of facilities.

The industry will undoubtedly expand in the future, both in growth and improvement of present facilities and in the extension of new lines to new users, including commercial, industrial, farm, and home. The number of telephones operated under the Bell System, for example, increased from about 230,000 in 1890 to well over 16 million in 1940 and to about 32 million in the spring of 1949. It seems likely this increase will continue, although at a slower rate. The introduction of improved facilities, such as the coaxial cable and others, will contribute greatly to the growth of the industry. Research and development work will grow to some extent, though employment of engineers is not expanding as much as in several other industries.

Wireless telegraphy, the forerunner of modern radio, was introduced around 1900. Although experiments were made several years earlier, Marconi first demonstrated practical radio communication in 1896 and then further developed it over the next several years. About this same time, a number of scientists in the United States also began to experiment with and develop radio. In 1920, broadcast transmission service was introduced, and shortly afterward this part of the radio industry began to expand very rapidly. The number of electrical engineers in radio broadcasting more than tripled between 1930 and 1940 and more than doubled from 1940 to 1948. Innovations such as television and frequency modulation were introduced. Engineers were responsible for much of the improvement in radio communication and the industry looks to them for further progress.

Radio broadcasting is now in the midst of a substantial expansion. Many new stations are being added—both AM, FM, and television. While a large part of the development of new equipment is being done by engineers employed in communications laboratories and in the electrical machinery and equipment manufacturing industry, a number of engineers are now engaged in the broadcasting end of the field and some expansion may be expected, particularly in television. In 1948 alone, the number of television sets in use multiplied several times. Many new stations are authorized and equipment is improving rapidly.

A notably high proportion—perhaps 40 percent—of the electrical engineers employed in the communications industry group are engaged in research, design, development, analysis and testing, and similar functions. (See table 3.) In the telephone industry, for example, these positions cover a wide range, from that of an engineer who is developing a new piece of equipment to that of an engineer making a critical study of a telephone plant to obtain cost data. About a third of the electrical engineers in these industries are in administrative or management positions, such as manager or official of a telephone company. Other electrical engineers are employed in work dealing with the regular operations of a company, such as inspection or maintenance.

Considering all three parts of the communications industry, employment of electrical engineers is expected to increase. Though the long-run trend of employment has been upward in the telephone and telegraph industries, the rate of increase has been slowing down, particularly in the telegraph industry. The number of telephones in use is expected to increase considerably in the future, because of trends toward greater per capita use of the service plus the general increase in population. However, this expansion will probably not be accompanied by a proportionate increase in employment of engineers. An increase in the use of engineers is also expected because of the further development of television; that field is small, however, compared to other forms of communication.

Other Industries

The employment of electrical engineers is also expanding to some extent in other industries using electrical and electronic equipment. (See appendix table D–9.) Greater use is being made of engineers in these industries and employers will probably need men, particularly in research and development work. In addition, because of greater emphasis placed on research activities by the Federal Government, additional electrical engineers will be needed in Government agencies. As of July 1947, over 7,000 electrical engineers were employed by the Federal Government. Electrical engineers have been doing much in the various experimental fields such as atomic energy, radar, guided missiles, and others. Work along these lines is expected to continue at an accelerated rate. While many of the engineers engaged in this research are employed by industrial firms which have contracts with Government agencies, the number of research engineers employed in Government is also increasing over the long run.

Summary: Outlook for Electrical Engineers

It seems evident that the total demand for electrical engineers will continue to grow. However, the phenomenal increase during the decade of the twenties of the major industries in which they are used—associated with the simultaneous development of radio broadcasting, doubling of electric power generating capacity, and the rapid growth in the manufacture of industrial electrical equipment and electrical household equipment—may not be repeated in future decades. But a review of the prospects in each major industry suggests a continued expansion in the use of electrical engineers, particularly in electrical machinery and equipment manufacturing and in television. From the more than 55,000 employed in 1940 the profession expanded to between 70,000 and 75,000 in early 1948 (see appendix table D–2) ; the number employed could well increase to around 95,000 by 1960—an average growth of over 1,800 jobs annually. Employment may continue to rise thereafter, but the rate of growth will probably tend to level off.

Geographical Location

Employment of electrical engineers is heavily concentrated in the industrial centers where electrical equipment manufacturing is carried on—over 65 percent are found in the States of New York, Pennsylvania, New Jersey, Ohio, Illinois, Massachusetts, and California. There are also jobs with electric light and power companies, telephone companies, and some radio stations in every State and in cities throughout the country. A detailed tabulation of the geographical distribution is shown in appendix table D–10.

CHEMICAL ENGINEERS

While it is one of the oldest sciences, chemistry has made its greatest gains since it was developed as a systematic science in the nineteenth century. The industrial uses of chemical knowledge have also developed most rapidly in the last few decades.

A leading place in this development has been taken by chemists, and only in relatively recent years has the separate profession of chemical engineer emerged to specialize in the industrial application of chemical knowledge. Chemical engineering is perhaps the youngest of the major fields of engineering. The first college curricula in this branch were set up in the nineties.

Chemical engineers are concerned with the application of chemistry and other basic sciences, and of engineering principles to the design, construction, operation, control, and improvement of equipment for the utilization of chemical processes on an industrial scale. These processes are usually separated into individual operations or processes known as "unit operations." The work of the chemical engineer involves the application of a series of these "unit operations" to the manufacture of a product. Ceramic and petroleum engineers are discussed in this section, although those concerned with the extraction of minerals or petroleum are considered to be in the field of mining engineering.

The typical pattern of the working relationship between the two professions has been that the chemist first makes a discovery or works out a process in the laboratory, and the chemical engineer plans and directs the carrying on of this process on a commercial scale; but the exceptions to this rule are numerous. Today the dividing line between the chemist and chemical engineer is still somewhat hard to determine, and many men trained in either of these fields find employment in the other.

Another important characteristic of chemical engineering is the high technical requirements in the field, illustrated by the relatively large proportion of persons with advanced degrees. (See table 6.)

The chemical engineer may specialize industrially (as for example in petroleum, plastics, rubber, food, or industrial chemicals), by type of operation (as for example in absorption and adsorption, heat transfer, disintegration, or distillation), and functionally (as for example in management, research, design, or operation).

Four out of every five chemical engineers are

852396°—50——3

employed in manufacturing industries. Over a third are found in the chemical and chemical process industries, while about a fifth work in the petroleum and coal products industries. The trends and outlook in these industries tell much of the story of the growth of the profession. Chemical engineers are also found in many other industries, as may be seen in the following tabulation of the distribution in 1946.

Industry field	*Percentage distribution*
Total	100.0
Mining	1.4
Construction	2.0
Manufacturing	82.6
Food and textiles	5.2
Lumber, furniture, and paper	4.0
Printing and publishing	1.3
Chemicals and allied products	34.8
Petroleum and coal products	20.7
Rubber, and stone, clay, and glass	6.3
Iron, steel, and nonferrous metals and their products	3.4
Machinery (including electrical machinery)	2.6
Transportation equipment	1.0
Other manufacturing industries	3.3
Utilities	1.0
Government	5.7
Other industries	7.3

Chemical Industries

The chemical industry, it has been said, dates chemically from Le Blanc's discovery of his soda-ash process in 1791 and industrially from World War I. Through the nineteenth century many discoveries were made, but until the period between 1885 and 1900 the industry as a whole did not begin to crystallize and develop. The industry received its first major impetus as a result of World War I, when the demand for explosives and allied products created a great need for new plants and processes. The synthetic dye industry also was expanded as a result of the stoppage of imports from Europe. Great new industries grew up in the period after the war and others expanded rapidly.

The chemical industry in general declined somewhat less than the durable goods industries during the depression years and recovered more rapidly than most others in the economy. With the advent of World War II, the industry and the profession were expanding. The war itself added impetus to this trend—on a much greater scale than the First World War. Several new products and processes came into use, such as synthetic rubber, new drugs (sulfas, penicillin), new types of plastics, and many others. Research and development expenditures in the chemical industry today are at an all-time high and will probably continue to increase.

Today almost 45 percent of all chemical engineers in the chemical industry are working in design, development, research, and similar functions. (See table 4.) Only about 18 percent are in such jobs as production or operations supervisor or engineer in charge of installation. Fewer than one-third of the chemical engineers are found in administrative or management positions. Other chemical engineers work as consultants or in sales.

TABLE 4.—*Percentage distribution of chemical engineers, by occupational status in selected industry fields, 1946*

Occupational status	All industries [1]	Chemicals and allied products (manufacturing)	Petroleum and coal products (manufacturing)
Total	100.0	100.0	100.0
Administration and management	30.0	29.8	29.0
Administration-management, nontechnical	2.0	2.4	1.6
Administration-management, technical	27.1	26.9	27.0
Construction supervision	.8	.4	.4
Personnel-labor problems	.1	.1	
Consulting	3.3	2.8	2.3
Consulting, independent	1.1	1.2	.7
Consulting as employee of private firm	2.2	1.6	1.6
Manufacturing and production	14.6	17.9	15.9
Estimating	.4	.5	.2
Inspection	.5	.1	1.3
Installation	.2	.5	
Maintenance	.7	.6	.5
Operation	4.2	3.9	8.2
Production	8.2	11.9	5.3
Safety engineering	.4	.4	.4
Design, development, and research	44.4	44.6	49.6
Design	7.7	7.6	14.2
Development	17.4	20.7	15.1
Analysis and testing	3.7	1.6	4.6
Drafting	.4	.5	
Patents	.5	.6	.9
Research in basic science	.9	.8	.2
Research applied	13.8	12.8	14.6
Sales	3.0	3.4	1.1
Other	4.7	1.5	2.1
Editing and writing	.3	.1	.2
Library and information service	.1	.2	.2
Retired	.1	.1	
Student	.9	.6	.2
Teaching, college or university	2.5		
Occupational status not specified	.8	.5	1.5

[1] See appendix table D-9 for list of industries.

Manufacture of Products of Petroleum and Coal

Although coal was first discovered and mined early in the history of the United States it was not until after the middle of the nineteenth century that the manufacture of byproducts from coal was commercially feasible. In 1882, coal-tar distillation was started in this country on a commercial basis by H. W. Jayne in Philadelphia. Today hundreds of byproducts are derived from the several types of coal; they include the gases (fuel and illuminating), ammonia products, light oils (benzene, varnish, naphtha), tar acids (phenols, cresols), heavy tar oils, pitch, refined tar, and coke products.

The production of petroleum in the United States from wells specificially drilled for that purpose began in 1859 with a well at Titusville, Pa., and spread rapidly as oil was discovered in many other States. The first petroleum refinery was also constructed at Titusville in 1861. The primary products of petroleum refineries at first were kerosene and lubricating oil. Even in the early days, however, refiners developed byproducts such as vaseline and special lubricants.

The development of the automobile and other machinery using internal combustion engines brought about great change in the petroleum industry. Gasoline, formerly a waste product, now became the primary product of the whole industry as the demand for it increased enormously. The refiners were faced with many problems, as many of the oil pools then being exploited did not yield a very large percentage of the new fuel. After much research and years of intense development work, the catalytic cracking process (the conversion of heavier oils into lighter ones by distillation under heat and pressure with the help of a catalyst) was developed. Other means of refining petroleum have also been developed in recent years such as hydrogenation and polymerization which have added immensely to the efficiency of the industry.

The products of the petroleum industry invade almost every niche of our economy. In addition to the first two major uses of petroleum (as a source of fuels and lubricants) it began to be used as a source of new chemical byproducts. Among those available today are: Carbon black, used in tires and ink; petroleum ethers; solvents such as special alcohols, and paint thinners; heavy distillates and paraffin; medicinal oils and ointments; waxes, and heavy oils for asphalt shingles, roofing, and pavements. The industry has received great impetus from both World Wars, especially World War II. Its growth has been, on the whole, steadily upward, because of the diffusion in the use of byproducts and the increase in demand for regular petroleum products. Today, the demand is even higher than during the war.

Research and development for new or improved products and processes is at a very high level today. Petroleum refining demands a great deal in the way of engineering service because for either new or enlarged facilities specific units have to be designed and constructed and each one presents a special engineering problem. Faced with the possibility of a dwindling supply of petroleum compared with the growing demands of the economy for fuel and other products, chemical engineers are concerned with such problems as making liquid fuels out of natural gas or coal on a commercial basis. The employment of chemical engineers by this industry should continue to increase.

Nearly half of the chemical engineers in the petroleum and coal products industry are engaged in design, development, and research functions. (See table 4.) About 45 percent are in administrative or management positions and in manufacturing or production jobs. Smaller numbers of chemical engineers may be found in consulting or sales.

Ceramic Engineers

Another field of engineering—ceramic—is very closely allied to chemical engineering.[15] Ceramic engineers (sometimes called "ceramic technologists") are concerned with the mining and processing of clay, silicates, and other nonmetallic minerals and the manufacture of products from these raw materials; also with the construction and design of plant equipment and structures. They may also work in research or sales. Specialization is usually by type of product—for example, structural materials (such as brick, tile, and terra cotta), pottery, glass, enameled metals, abrasives, refractories (fire and heat-resistant materials, such as fire brick), limes and plasters, cements, and many others. More ceramic engineers are employed in the stone, clay, and glass industries than in any other group of industries. Some find employment in automobile and machinery plants and other industries which use ceramic products.

[15] U. S. Department of Labor's Bureau of Labor Statistics, *Economic Status of Ceramic Engineers, 1939 to 1947*, July 1948. Available free in mimeographed form from issuing Office, Washington 25, D. C.

It is estimated that over 3,000 ceramic engineers are employed. Many technological improvements are expected in the ceramic industries in the next few years; additional engineers will be needed to bring about these improvements. Other factors which will tend to increase the number employed are the new uses to which nonmetallic minerals are being put and the trend toward expansion in industries using these materials. An expanding use of glass, enameled metals, abrasives, and other ceramic products will require research and development in connection with the adaptation of products to various uses and thus will contribute to the increasing demand for engineers.

Future Developments

As we have seen, the chemical engineering profession is very young compared to other branches of engineering—half of these engineers had less than 8.8 years of experience in 1946—(see appendix table D–13) and is furthermore concentrated in several dynamic and rapidly growing industries.

Since the industries in which most chemical engineers are found, namely chemicals, petroleum and coal products, and industries closely allied to these, are probably now only at the beginning of great future development, the profession should continue to grow over the long run. Several developments will probably add greatly to the progress and growth of chemical engineering. The entirely new field of atomic fission may open large vistas of research and development. The synthetic fuel research program could eventually create a whole new industry. Not only will the chemical industry itself continue to expand but chemical engineering methods will further penetrate other industries. Nearly every phase of the chemical field—foods, drugs, plastics, paints, oils and soaps, synthetic fibers, and others—will probably be characterized in the future years by discoveries and developments entirely unforeseen at present.

Chemical engineers numbered between 35,000 and 40,000 in early 1948, double the number in 1940. (See appendix table D–1.) To some extent, the rate of growth may be slowing down, although not as much as in other fields of engineering. A very substantial gain in employment of chemical engineers is expected within the next decade or so; perhaps it will reach 55,000 by 1960—an average growth of about 1,500 jobs annually. (There may of course be short-run fluctuations in the employment situation for chemical engineers. In the spring of 1949 there were reports that some large firms were laying off experienced chemical engineers.)

Geographical Location

Chemical engineers to some extent are employed in all States, both in or around large industrial cities. Over three-quarters of all chemical engineers in 1946 were employed in the following 11 States: New York, New Jersey, Pennsylvania, Ohio, Illinois, Texas, California, Massachusetts, Michigan, Delaware, and Indiana. Over 40 percent at that time were found in the first 4 States. Concentration of chemical engineers by industry varies somewhat. In the largest industry, chemicals and allied products manufacturing, over half of all chemical engineers are employed in 5 States: New Jersey, New York, Pennsylvania, Delaware, and Ohio. In petroleum refining, for example, over three-fifths are located in 4 States: Texas, New Jersey, California, and Pennsylvania, while in other products of petroleum and coal about half are found in 3 States: Texas, New Jersey, and Oklahoma. A detailed geographical distribution of chemical engineers is presented in appendix table D–10.

MINING AND METALLURGICAL ENGINEERS

Mining and metallurgical engineering are separate but traditionally related fields. Their relationship arises out of the fact that both types of engineers are engaged in work connected with the mining, refining, and industrial use of metals. Altogether there were about 9,800 mining and metallurgical engineers in the United States in 1940. The mining engineers are believed to have outnumbered the metallurgical engineers. Although these two fields are combined as far as most statistics are concerned, a clearer picture can be given if they are examined separately.

Mining Engineers

Mining engineers are responsible for locating and extracting coal, petroleum, metallic ores, and nonmetallic materials; planning the construction of mine shafts, slopes, and tunnels; devising the means of extracting the minerals, the methods to be used in transporting them to the surface, and in separating them from worthless or relatively unimportant earth, rock, or other minerals. In many cases, they deal with the processing (usually smelting) of the ore to extract the metal. They usually are concerned with the design, construction, and installation of water supply, ventilation equipment, and electric light and power facilities at the mine, and are responsible for mine safety. Petroleum and ceramic engineers who are concerned with the extraction of minerals or petroleum are considered to be in this branch.

Mining is one of the world's oldest industries, but until relatively recently most mining was accomplished by hand methods, using small tools for digging. The industrial revolution, with its demands for metals and coal, provided great impetus for the development and progress of this industry.

At one time, the functions of mining engineers were discharged by mechanics and mine supervisors who did not have formal training. As the industry expanded, the need for a specialized store of knowledge to cope with technical problems was recognized. Courses in mining technology were offered in the few engineering schools then in existence; gradually an entire curriculum was established for the education and training of mining engineers. The American Institute of Mining and Metallurgical Engineers was formed in 1871.

Today, the greatest number of mining engineers are employed in metal mining—most of these in the nonferrous metal mining industry. A sizable number are found in coal mining and crude petroleum and natural gas production. Others are employed in quarrying and nonmetallic mining.

The exhaustion of easily mined deposits and the growing industrial needs for metals place mining engineers at the forefront of a constant battle—devising ways of mining poorer deposits, or those which are more difficult to work, at a competitive cost. They have advanced the technology of locating and extracting ore, removing worthless earth or rock, and of the refining processes. Frequently, new alloys are developed and new uses of metals discovered which create a greatly increased demand for a little-known ore. Experience during the recent war stressed the fact that this country does not have readily accessible deposits of some of the most important metal ores. Thus, the constant search for and development of new mineral deposits and improved ways of exploiting known deposits will continue.

The progress recently made in atomic fission has led to a growing activity in the search for the ores used in this type of work, such as uranium. Even though it is the geologist who is primarily concerned with the location of such ores, the mining engineer is needed for the development of these deposits.

Another group of mining engineers is concerned primarily with the production of crude petroleum and natural gas. This branch has developed more recently than either metal or coal mining. Today several thousand engineers are employed in this field. The petroleum industry, as we have seen from the section on chemical engineers, has been a rapidly expanding industry and one which will probably continue to grow for some time. Although the United States is the leading producer of petroleum, the undeveloped reserves are not unlimited. So far, as in most mining industries, we have been working only the richer and more accessible fields. Petroleum engineers and geologists are today constantly searching for new fields, both in the United States and in other countries. Taking these factors into account, it seems reasonable to expect continued growth in the relatively small field of mining engineering.

Geographical location.—Mining engineers are in most cases employed at the location of mineral deposits. Because of this, unlike other types of engineers whose jobs are located at centers of industry and population, mining engineers often work in out-of-the-way places—in mountains or deserts. The majority are employed in Pennsylvania, Texas, California, New York, Illinois, Ohio, West Virginia, Oklahoma, and Colorado.

Metallurgical Engineers

Metallurgical engineers direct the industrial processing of ores and the treatment and alloying of metals. They may also analyze ore, or design processes which will eliminate worthless or relatively unimportant minerals before the ore goes to the smelter. Metallurgy is usually divided into two main branches—chemical or process metallurgy, and physical metallurgy or metallography. Generally speaking the terms metallurgist and metallurgical engineer are used interchangeably. Some of those working in metallurgy have obtained their basic training in chemical engineering.

Most metals used by early civilizations were either natural or synthetic alloys. The worker simply smelted a certain ore and recovered what he called "copper"; actually it might have contained some tin, zinc, lead, iron, or various other metals. Gradually some rule-of-thumb knowledge was developed as to what type of ore (usually designated by color) would produce a metal for a particular purpose. For many years, metalsmiths and alchemists continued to experiment with various forms of metals and tended to keep their discoveries closely guarded secrets.

Advances were made over these empirical methods when the science of chemistry made great contributions through analysis of ores and metals and development of chemical means of treating ores, and alloying metals. Finally, the science of metallurgy began to emerge as a specialization in the fields of chemistry and physics. The development of microscopic analysis and X-ray examination at last broke through the wall of mystery surrounding the study of metals. That metals are composed of crystals was shown by microscopic study; X-ray analysis then explained how the crystals themselves were constructed, enabling scientists to study the effects of heat or force on various metals.

Metallurgical engineering or metallurgy as a distinct field of study thus began to develop rapidly. The demand for better, cheaper, and lighter metals rose very fast. The development of aluminum and magnesium are illustrative of this trend; one of the early landmarks was the invention of the aluminum reduction process by Charles Martin Hall in 1866, which in modified form is still used today. Magnesium has also been developed over a similar period.

Today metallurgical engineers are to be found in many industries, but mostly in those dealing with metals and metal products. About half are employed in the making of iron and steel and their products, and about 15 percent in the manufacture of nonferrous metals and their products. Metallurgical engineers are also employed in the machinery and transportation equipment industries, and in the mining industry.

Functionally, metallurgical engineers are distributed approximately as follows: Over two-fifths are engaged in administrative or management positions; about one-third are in research, design, or development work; one out of every seven is employed in manufacturing, operation, or production jobs; and others are engaged in sales, teaching, consulting, or other positions. (See table 5.)

TABLE 5.—*Percentage distribution of mining and metallurgical engineers, by occupational status in selected industry fields, 1946*

Occupational status	All industries[1]	Mining	Iron, steel, and nonferrous metals and their products (manufacturing)
Total	100.0	100.0	100.0
Administration-management	42.4	48.1	42.9
Administration-management, nontechnical	2.8	5.2	1.4
Administration-management, technical	38.8	41.4	41.5
Construction supervision	.8	1.5	----------
Consulting	7.1	10.3	5.0
Consulting, independent	3.1	6.6	.8
Consulting, as employee of private firm	4.0	3.7	4.2
Operation and production	15.1	20.8	15.1
Estimating	.5	.8	.6
Inspection	1.3	2.3	.8
Maint nance	.5	.8	.6
Operation	5.7	7.7	6.2
Production	6.3	7.5	6.7
Safety engineering	.8	1.7	.2
Design, development, and research	28.0	15.8	33.6
Design	.8	1.2	.2
Development	5.9	3.9	6.7
Analysis and testing	3.4	2.3	3.2
Drafting	.1	.2	----------
Research in basic science	2.0	1.4	1.4
Research, applied	15.8	6.8	22.1
Sales	2.3	1.5	1.8
Other	5.1	3.5	1.6
Editing and writing	.5	.6	.2
Library and information service	.1	.2	----------
Student	.2	.2	----------
Teaching, college or university	2.6	.6	.4
Teaching, other	.1	----------	----------
Any occupational status not specified	1.6	1.9	1.0

[1] See appendix D-9 for list of industries.

It is generally agreed in the field of metallurgy that we have only scratched the surface of the potential use of metals. There is demand in the industry for metal products which are not only stronger but lighter than those in use today. One disadvantage of the light metals such as aluminum or magnesium is their lack of strength and elasticity. Metallurgists are attempting to overcome this disadvantage by developing methods of alloying and treatment.

Research in "fatigue" of metals is also a rapidly growing field. Another line of development being undertaken by metallurgical engineers is the study of those metals which have a pronounced effect on the properties of other metals even when combined with them in very small quantities. Among these metals are beryllium, tantalum, tungsten, zirconium, and titanium. Some of them have been used for a number of years for specialized jobs.

Developments of World War II contributed greatly to the advancement of metallurgy. More important are the prospects for future discoveries made possible by these developments. Research in the atomic energy field has opened the door to a whole new field of study of metals and their uses. Many metal problems are currently being investigated, such as the development of metals capable of withstanding extreme heat, for use in jet propulsion engines.

The field of metallurgy therefore will probably expand in the future. However, this field is not large and openings are likely to remain few compared to those in other major fields of engineering.

Geographical location.—Metallurgical engineers are located particularly near large metalworking centers of the country such as the Middle Atlantic States, New York, New Jersey, and Pennsylvania, and the East North Central region particularly in Ohio, Illinois, Indiana, and Michigan. However, some metallurgical engineers are employed in the extractive industries and therefore are sometimes found near the mineral deposits.

Trends in Supply of Engineers

Against the foregoing evaluation of the prospective demand for engineers may be set an appraisal of the supply of trained men likely to be available. This section briefly reviews engineering education, first in terms of its development and methods, and then in terms of trends in the numbers of persons being trained. The inflow of men without engineering degrees into the profession is also pointed out. Offsetting these additions to the supply of engineers are certain drains upon this supply: the death and retirement of older members of the profession, and the transfer of engineers to other occupations.

TRENDS IN ENGINEERING EDUCATION

Methods of Training

The engineers of early years were for the most part a self-taught group of practical builders of machinery and instruments; surveyors; and constructors of bridges, roads, and canals. In general, men became engineers by taking some informal education and entering on-the-job training with a person already in the field. Gradually, as science progressed and knowledge of engineering became more complex, the need for formal preparation became more and more evident.

In 1747 in France, Perronnet established what is considered to be one of the first formal engineering schools. As an engineer he was directed to undertake the repair of the economic structure of France under Louis XV. His first act was to establish a school which at first consisted only of several specialized classes for engineers and workmen. During the next quarter century, a system of engineering schools was started in France, which was to become the model of professional engineering education for many years.

In the United States, before the nineteenth century, engineers prepared for their profession by entering a training period with an established engineer or by obtaining employment in a factory or shop. When the United States Military Academy was opened in 1812, courses in science and engineering were offered. The first civilian engineering schools were founded shortly afterward. The number of engineering schools and schools of applied science were few until 1862, when the Morrill Act was passed, granting Federal aid to the States for the founding of colleges of agriculture and mechanic arts. The number of engineering colleges began to increase rapidly, from 17 in 1870 to 85 in 1880 and 110 in 1896. Engineering schools were called upon to furnish technical graduates to aid in the development of the railroads, manufacturing, and electric utilities.

Around the beginning of the twentieth century, the rate of increase in the number of engineering schools slowed down owing in part to the emphasis on agricultural and business education. World War I again added impetus to engineering education. The engineer's contribution to the war effort served to direct attention to the profession. Since that time, many schools have been founded, until today over 170 schools confer engineering degrees and in addition several hundred other schools offer some courses in engineering. That the high quality of American engineering education has been recognized throughout the world is evidenced by the numbers of foreign students who have come to this country for training, as well as by the demand for American engineers in foreign countries.

The rapid growth in engineering schools has been accompanied by a change in educational methods, particularly since 1870. Prior to this time, emphasis was placed on practical knowledge combined with occasional scientific demonstrations of new discoveries and techniques. Traditional engineering education fostered a distrust of theory and placed an emphasis on utilitarian training. Around 1870, leaders in the engineering profession, both in education and in industry, began to realize that preparation for the field was far behind accumulated knowledge. The rise in electrical engineering, followed by chemical engineering, just before the end of the nineteenth century added emphasis to this point. Gradually, a new type of engineering training began to evolve. Laboratories and the laboratory method of investigation became of great importance. Over a long period of evolution, engineering colleges have been left with more freedom to devote their energy to the basic scientific foundations necessary for the progress of the field. The task of practical training and the teaching of individual industry techniques has been assumed in many cases by the industry employing the young graduate engineer.

Today, many industrial concerns have special testing and training programs in operation for recent engineering graduates. For the most part persons in the profession realize that a student has not been completely prepared for a fully professional engineering job merely by finishing an undergraduate course. Also, many companies prefer to teach specific industry techniques in their own manner. A recent report prepared by the Committee on the Economic Status of the Engineer of the Engineers Joint Council [16] indicates that about a third of the industrial concerns surveyed have formal training programs for graduate engineers. A majority of the reporting concerns shift new engineers from one job to another to provide broader training and many either have specific technical education programs or encourage additional outside training. Several large companies and some government agencies have special academic postgraduate training programs operating in conjunction with engineering colleges, where the engineers employed by the firm or agency can earn advanced degrees and at the same time receive practical training with the company. Many graduates find it necessary to obtain subprofessional engineering employment such as drafting or surveying to gain the practical experience necessary for professional advancement or because there are no vacancies among the usual starting positions for new graduates. Moreover, in several large metropolitan centers, employed engineers may take postgraduate courses in late afternoon or evening at neighboring engineering colleges.

Although there is demand in industry for men trained to several different levels of competency of technical work, the emphasis on our educational system has largely been on one level—the 4-year undergraduate curriculum. Whereas many leaders in industry have said that they need several technicians at the semiprofessional level to every graduate engineer, the ratio of the number trained in each field is almost the complete opposite. As a result, many semiprofessional jobs are filled by men who drop out of engineering colleges as well as by men trained in technical institutes, junior colleges, or other institutions specifically designed to prepare students for such positions, and even by some engineering graduates who have a low professional ceiling. At the same time, a need has

[16] National Society of Professional Engineers, *American Engineer,* May 1947, p. 10, Washington, D. C.

been recognized for engineers able to perform at a very high scientific level. University training beyond the bachelor's degree is the accepted method of preparation for the increasing number of such positions.

In the earlier periods, the content of undergraduate curricula, as mentioned above, consisted chiefly of practical subjects and field exercises. Next came the trend toward a more scientific type of training. More recently leaders in the profession have been concerned with the lack of nontechnical and general knowledge on the part of large numbers of engineers. Therefore, there is a trend toward the reemphasis of nonengineering courses in college curricula.[17] These courses are of two types: those which may help in the work of an engineer and aid him in understanding the problems of his company—such as business administration, industrial psychology, economics, statistics, labor relations, and accounting—and those, such as English, political science, and the humanities which are designed to make him a well-rounded person and citizen.

One model undergraduate engineering course suggested by educators consists of four major divisions: mathematics and science, nontechnical and social-humanistic studies, basic engineering, and professional specialization.

The introduction of more nontechnical courses, plus the retention of the full program of technical subjects, has resulted, in the opinion of some engineering educators, in overcrowding of the undergraduate's schedule, with the result that the student is striving to cover 5 or 6 years work in 4. A number of prominent engineering schools have already adopted 5-year courses and still others are contemplating the same step at the present time. Owing to the stress placed on a diversified rather than a specialized curriculum, some educators have suggested that the extra fifth or sixth year be devoted to specialization and that the main undergraduate period be spent in gaining an all-inclusive engineering education.

Along with these specific trends affecting engineering education is one which affects the entire method of training—the recent emphasis on problems of selection. Under the laws setting up land-grant colleges, for example, any person is free to enter engineering training as long as he has the prescribed *minimum* qualifications—usually indicated by the fact that he has been graduated from an accredited high school in the State. Therefore, over a long period of time engineering schools, like other institutions of higher education, have experienced a very high drop-out rate. Some educators have estimated that only about 4 out of every 10 persons entering engineering schools actually receive a degree; many need more than 4 years to graduate. While some may have dropped out because they were financially unable to continue, a great many did so because their aptitudes, abilities, or interests were better adapted to some other field. In addition, a number of engineering graduates, even in periods of high business activity, fail to obtain engineering jobs. The practice of industry—particularly firms having large engineering staffs—has long been to "skim the cream" from the top of each graduating class; how far down into the "milk" they have dipped has depended on economic conditions and the relation of the size of each graduating class to industry's current needs for engineers.

As a result of these factors, a large proportion of those who began engineering training never entered the profession. Because of this experience, leaders in the profession have given much thought to developing means for the proper selection of engineering freshmen, including aptitude testing and personality evaluation techniques.

Engineering education is not static—it is constantly changing and improving. Progressive schools are leading the way, with new and more efficient means of teaching and research. The American Society for Engineering Education, (originally the Society for the Promotion of Engineering Education) has been very active in promoting better education and preparation for the profession. Standards of entrance qualifications have been raised, and a better integration of education and training with practical knowledge demanded by employers has come about.

Gradually the educational level of the entire profession has been rising. A major proportion now have a college education, and many have advanced degrees as well. In 1946, for example, over 80 percent of all engineers reporting to the Bureau's survey of the profession were engineering college

[17] *Engineering Education After the War*, Journal of Engineering Education, May 1944; *Aims and Scope of Engineering Curricula*, Journal of Engineering Education, March 1940.

graduates, compared to about 75 percent reporting to a similar survey 12 years earlier. In 1934, only 6 percent had a master's or doctor's degree compared to nearly 15 percent in 1946. In addition, the educational level of engineers varies by field of engineering as may be seen in table 6. The trend toward postgraduate training will probably be accelerated in the next few years when (as suggested in a later section of this report) many engineering graduates will be unable to get engineering jobs.

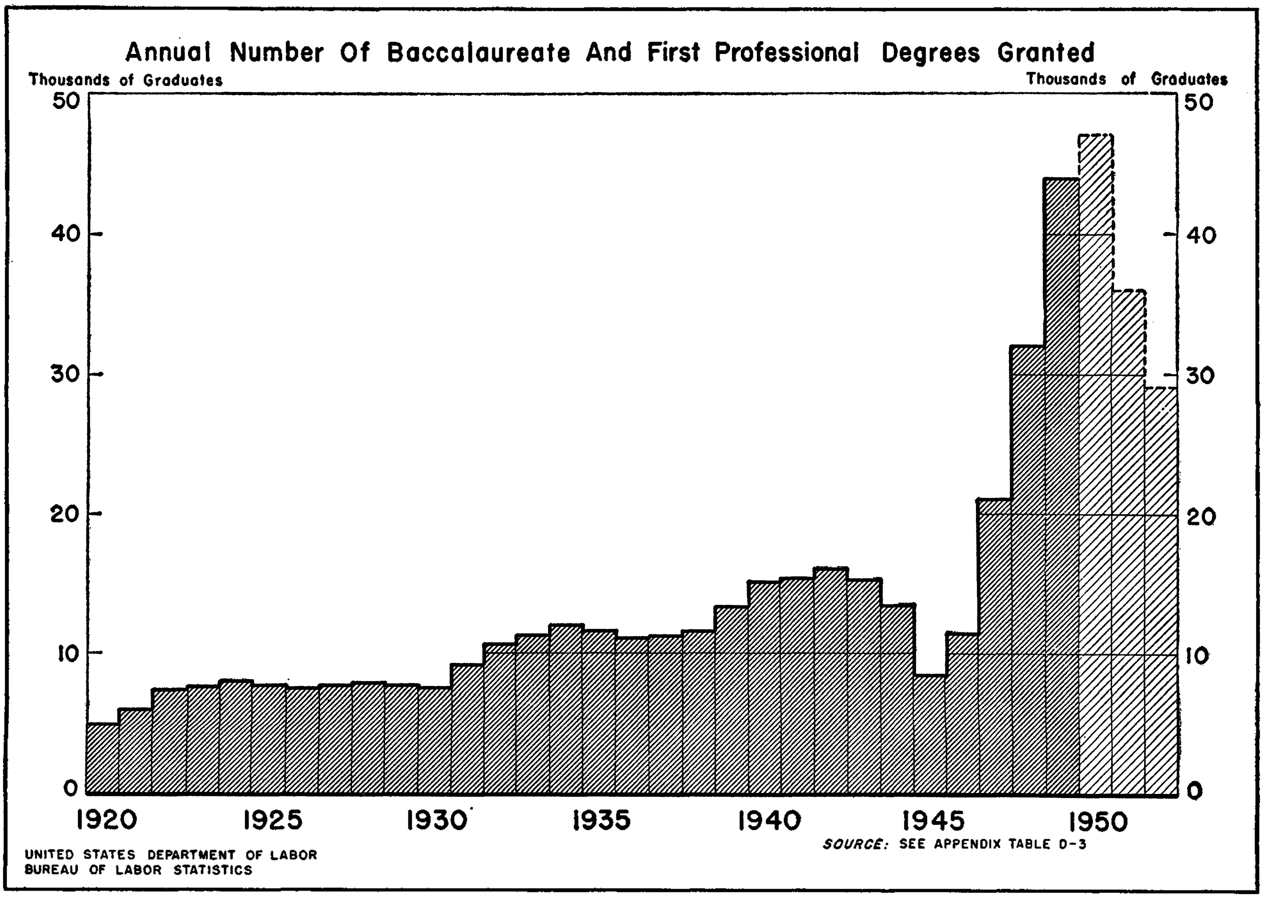
The educational level of engineers also differs by occupational status. For some positions, such as research or teaching, the proportion of engineers with advanced degrees (master's or doctor's) is much higher than in other positions. On the other hand, in administrative, management, or supervisory jobs the level of education does not appear to be a requisite for success. In these positions,

TABLE 6.—*Percentage distribution of engineers by educational level for each field of engineering employment, 1946*

Field of engineering employment	Total	Doctor	Master	Bachelor	Incomplete college	No college
Chemical	100.0	5.7	18.5	69.1	5.8	0.9
Civil	100.0	1.2	9.8	65.8	19.4	3.8
Electrical	100.0	2.1	11.8	68.7	13.9	3.5
Mechanical	100.0	1.8	10.9	67.9	15.9	3.5
Mining and metallurgical	100.0	5.2	17.9	62.4	12.2	2.3
Other	100.0	2.3	11.2	60.7	21.0	4.8

other factors such as leadership or organizing ability probably have more importance. A large number of engineers who presently occupy such positions entered many years ago when formal engineering training was not considered as essential as it is today. It is expected that in the future a greater proportion of these jobs will be filled by men who possess at least a bachelor's degree in engineering. Many junior executives and graduate

Chart 8.—Number of Engineering Graduates, 1920–52



engineers in industry are taking postgraduate training in industrial engineering.

Despite the growth of engineering colleges and their acceptance as the standard method of training engineers, some men have been able to enter the profession without having completed their formal training, and some even without any engineering college training at all. Some of the latter have had technical institute training, or college training in related sciences, such as chemistry, physics, or mathematics. Others have had no education beyond secondary school, and have picked up their engineering knowledge by self-study and on the job. Some of the leading engineers entered in this way in past years. Nevertheless, the proportion entering the profession without completing engineering college training has been growing smaller. The difficulty of entering in this way has also become greater.

It is important for prospective engineering students to select a properly accredited school of engineering since persons trained at such schools generally have the best employment opportunities. Lists of accredited curricula are presented in the annual reports of the Engineers' Council for Professional Development dated September of each year. Reprints of the accredited lists as well as the complete reports are available from that organization which is located at 25–33 West 39th Street, New York 18, N. Y.

Numbers in Training

The growth of the engineering profession has been made possible by a steady expansion in the numbers of students trained by the engineering schools. In addition to supplying the engineers needed in American industry the engineering schools of the United States have to a small extent provided engineers for many foreign countries. The number graduated increased from about 5,000 a year in 1920 to about 44,000 in the academic year ending June 1949. However, graduations did not rise continuously each year during this period, as may be seen in chart 8.

Because of the number of years required to train an engineer, the supply of graduates is not readily adjusted to the current demand. For example, owing to the high enrollments toward the end of the 1920–29 decade, annual graduations reached new peaks during the early depression years, when many experienced engineers were unemployed. Graduations dropped slightly for 2 or 3 years thereafter, and then resumed the upward trend, reaching a new high of over 15,000 with the advent of World War II. The trend in enrollments in engineering schools has in general moved along the same lines as graduations. (See tables 7 and 8.)

World War II created an enormous demand for engineers both in war production industries and in the military forces. Leaders in the war effort, edu-

TABLE 7.—*Undergraduate enrollment in engineering schools [1] in the United States, by field of engineering, 1931–49*

Academic year ending June	Civil [2]	Electrical	Mechanical [3]	Chemical [4]	Mining and metallurgical	Other [5]	Total, United States and Canada	Total, Canada only	Total, United States only
1931	13,813	18,565	15,053	10,673	2,771	12,531	[7] 73,386	(7)	73,386
1932	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
1933	13,531	14,525	14,995	9,293	2,237	8,538	[7] 63,119	(7)	63,119
1934	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
1935	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
1936	9,683	11,117	16,157	9,919	2,452	14,809	[7] 64,137	(7)	64,137
1937	9,459	10,678	16,073	10,727	2,374	18,204	[7] 67,515	(7)	67,515
1938	11,194	13,424	22,249	13,108	3,307	21,265	[7] 84,547	(7)	84,547
1939	12,374	13,135	23,926	12,924	3,536	18,206	84,101	1,417	82,683
1940	12,956	15,680	30,228	15,923	4,525	26,590	105,902	3,013	102,889
1941	13,135	15,505	34,774	16,907	4,570	25,727	110,618	1,707	108,911
1942	12,724	14,426	35,833	19,466	3,985	24,152	110,586	2,495	108,091
1943	13,598	14,671	37,368	19,130	3,990	21,785	[7] 110,542	(7)	110,542
1944	5,468	7,599	15,143	8,752	1,244	11,181	49,387	4,032	45,355
1945	4,336	5,934	9,570	5,648	696	12,284	38,468	3,577	34,892
1946	8,422	11,094	18,007	8,216	1,282	22,126	69,147	6,083	63,064
1947	34,505	36,129	55,094	24,289	4,584	44,255	[7] 198,856	(7)	198,856
1948	37,763	52,292	70,285	29,250	5,836	[8] 42,490	237,916	7,736	230,180
1949	40,676	49,907	66,650	26,771	5,541	[8] 43,690	234,190	8,073	226,117

[1] Includes only those schools reporting in issues of the Journal of Engineering Education. Each field includes Canadian students except where indicated.
[2] Includes agricultural, architectural, and sanitary.
[3] Includes aeronautical, industrial, and naval architectural and marine.
[4] Includes ceramic and petroleum.
[5] Includes general, other, and unclassified.
[6] Not available.
[7] Each field for this year includes United States students only.
[8] Includes enrollments in extension centers.

Source: Journal of Engineering Education, issues from April 1933 to February 1949.

cators, and engineers themselves endorsed emergency measures for increasing the supply of engineering personnel. Plans were drawn for financial aid for students, improved selection of engineering freshmen to alleviate the drop-out rate, and for the recruitment of high school graduates for training. The Engineering, Science and Management War Training Program[18] offered refresher courses to help engineers, including those who had left the profession, to prepare for work in connection with war production.

In response to such appeals, engineering enrollment rose rapidly. In the academic year 1942–43, the number of freshmen reached a new high of over 45,000 and total enrollment was more than 110,000 in accredited schools only. Annual graduations also continued their upward trend, reaching a peak of about 16,000 in the academic year 1941–42. Engineering enrollments dropped during the later war years. From 1942 to 1945, the number of graduates decreased, owing to the change in Selective Service policy, which discontinued deferments for some college students; in 1945 a low of around 8,500 was reached—a smaller number of graduates than in any year since 1937. Nevertheless, engineering graduations for the first 5 years of the present decade totaled more than in any previous 5-year period—nearly 85,000 between 1940 and 1945 compared with the previous high of slightly over 70,000 between 1934 and 1939.

Thus engineering education as a whole fared much better during the war than most nontechnical fields. Enrollments in education, commerce, law, agriculture, and architecture were affected quickly by the withdrawal of students because of the draft. Only such fields as medicine and dentistry were able to maintain the prewar level of graduations over the entire war period.

In the first postwar year, engineering education began to resume its prewar trend in growth. Data from the Journal of Engineering Education (the official publication of the American Society for Engineering Education) show that, for those schools reporting, enrollment was about twice as high in the academic year 1946–47 as in any prewar year. Former students who had been drafted during the war years, veterans who became interested in the field, and high school graduates impressed by the wartime drive for trained engineers flocked into engineering schools. In the academic year ending June 1948 engineering enrollments again increased. Estimates of the number of undergraduate students in all engineering schools showed an all-time high of nearly 250,000 in colleges and universities and around 75,000 in junior colleges, or about 14 percent of total college enrollment.[19] Enrollments were only slightly lower in the academic year ending June 1949. Engineering graduations also increased from the low of the later war years, numbering about 11,500 in 1946, over 20,000 in 1947, about 32,000 in the year ending June 1948, and nearly 44,000 in 1949. Considering engineering college enrollments in the academic year 1948–49, and assuming that drop-out rates will be as high as the prewar experience, future engineering graduations may be estimated at 47,000 in 1950, 36,000 in 1951, and nearly 29,000 in 1952. (See appendix table D–2.) These estimates may be nominal if drop-out rates should be lower than prewar—and there is some scattered evidence to this effect—and if any substantial number of junior college students enter engineering schools.

A study of engineering enrollment by field shows some shifting in interest among fields during the war years; these shifts have in general followed the developments occurring within the various fields. (See table 7.) Enrollments in mechanical, chemical, and mining and metallurgical engineering rose to peak levels during the first war years. On the other hand, though they increased from prewar levels, enrollments in both civil and electrical engineering failed to reach the high levels of the early thirties.

After decreasing in the later war years, enrollment in all fields of engineering rose to new peaks in the postwar period, though some expanded more than others. Civil, electrical, and mechanical engineering show the greatest increase from the wartime highs—the first two fields more than tripled from 1943 to 1948, while mechanical nearly doubled. Though both chemical, and mining and metallurgical did reach record levels in 1948, they did not increase as much as the other three fields of engineering.

[18] Federal Security Agency, U. S. Office of Education, Bulletin 1946, No. 9, *Engineering, Science, and Management War Training—Final Report*, Superintendent of Documents, Washington 25, D. C., 1946. Price 35 cents.

[19] M. M. Boring, *Report of the Committee on Manpower*, Journal of Engineering Education, October 1947, p. 110.

Graduations by field of engineering have in general been moving along the same lines as have enrollments by field. Table 8 shows the estimated number of graduations by major field between 1940 and 1949.

TABLE 8.—*Estimated number of engineering degrees awarded, by field of engineering, 1939–40 to 1948–49* [1]

Academic year	Total	Civil	Electrical	Mechanical (includes industrial)	Other (includes chemical, mining, metallurgical and other)
1939–40	15,100	2,420	2,880	4,770	5,030
1940–41	15,200	2,050	2,860	5,320	4,970
1941–42	16,000	2,160	2,830	5,920	5,090
1942–43	15,300	2,080	2,500	5,920	4,800
1943–44	13,500	1,930	2,470	4,960	4,140
1944–45	8,500	1,260	1,540	3,010	2,690
1945–46	11,500	2,400	2,110	3,910	3,080
1946–47	21,000	3,250	3,990	8,590	5,170
1947–48	32,000	4,410	6,720	10,780	10,090
1948–49	44,000	6,350	11,200	14,350	12,100
Total	192,100	28,310	39,100	68,530	57,160

[1] See tabulation below for estimates of engineering graduates by field for 1950.

Source: Journal of Engineering Education, issues from December 1941 to February 1949. Data adjusted by Bureau of Labor Statistics to include graduates of all engineering schools.

Future graduations by field of engineering are almost impossible to estimate because many students do not choose a specialty before their third year. Examination of enrollment data by class and by field for the academic year 1948–49 makes it possible to estimate graduations for at least the next year, as shown in the following tabulation. (Prewar drop-out rates were used in these estimates.)[20]

Field	*Academic year 1949–50*
Total	47,000
Civil	7,700
Electrical	12,500
Mechanical	16,000
Chemical	5,200
Mining and metallurgical	1,500
Other	4,100

The peak enrollments of the postwar years are of course temporary, since they represent in large part both those who would normally have attended school during the war and the college attendance of veterans who would not have been able to finance a college education without the aid of benefits under the Servicemen's Readjustment Act of 1944 and subsequent legislation. That the peak is already past is evidenced by the drops in the freshman classes of the academic years 1947–48 and 1948–49. Engineering enrollments for the year 1948–49 as reported in the February 1949 issue of the Journal of Engineering Education show the following percentages of veterans by class: Seniors, 82.5 percent; juniors, 78 percent; sophomores, 58.2 percent; and freshmen, 36.6 percent; indicating that the high veteran enrollments are passing and that from now on classes will be composed almost entirely of regular high school graduates.

Furthermore, freshman engineering enrollments may well continue to decrease for a number of years if the trend follows that of total freshman enrollments in college. The Bureau of the Census estimates that the number of persons 17 years of age will decrease until 1951 and then slowly increase up to 1964 on the basis of recent births.[21] Starting with these estimates, the Bureau of the Census has estimated senior year enrollments in secondary schools.[22] On the basis of past trends in the proportion of high school seniors who were graduated—rising toward 95 percent in recent years [23]—estimates of the future number of high school graduates may be made. During the late thirties, the proportion of high school graduates who entered college ranged around 35 percent.[24] Many persons feel that this ratio will rise in the future.[25] It may be assumed that, unless there should be a serious depression, at least 35 percent of all high school graduates in the 1950's would enter college. While the initial effect of a depression would be a reduction in nonveteran enrollments, after a few years such enrollments might increase again (as happened in the early thirties);

[20] Armsby, Henry H., *A Reexamination of the Compton Report in the Light of Enrollment in Engineering Curricula, Fall of 1946,* Journal of Engineering Education, May 1947, pp. 681 and 682. Prewar survival rates were estimated as follows: Freshmen, 53.8 percent; sophomores, 64.7 percent; juniors, 71.8 percent; and seniors, 83 percent.

[21] The estimates up to 1955 were published in *Forecasts of Population and School Enrollment in the United States: 1948 to 1960,* Series P–25, No. 18, Feb. 14, 1949. U. S. Department of Commerce, Bureau of the Census, Washington 25, D. C.

[22] Ibid, table 5, p. 16.

[23] Federal Security Agency, Office of Education, *Statistical Summary of Education, 1943–44,* table 27, p. 31. Washington 25, D. C., 1947. Price 15 cents.

[24] Ibid, table 26, p. 31.

[25] President's Commission on Higher Education, *Higher Education for American Democracy,* Vol. I, Washington 25, D. C., 1947, Superintendent of Documents. Price 40 cents.

moreover any initial decrease in nonveteran enrollments would tend to be offset by an increase in veteran enrollments. Under the above assumptions, college freshman enrollments will probably decrease until the academic year 1952–53 and then increase slowly through the decade and for several more years reaching its present levels after 1960.

Will the general increase in college enrollments be paralleled by an increase in enrollments in engineering schools? This depends on the trends in occupational interests of students, and on the policies of engineering schools with respect to the selection and admission of students. The policies of schools are now under study in the American Society for Engineering Education. Individual engineering educators have also been studying enrollment trends, attempting to determine future levels.[26] The interest of students may change, and they may be influenced in such change by the economic situation and by proper vocational guidance.

Based on past trends, however, it may be said that the interest in engineering as a career is growing rather than diminishing. The ratio of engineering enrollment to total college enrollment rose very slowly from the early thirties—from about 6 percent in 1934 to about 7 percent in 1940. During the war, owing to the comparatively rapid increase in importance of the engineering field and the drafting of college students from other fields, the ratio increased to about 13 percent in 1944. The ratio in 1948–49 (about 10 percent), though lower than the war peak, was still somewhat above the average which prevailed during the prewar decade, owing to the intense interest in engineering. The proportion of college *freshmen* who were in engineering was slightly lower than this—about 9 percent.

If the interest in engineering continues to increase as it has in the past, it is likely that the ratio of students who wish to enroll in engineering to the total number of college students will remain above the average prewar ratio. If it should be 8 percent, for example, freshman enrollment in engineering schools would decrease from the peak in 1946–47 of about 93,000 to a low of around 33,600 in 1952–53. Thereafter, freshman enrollment would increase through the decade, reaching over 45,000 in 1960 and even more in the next few years. It should be emphasized that these estimates are probably minimal because the assumptions on which they are based do not allow for such possibilities as rising survival rates in high schools and increasing percentages of high school graduates who enter college.

It is also possible to estimate roughly the number of engineering degrees awarded from freshman engineering enrollments. Using prewar survival rates of freshman engineering classes to graduation, it may be estimated that the number of degrees awarded would decrease from the high of 47,000 in the year ending June 1950 to slightly over 18,000 in the year ending June 1956. Graduations would then increase over the remainder of the decade and past 1960, reaching about 25,000 around 1964. The increase in high-school graduations expected after 1960 would result in a further increase in engineering graduations through the decade up to 1970. Again it should be emphasized that these estimates could well increase over the levels assumed; there is evidence of a rising trend in college attendance and interest in engineering as a career. Also, owing to better selection of students, survival rates of engineering students could be raised.

Several other developments could also tend to increase college enrollment in general and therefore engineering enrollment. The President's Commission on Higher Education [27] estimated, on the basis of anticipated population growth and the trend for an increasing proportion of young people to go to college, that total college enrollment would rise from about 2,400,000 in the academic year ending in June 1949 to 2,900,000 in 1960. Furthermore, the Commission felt that these numbers could very well be increased by removing economic and other barriers which prevent a number of qualified persons from attending an institution of higher learning. The Commission suggested a goal of 4,600,000 enrollees in institutions of higher education in 1960.

[26] Hollister, S. C., *Postwar Engineering Enrollment Rapidly Adjusting to Near Pre-War Level*, Journal of Engineering Education, March 1949, pp. 355–359.

[27] President's Commission on Higher Education, *Higher Education for American Democracy*, Vol. I, Superintendent of Documents, Washington 25, D. C., 1947. Price 40 cents.

ENTRANCE OF NONGRADUATES

Not all engineers are college or university graduates, although there is a trend toward requiring at least a bachelor's degree. As pointed out above, some men who had not completed engineering school have always been able to enter the field. For example, during the decade 1920 to 1930 about 75,000 engineers received degrees (see appendix table D-3) and during the same period the profession grew by about 85,000 (see appendix table D-4). If we consider, in addition, the number needed for the replacement of older engineers who died or retired (estimated at about 25,000—see p. 42), it appears that no fewer than 35,000 persons without an engineering degree must have entered during the twenties. This makes no allowance for engineers or engineering graduates who may have left the profession for other occupations; if such allowance were made, the estimates of the number of nongraduates who entered would be correspondingly greater than 35,000.

Even during the depression decade of the thirties, when many engineers lost their jobs and had to seek other employment, and when many graduates were unable to find engineering jobs, a large number of nongraduates came into the field. It may be shown that in the age groups up to 35 at least 50,000 men (including graduates who may not have held an engineering job) left the profession for other fields of work during the decade. Yet in the age group 35 to 60 there was an excess of 26,000 entrants (probably mostly nongraduates) over the number leaving. (See appendix table B-1.)

The utilization by industry of sources of supply other than the graduates of engineering schools is reflected also in the fact that the 1940 Census showed that almost two out of every five employed engineers had completed less than 4 years of college. In this tabulation the Bureau of the Census did not classify as an engineer any person under 35 years of age who reported having had less than 4 years of college. It was estimated that as many as 12,000 persons were excluded from the engineering classification by this procedure.[28]

Men who were not engineering graduates continued to enter the field during the war. The demand for additional engineers at the initial stage of the defense program could be met by the mobilization of a great part of the 23,000 or more reserves available in 1940 (7,000 men employed in other occupations who reported to the Census that their usual occupation was engineering, and 16,000 engineers who were unemployed). Soon, with the further increase in industrial activity and the entrance into the armed forces of many engineers, (at least 60,000 were in the service according to data made available by the armed forces) leaders in the profession, in industry, and in government began to realize the necessity for additional engineers. Steps were taken to secure the services of men who had dropped out of school before completing the engineering course, persons holding degrees in related fields, and experienced semiprofessional technical personnel who could be upgraded with intensive training. Many were prepared for some phase of engineering work in connection with war production by the Engineering, Science and Management War Training Program (ESMWT) mentioned above, which gave instruction at college level, but by shorter and more intensive courses.

The remarkable achievements of the profession, industry, and the schools in meeting the wartime shortage of engineers contributed greatly to the unprecedented production of munitions and to technical improvements at a time when a number equal to nearly a fourth of the engineers available in 1940 were serving in the armed forces. As one writer pointed out, "Industry, hard pressed for more technically trained men than the colleges can supply, has doubtless solved its problem in part at least by the employment of men with less than 4 years of collegiate training. These men may consider themselves engineers by profession, and by basic definition and in the minds of the public they are perfectly justified in doing so."[29]

Thus, many thousands of men with less than 4 years of college entered the profession through intensive training on college level as well as through upgrading to positions in which they

[28] *Comparative Occupation Statistics for the United States, 1870 to 1940*, p. 24, U. S. Department of Commerce, Bureau of the Census, Washington 25, D. C., 1943.

[29] L. M. Grain, *Engineering—a Profession*, in Journal of Engineering Education, October 1944, p. 117.

gained professional experience. Information gathered from employers in 1946 indicates that considerable numbers of men holding engineering jobs were upgraded during the war from semiprofessional positions. Also, for appointments to some Federal Government positions, completion of ESMWT courses was accepted for at least partial satisfaction of the requirements.

No data are available by which the number of nongraduates who entered since 1940 can be accurately estimated. Conditions prevailing during the war may be compared to those during the 1920–30 decade when, as pointed out above, the rapidly increasing demand was greater than could be taken care of by engineering college graduations, and at least 35,000 nongraduates entered the profession. There was certainly more opportunity for nongraduates to enter during the war than in the depression decade of the thirties, when at least 26,000 nongraduates entered. In the absence of exact data, it seems reasonable to assume that as many persons without engineering degrees entered the profession between 1940 and 1948 as did between 1920 and 1930 under less pressing peacetime circumstances.

As mentioned above, the ratio of nongraduate engineers to the total in the profession is steadily decreasing. It is likely, then, that a smaller number will enter in the future, especially when engineering graduations are high in relation to the demand. In addition, if the level of business activity should decline or even remain stable for some time, the prospects for employment of nongraduates will not be promising. It will still be possible, however, though increasingly difficult, for the able man who has not completed formal training to advance to an engineering position.

LOSSES TO THE PROFESSION

In engineering as in other fields of work, many employment openings in the engineering profession result from vacancies arising from death, retirement, or transfer of engineers to other occupations. In the past, because of the rapid growth of the profession more openings have been provided by an increase in jobs than by replacements. This will not necessarily be true in the future.

Death and Retirement

In order to aid in estimating losses to various occupations the United States Department of Labor's Bureau of Labor Statistics has developed a set of tables of working life expectancy [30] reflecting the death and retirement experience of workers in the United States. These tables show the average working life expectancy for persons of a given age, and make it possible to estimate the average annual losses arising from both death and retirement in any occupation in which the age composition of the members is known.

Because of the growth of the engineering profession, losses owing to death and retirement have been increasing steadily. They amounted to about 25,000 in the decade 1920 to 1930 and more than 40,000 in the decade 1930 to 1940, according to estimates based on the tables of working life expectancy. This means that during the twenties an average of about 2,500 persons were needed annually to replace those dying or retiring, and during the thirties about 4,000 were needed each year.

In the present decade, replacement needs have continued to rise. By applying the separation rates from the tables described above, it may be estimated that the number needed for replacement has risen from about 5,000 a year in 1940 to around 6,000 or 7,000 a year at the present time. Thus, between 1940 and early 1948, some 43,000 engineers were lost to the profession (appendix table D–2). Over the entire 1940 to 1950 decade, losses to the engineering profession arising solely from death and retirement will number between 55,000 and 60,000.

It is expected these losses will continue to increase. In the first several years of the next decade, it is likely that these losses will run between 7,000 and 8,000 per year, and they will increase to almost 9,000 a year around 1960. Over the decade 1950 to 1960 these losses to the profession will probably total about 80,000.

When the losses in each individual field of engineering are estimated on the basis of the labor force life tables, striking differences are noted in the impact of death and retirement. These dif-

[30] A report including these tables will be released in the near future.

ferences result from the age composition in each field; for example, 2.7 percent of all civil engineers are estimated to die or retire annually at the present time as compared to 1.8 percent of electrical engineers, 2 percent of mechanical, and only 1.1 percent of all other engineers (chemical, mining, and metallurgical). In terms of actual numbers, annual losses are estimated as follows: Civil, 2,400; mechanical (including industrial), 2,600; electrical, 1,400; all other engineers (includes chemical, mining, and metallurgical), 600. By the end of the 1950 to 1960 decade these annual losses may rise to the following levels: Civil, 2,900; mechanical, 3,300; electrical, 1,900; all other engineers, 800. Since the losses occur almost entirely among the older groups, the estimates for the end of the next decade are primarily related to the number of engineers who entered prior to 1940, and they are not significantly affected by differing assumptions which may be made as to the future growth of the profession or the numbers of new graduates who may enter.

Transfers Out of the Profession

A second replacement factor which must be taken into consideration is the transfer of engineers to other occupations—both those engineering graduates who do not enter the field after graduation and those engineers who enter other occupations after once having started their engineering career. There is always a certain amount of movement of individuals among occupational fields and any evaluation of the number of engineers who have to be trained must make some allowance for this normal amount of movement out of the profession.

Transfers are affected by many varied factors, including general business conditions within a particular period, the balance between the supply and demand in the profession itself, and the level of compensation of engineers, particularly as compared to other occupations. Information on the employment experience of engineers during the 1930 to 1940 decade indicates that established persons, as well as inexperienced graduates, transfer to other occupations. The advancement of engineers to administrative positions, which is frequent, probably should not be considered to constitute a loss to the engineering profession. (See appendix A.)

Losses among new graduates may be high. However, analysis of past conditions indicates that some men attend engineering school with no idea of entering the profession. It is widely recognized that an engineering background is of great value in many occupations. Many graduates have entered other types of positions in the business world, and have thus successfully utilized their training without ever having been employed as engineers.

Annual losses arising from transfers from the occupation are much more difficult to estimate that losses arising from death and retirement, and little statistical information is available with regard to them.

Data from the 1946 Survey of the Engineering Profession provide some indication of the approximate magnitude of replacement needs arising from movements out of the profession. These data indicate that about 3 percent of the men reporting engineering employment in 1939 had transferred to nonengineering work by 1946, or something like one-half of 1 percent a year. (See section on occupational mobility of engineers, p. 69.) Applying this percentage to those actually in the field as reported by the 1940 census, an estimate of 8,000 transfers of engineers out of the profession is obtained. This is probably a minimal estimate, since many engineers who left the profession between 1940 and 1946 were not on the mailing list for the survey, or, if they received questionnaires, may have been less prone to fill them out and return them than were those who maintained an active interest in their profession. Allowing for this, the number of those transferring out in this period may therefore be estimated as at least 9,000.

Data from the 1946 survey also indicate that approximately 3½ percent of those graduating between 1939 and 1946 were engaged in nonengineering work in 1946. Applied to the total number of graduates from 1940 to 1946, this rate of one-half of 1 percent a year would indicate that close to 4,000 engineering graduates were lost to the profession in this period. The same survey bias described above also applied to this case, perhaps even to a greater degree. The number of graduates lost to the profession in the 7-year period is probably closer to 6,000. Several follow-up surveys of engineering graduates have provided measures of the number leaving the profession. An

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employment survey of Stanford University engineering graduates of the school year 1947–48 [31] reveals that 6.7 percent of all graduates were in nonengineering work as of December 1948. A study of the employment histories of engineering graduates of the University of California of the years 1920 to 1942 [32] shows that about 3½ percent of all positions held by the graduates during the first 5 years of employment were in nonengineering work. Still another study of engineering graduates of the class of 1947 made by New York University, although showing no tabulations, reveals that a number of graduates do not enter the field even in times of good employment opportunities. From these and similar studies and from other information, it may be reasonable to assume that during "normal" times a number of engineering graduates (perhaps as many as 5 percent) do not enter the profession. Taking into consideration the losses of both experienced engineers and new graduates, one may conclude that between 1940 and 1946 at least 15,000 engineers (or about 1 percent per year) transferred out of the profession. In this war period engineers were in great demand; in time of peace the proportion transferring out might well be larger.

The total loss to the profession from transfers during the present decade, then, at the rate of one-half of 1 percent per year for older engineers and 5 percent per year for new graduates will probably be in the neighborhood of 30,000. In the next decade from 1950 to 1960, assuming continued high employment levels, the minimum losses arising from persons transferring out of the field should rise somewhat owing to the larger engineering labor force expected. At least 4,000 engineers per year, or 40,000 in the decade, may either leave the occupation or never enter after graduation. This compares with a loss of at least 50,000 engineers under the age of 35 during the depression decade of the thirties—mostly graduates who could not find engineering employment. (See appendix table B–1.) Losses from each major field of engineering are even more difficult to estimate. In view of the lack of data, it may be helpful, for illustrative purposes, to assume that the losses are distributed according to the number in each field.

These figures should serve merely as a possible bench mark. We have seen above that this transfer-out loss is dependent upon several factors which are extremely variable. Possible overcrowding in the engineering profession or poor general business conditions could easily force many additional people to leave the field.

Summary

Rough estimates of present and possible future losses to the profession, arising from all factors including death, retirement, and transfers to other occupations, may be made, but they are subject to a considerable error. First, from the age composition of the profession it is possible to estimate with a fair degree of accuracy the annual losses arising from death and retirement. At the present time this loss is about 6,000 or 7,000 per year, or nearly 2 percent of the employment in the profession, and by the end of the next decade, it may rise to around 9,000 per year. Next, it has been suggested that at the present time losses from transfers to other occupations are occuring at the rate of about one-half of 1 percent of the number in the field each year plus 5 percent of the new graduates or a little more than 3,000 per year. In the 1950 to 1960 decade this number could rise to at least 4,000 per year.

Losses from all factors are therefore around 9,000 or 10,000 a year at the present time, or about 3 percent of the membership of the profession.[33] Total annual replacement needs occurring at the present time may be roughly distributed as follows: Civil, 2,900; mechanical, 3,500; electrical, 1,900; all other engineers (includes chemical, mining and metallurgical), 1,000. These needs could rise during the next decade until, by 1960, losses to the profession from all factors could amount to at least 13,000 a year, distributed approximately as follows: Civil, 3,900; mechanical, 5,000; electrical, 2,900; all other engineers, 1,400. Again, it must be emphasized that

[31] Stanford University, *An Employment Survey of Stanford University Engineering Graduates Who Received Degrees During the School Year June 1947 to June 1948*, Stanford University, Calif., Dec. 17, 1948. (Mimeographed.)

[32] Howe, E. D., *Employment Histories of Engineering Graduates*, Journal of Engineering Education, March 1947, pp. 513–519.

[33] It will be noted that a similar figure as to the rate of loss was arrived at by the Compton committee in its report referred to above in footnote 3, p. 10.

there are many factors which affect replacement needs and that the figures given above are only approximations.

Because replacement needs are an important consideration in any analysis of the future demand for engineers and because present data on these needs are fragmentary and are subject to a wide margin of error, there is a pressing need for additional information on the subject. Engineering colleges could make a real contribution by conducting follow-up surveys of engineering graduates such as those conducted by Stanford University, University of California, and New York University.

Conclusions: The Employment Outlook for Engineers

From the above discussion it may be seen that engineering is one of the most dynamic and rapidly growing professions; its expansion over the past several decades, particularly during the present one, has been striking. Moreover, the profession is expected to grow substantially in the future. It is estimated that about 350,000 engineers were employed in the United States in the spring of 1948—an increase of more than 100,000 since 1940. Upon the basis of past trends in the use of engineers by industry, it would appear that employment of engineers could well increase by some 100,000 more by 1960 to a total of about 450,000, if generally high employment levels prevail in the United States. This would mean an expansion of about 8,000 jobs a year on the average from 1948 to 1960, although the increase will vary from year to year. In addition, engineers will have to be trained to replace losses to the profession (owing to death, retirement, and transfer) which are estimated to be occurring at the rate of around 9,000–10,000 per year at the present time and which may rise to over 13,000 per year by 1960.

The demand for engineering graduates in the United States for the next few years may be estimated, then, at approximately 17,000 or 18,000 per year. Toward the end of the 1950 to 1960 decade, when death and retirement losses are expected to increase, the yearly demand may well rise to around 21,000 or 22,000. This points to an annual need for engineering graduates roughly twice as great as the average number turned out by schools in the decade before the war. These estimates may be high, since they are based on the assumption that the general economic situation will be favorable. On the other hand, they assume only peacetime needs.

A review of the trends in supply of graduate engineers shows that engineering schools have trained increasing numbers of students. In line with the general increase in college graduations, the number of men receiving engineering degrees rose from an average of 7,000 per year in the twenties to about 10,000 in the thirties. Graduations increased rapidly in the early years of World War II and then dropped a great deal in the later years. With the tremendous expansion in engineering enrollments after the war, the number of graduates has reached unprecedented heights. In the academic year 1947–48, some 32,000 engineering students were graduated and in 1948–49, 44,000—an all-time peak. On the basis of enrollments in the fall term of 1948, it may be estimated that about 47,000 students will be graduated in 1950, about 36,000 in 1951, and nearly 29,000 in 1952. Actually, graduations in these years may be higher, owing to transfer of students from junior colleges to engineering schools and to the possibility that drop-out rates may actually be lower than the prewar rates used in the estimates.

It is of course impossible to estimate graduations more than 4 years in advance. Enrollments in engineering courses may be influenced by economic and social conditions, changing occupational interests of young people, and vocational guidance buttressed by informational materials such as this report. Nevertheless, it is of interest to illustrate what the level of engineering graduations may be, solely on the assumption that past trends will continue. These estimates may provide a benchmark by which the effects of possible alternate conditions may be appraised by educators and other leaders in the profession. The estimates presented here suggest, on the basis of past trends in college enrollment, the proportions of college students entering engineering training, the survival rates of students, and future trends in population that the number of engineering degrees awarded may fall to *not less than* 18,000 in 1956 and then rise gradually to *at least* 25,000 in 1965.

A comparison of the estimated supply of and demand for engineering graduates leads to several conclusions. *In the next few years, approximately 1949 to 1952, the number of graduates will greatly exceed the demand for graduate engineers.* After that, if past trends affecting enrollments should continue, the annual demand for graduates and the supply of new graduates would roughly be in balance.

The conclusion concerning the immediate outlook is substantially in line with that of the Manpower Committee of the American Society for Engineering Education, which said in a report prepared in the early summer of 1948:[34]

> Under conditions of normally increasing industrial operations, it is believed that present trends in engineering enrollment will produce a reasonable balance between supply and demand *after 1951. In the next 2 years the transient condition created by veteran enrollment will create a supply in excess of that which should normally be absorbed in strictly engineering occupations. The maximum is probably not more than about 1 year's supply,* although it is possible that little or no surplus will be noticeable as engineering education has long been recognized as having great value as general education and as a good foundation for work in almost any profession.

Enrollment figures for the fall term of 1948 and other information not available at the time the Manpower Committee's report was prepared suggest that the condition they foresaw might be continued through 1952.

It should be noted that the above appraisal of the outlook is based upon the assumption of a high level of general economic activity. The difficulties which face the graduates would be intensified by a drop in general business conditions. At the time this report was being written (spring 1949) employers were beginning to be more cautious in hiring.

The foregoing evaluation is based solely on a comparison of the prospective demand with the expected supply of engineering graduates and does not take into account the fact that some engineering jobs will be filled, as in the past, by men without engineering degrees. In view of the long-run trend toward requiring formal engineering training, and the ample supply of graduates, it seems likely that nongraduates will have greater difficulty in getting jobs than in recent years. To the extent that they may succeed, however, opportunities for graduate engineers would of course be reduced.

The above appraisal of the employment outlook for engineers is somewhat affected by the fact that American engineering schools are a source of supply of engineers for many foreign countries. Some of the engineers who will work overseas are foreign students; others are American students who find engineering employment abroad.[35] At the time this report was being written plans were under discussion to provide technical assistance to foreign countries, following a recommendation by the President in his 1949 inaugural address. A small additional allowance has to be made in the estimate of the number to be trained to provide for this element of demand. To some extent this is offset by the supply of engineers trained in foreign schools (particularly Canadian) who find employment in the United States.

Although it is likely that in the next 4 years the total number of engineering graduates will be greater than the number of engineering positions available, the employment situation will vary greatly as between engineering positions at different levels and among the various fields of engineering. At almost any time during the growth of the profession, even in times of depressed industrial activity, the engineer who is at or near the top in ability has had little trouble in obtaining or keeping a job. Even when competition becomes stiffer, as expected, it is likely that a demand for men with special abilities or training in such work as research and design will still prevail.

Also, though there is expected to be an excess of trained personnel over available positions in all fields, the surplus will occur earlier and be larger in some branches of engineering than in others. Comparison of the estimated supply and demand in the various fields suggests that the oversupply

[34] *Annual Report of Manpower Committee of ASEE*, Journal of Engineering Education, September 1948, pp. 36–38.

[35] The survey of members of six engineering societies in 1946 showed that 2.2 percent were in residence abroad as civilian engineers. *Engineering Profession in Transition.* Engineers Joint Council, New York, N. Y., 1947, p. 64.

of new graduates will be largest in electrical engineering. Within the field of mechanical engineering, some specialties are likely to have an oversupply before others. On the other hand, an imbalance between the supply of and demand for engineers in the civil and mining and metallurgical fields is not expected to occur as soon or to as great a degree as in the other branches mentioned above. Somewhat similar conclusions were reached by the Committee on Manpower of the American Society for Engineering Education in their report to the Society in June 1947.[36]

Engineers unable to get a beginning job in the field for which they were trained will be able in many cases to start in another engineering field. Examination of data on occupational mobility shows that graduates sometimes obtain employment in a field of engineering other than that in which they studied. If competition becomes stiff in electrical engineering, for example, some persons trained in this field may be able to switch to civil, mining and metallurgical, or some specialties of mechanical engineering. Such transfers will tend to reduce the differences in employment outlook among the various fields of engineering. Thus an oversupply of applicants for employment in all major fields of engineering is in prospect within the next several years.

To students in engineering schools and to the individual interested in engineering as a career, it should be pointed out that intense competition for nearly all types of beginning engineering jobs will be experienced within the next few years. This will be true even if general business conditions are good. The competition would be intensified if there should be a recession. Students now in school would be well advised to get the best possible training. The minimum educational requirements are being raised gradually and the proportion of engineers with advanced degrees, though small, is increasing. The engineering student of the future may be required to meet higher standards for entrance into and progress in the engineering curriculum, and may have to complete more than the traditional 4 years of education in order to succeed in his chosen profession. The would-be engineer should endeavor also to make the best possible record of achievement in his studies and to broaden his training as much as possible. Furthermore, many employees emphasize the extra-curricular college record of prospective employees.

Those engineering graduates of the next few years who are unable to get engineering jobs may attempt to adjust to the situation in several ways. Some will find that their education has qualified them in the eyes of employers for other jobs in industry, such as administration, sales, or technical jobs. Others, who have a particular interest and aptitude in engineering, may decide to remain in school and obtain a postgraduate degree in engineering to improve their chances for employment. Some may find that with additional training built upon the foundation of their engineering education, they will be able to find employment in other professions or occupations which are expected to have a continued need for new workers.[37]

Those who will seek immediate employment in nonengineering occupations will find that their opportunities are improved by the growing belief on the part of employers that engineering education is a good background for many nonengineering jobs. The fact that employers are using engineering graduates in administration and other jobs has been recognized by engineering educators and is being reflected in attempts to adapt the training along those lines (footnote 17, p. 35).

On the other hand, their chances of finding other employment will be limited by intensified competition for entrance jobs in many fields over the next several years resulting from the postwar boom in college enrollments. Compared to a prewar peak of 1.5 million in 1939–40, enrollments were at a new high of 2.4 million in the fall term of 1948. These students have now begun to graduate. As a result of these high enrollments there will be more graduates in some professional and administrative fields than can be absorbed by industry; on the other hand, shortages of workers are expected in other occupations.

The high-school boy with a real interest in and aptitude for engineering should not necessarily be discouraged by the outlook for jobs in the next

[36] *Journal of Engineering Education,* October 1947, pp. 110–118.

[37] U. S. Department of Labor's Bureau of Labor Statistics, *Occupational Outlook Handbook,* Bulletin 940, Superintendent of Documents, Washington 25, D. C., 1949. $1.75. The Handbook contains employment information on 288 major occupations for use in vocational guidance, including the professions, skilled trades, clerical, sales, and service occupations, and major types of farming.

few years. It is quite possible that enrollments in engineering may return to a lower level and that by about 1953 the number of graduates may be more in line with current demand. Under these circumstances opportunities for new graduates will depend in part upon whether or not many future engineering graduates who do not get engineering jobs immediately will still seek to enter the profession. It is difficult to say what these men may do. If business conditions are generally unfavorable, if many engineering graduates are unable to find satisfactory employment in other occupations, or if large numbers should continue in engineering schools for postgraduate work, it is possible that many graduates of the next few years would continue to seek engineering jobs.

On the other hand, if there should be moderately good business conditions and if the great bulk of the graduates of this period are successful in obtaining satisfactory employment in engineering or other occupations, relatively few may still be actively seeking jobs in engineering. Under these conditions, there will continue to be opportunities for new graduates in this expanding profession.

To the engineering schools, the estimates presented here may suggest that over the long run there will be a demand for roughly twice as many graduates as were turned out annually in the decade before the war and that facilities and instructional staff will have to be provided. The great interest in engineering also suggests that there is both the opportunity and the need for a careful selection of students. Many persons in the profession have for some time felt that the rate of survival of engineering students was too low. Some of the drop-outs are caused by scholastic deficiencies, some by financial difficulties, and others by lack of interest. Progress has been made in the improvement of standards of entry and in selection techniques. Educators have devised engineering aptitude tests for applicants. If the standards of entry into engineering schools were raised and if more precise selection methods were used, it is evident that schools could admit even fewer students and still provide an adequate supply of engineering personnel.

To counselors in high schools, colleges, and other agencies providing vocational guidance, the implications of these conclusions need not be labored. The increasingly competitive situation expected for the next few years—in an occupation which, in any case, makes great demands on the student's ability and perseverance—may give pause to the marginal student, but should not be allowed to deter those with the aptitude for and realistic interest in this fascinating and rapidly growing profession.

The Earnings of Engineers

The person considering a career in engineering is interested in knowing what he can expect in the way of income from this profession. Do earnings, as in many other professions, increase with experience? If so, at what rate does this occur? To what extent does a man's educational background affect his earning capacity? What fields of engineering and what types of work within a field seem to offer the best income possibilities? Do earnings differ from one industry or location to another? How do engineers fare under changing economic conditions? This section discusses the factors affecting the earnings of engineers, and throws some light on the foregoing questions.

Earnings in a profession like engineering are undoubtedly influenced by many intangible factors, including the ability and personality of the individual and his importance to the particular company, the supply and demand situation in each field, and even the wage and salary structure which has been established for other workers in the industry. Many of these factors are too complex to be amenable to measurement in statistical studies such as the Bureau of Labor Statistics' 1935 [1] and 1946 [2] surveys on which this chapter is based. Only a few relatively simple factors could be measured in these surveys—the length of each engineer's professional experience, his educational attainments (in terms of degrees earned), the type of work he is doing, and the industry in which he is employed. In this section, the effect of these latter factors on earnings of engineers will be shown, but the fact that there are a host of significant factors which could not be taken into account in the figures must be borne in mind.

The 1946 survey from which most of the statistical data in this chapter are taken was made by the Bureau in cooperation with professional engineering societies in 1946, and included reports from nearly 25,000 engineers—including both members of professional societies and nonmembers. (A separate report was issued by the societies on their members.) [3] Information was reported for 3 widely differing years—1939, 1943, and 1946. Some data are presented, for comparative purposes, from the similar survey conducted by the Bureau in 1935.

Because of the many requests to the Bureau for earnings information for the engineering profession as a whole and for each major field of engineering, over-all median salaries are presented. However, it should be understood that such figures are not considered meaningful in themselves.

Within this section is a discussion of several of the factors affecting earnings of engineers which should convince the reader that over-all figures have only limited value. The distribution of engineers included in the survey by general field of employment and the median monthly salaries in each field in 1946 are shown in the following tabulation:

General field of employment	*Percentage distribution*	*Median base monthly salary 1946*
All engineers reporting	100.0	$392
Chemical	12.5	363
Civil	20.0	368
Electrical	21.7	393
Mechanical and industrial	29.3	409
Mining and metallurgical	5.9	417
Other	10.6	410

In order to emphasize the limited significance of earnings information for these broad fields, it may be mentioned that chemical engineers, who as a group had the lowest median salary, are found to be actually the highest paid of all the major types of engineers when allowance is made for length of professional experience.

[1] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934*, Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. 25 cents.

[2] See Scope and Method of the 1946 Survey of the Engineering Profession in appendix C of this report.

[3] *The Engineering Profession in Transition*, Engineers Joint Council, 33 West 39th St., New York, N. Y., 1947.

Major Factors Which Affect Earnings

Years of Experience

One of the most significant of all the factors affecting earnings of engineers is length of experience. This fact is, of course, widely recognized and has been amply demonstrated by surveys of various professions.[4] The fact is well recognized that the formal education preparatory for a profession—just as the apprenticeship which prepares one for a skilled trade—merely brings the worker up to a level of competence sufficient to enable him to begin practicing his profession. The major part of his learning and development in the profession begins with his working career, and throughout his working life he continues to increase his competence by experience. It should be emphasized, however, that the data do not permit of definite statements as to the progression of salaries of individuals. What is shown is a cross section *at one time*, of the salaries of persons employed in the field with varying amounts of experience.

In each field of engineering, the rise in average earnings with length of experience is persistent and amounts to a considerable increase over the span of an engineer's working life (table 9 and chart 9). The first 10 years show the greatest rise in earnings; in 1946 the increase for each year's experience up to 10 averaged $10 to $20 (or $120 to $240 annual salary) depending on field of engineering. After about 30 years of experience (at which time the average age of engineers is over 50 years) there tends to be a leveling off of average salaries.

[4] U. S. Department of Labor's Bureau of Labor Statistics, *Factors Affecting Earnings in Chemistry and Chemical Engineering,* Bulletin No. 881, Superintendent of Documents, Washington 25, D. C., 1946. Price 10 cents.

The Engineering Profession in Transition, Engineers Joint Council, 33 West 39th St., New York, N. Y., 1947.

U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934,* Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

U. S. Department of Commerce, Bureau of Foreign and Domestic Commerce, *Incomes in Selected Professions, Comparison of Incomes in Nine Independent Professions,* in Survey of Current Business, May 1944, p. 15.

U. S. Department of Labor's Bureau of Labor Statistics, *Economic Status of Ceramic Engineers, 1939 to 1947,* July 1948. Available free in mimeographed form from issuing office, Washington 25, D. C.

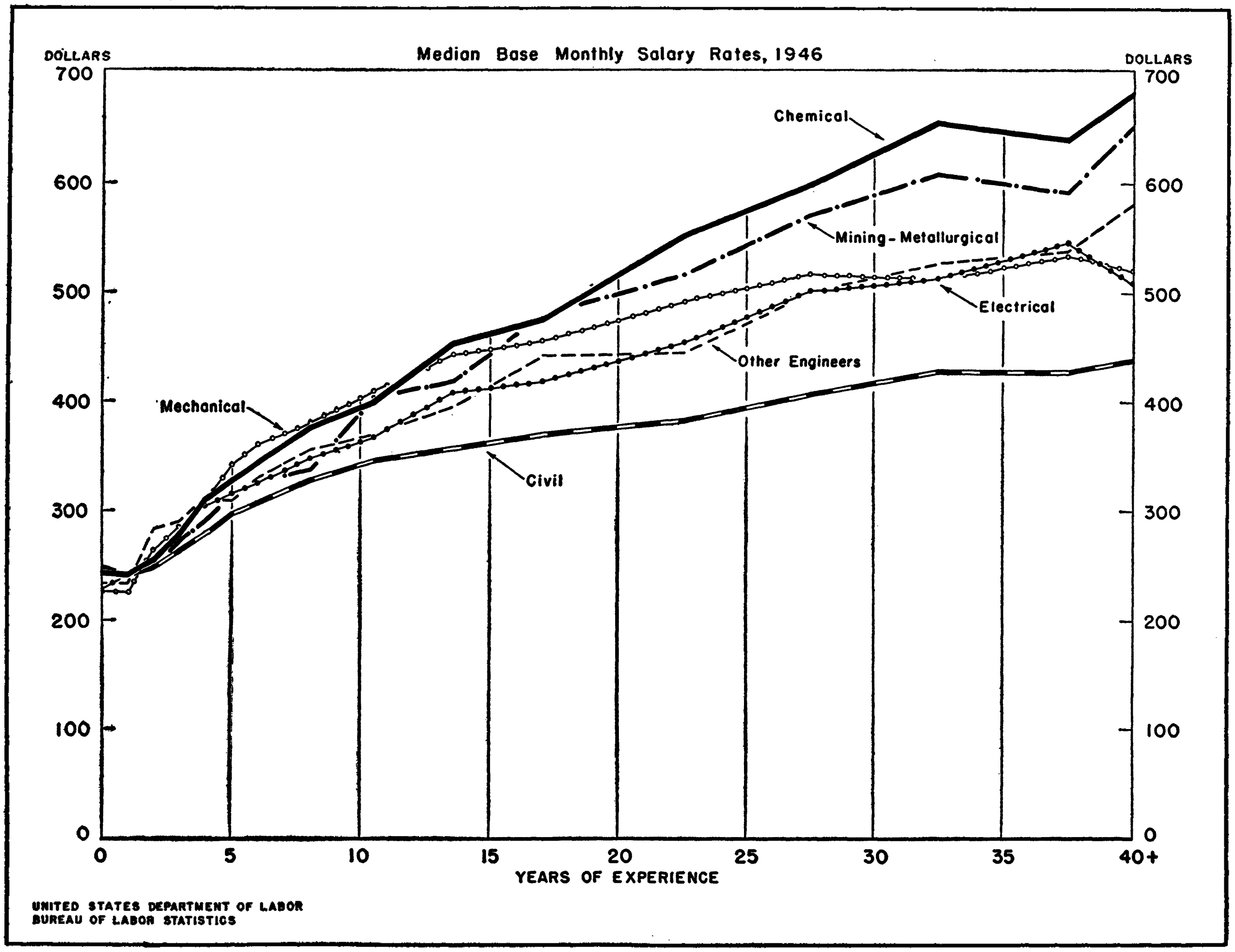
That the amount of increase in monthly earnings with years of experience varies greatly among engineering specialties is evident from table 9 and chart 9. Entrance salaries in all fields in 1946 were very close together, ranging from $226 to $247 per month. Yet median earnings of chemical engineers show an increase of about $440 or 185 percent during the working span while earnings of civil engineers increased by only about $200 or 85 percent. Increases in the median earnings of other types of engineers over a period of 35 or 40 years' experience were approximately as follows: electrical—$315 (140 percent); mechanical—$310 (140 percent); mining and metallurgical—$405 (165 percent); and other engineers—$350 (150 percent). These differences in salaries by type of engineering are explained in part in the following analyses of some of the other factors affecting earnings. However, part of the explanation undoubtedly lies in the history of each field as discussed in the first part of this report, particularly as related to supply and demand. For example, the relatively high earnings in chemical engineering may reflect the fact that in a period of rapid expansion in the chemical industry there was a scarcity of men with such training and promotions came early in their careers. Similarly, the relatively low earnings

TABLE 9.—*Median base monthly salary rates for each field of engineering employment, by years of experience, 1946*

Years of experience	Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other
All engineers reporting	$363	$368	$393	$409	$417	$410
Less than 1 year	242	247	228	226	247	231
1 year	241	240	237	225	(1)	(1)
2 years	255	247	249	264	(1)	283
3 years	278	263	277	285	272	290
4 years	310	278	303	308	290	311
5 years	327	297	315	342	313	310
6 years	344	307	325	360	327	330
7–8 years	375	327	347	380	337	356
9–11 years	399	345	366	408	404	370
12–14 years	452	356	409	442	417	396
15–19 years	474	369	418	455	478	443
20–24 years	552	382	454	492	516	445
25–29 years	598	407	502	518	570	501
30–34 years	655	427	513	514	608	528
35–39 years	640	428	545	534	592	539
40 years and over	680	438	509	520	650	580
Median years of experience	8.8	21.6	15.9	12.8	13.8	17.3

[1] Insufficient reports to compute median salary.

Chart 9.—Greatest Rise in Engineers' Earnings Occurs in the First 10 Years of Experience

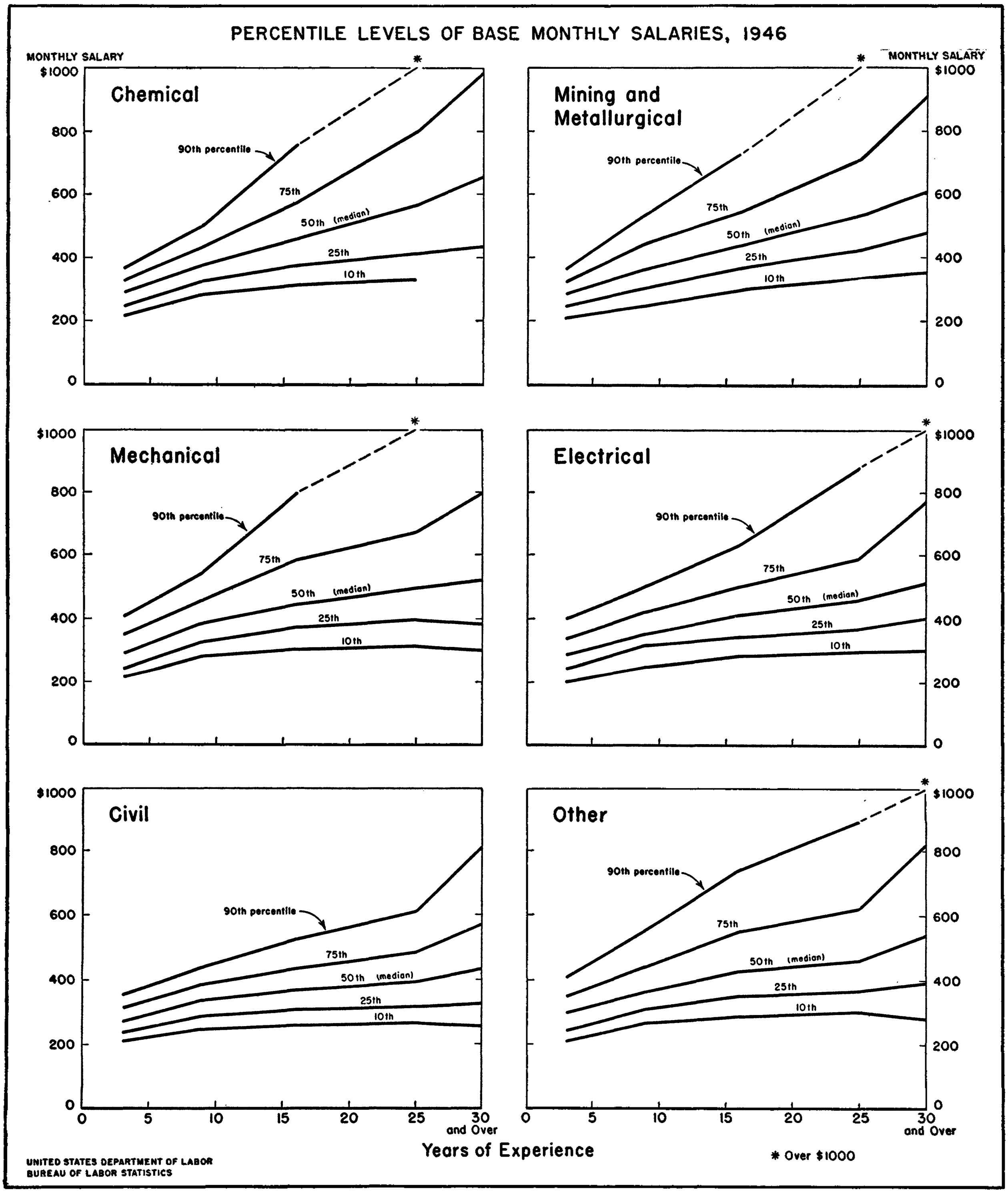


reported by civil engineers may reflect the fact that many of them are employed by government agencies in which salary scales are less flexible in response to the supply and demand situation than those in industry.

Average monthly earnings of men with less than 5 years of experience do not vary greatly among the major fields of engineering. Chart 9 shows a difference of less than $30 in 1946 between the highest and the lowest medians in the 6 engineering fields for men with 3 years of experience, but the difference for those with 30–34 years' experience is more than $200. This pattern of widening differences in salary with length of experience prevails in all 3 years covered by the survey—1939, 1943, and 1946. (See appendix table D–13.) This condition suggests that factors other than length of experience affect salaries of engineers, and that these factors come into play later in the engineer's working life.

This point is even more clearly brought out when the distribution of engineers' earnings at different points in their work history is examined. In chart 10 and appendix table D–12 the 10th, 25th, 75th, and 90th percentiles of this distribution are shown, as well as the median. It is evident from these data that mere increase in length of experience does not insure a substantial rise in earnings. The lowest 10 percent of engineers in most fields earned, when they had 20 to 29 years of experience, relatively little more than did the lowest 10 percent of those who had less than 6

Chart 10.—Salary Differences Within Each Field of Engineering Employment Increase With Years of Experience



years' experience. The earnings of the highest 10 percent rose much more rapidly, and the difference between the earnings of the better-paid and the lowest-paid engineers widens sharply with experience. This brings out the point that the figures on median earnings, discussed throughout this report, actually conceal a wide spread in earnings, particularly for the more experienced engineers.

The exact means by which the cumulation of professional experience results in increases in earnings was not fully brought out by the survey. Possibly the most common method is the promotion or advancement of the engineer to positions of greater responsibility or difficulty; the effect of this is discussed in the following paragraphs. Many of the salary increases take place without promotions, however. It is common practice in industry to recognize that a man's value to his company increases with experience, and to compensate him for this by salary raises. This practice is manifest either in formal arrangements for periodic salary increases, such as are found in some firms and in government agencies, or in a more informal manner.

Occupational Status

The type of work performed by an engineer apparently has much to do with the amount of money he is able to earn. Since it has been shown that length of experience directly affects earning capacity, it is important to examine earnings by occupation in relation to years of experience. For this reason, the median length of experience of each group is given with the median salary in the following discussion.

Top salaries in 1946 in all the major fields of engineering went to engineers employed in nontechnical administration-management jobs (table 10). It is evident that these jobs are attained only after many years of experience. There are relatively few engineers in nontechnical administrative

TABLE 10.—*Median base monthly salary rates and median years of experience for each field of engineering employment, by occupational status, 1946*

Occupational status	Chemical		Civil		Electrical		Mechanical		Mining and Metallurgical		Other	
	Median base monthly salary	Median years of experience	Median base monthly salary	Median years of experience	Median base monthly salary	Median years of experience	Median base monthly salary	Median years of experience	Median base monthly salary	Median years of experience	Median base monthly salary	Median years of experience
All engineers reporting	$363	8.8	$368	21.6	$393	15.9	$409	12.8	$417	13.8	$410	17.3
Administration-management, nontechnical	750	20.0	493	23.4	513	21.9	576	17.4	570	23.3	508	19.3
Administration-management, technical	479	13.7	448	24.5	493	20.3	516	17.5	501	18.1	496	20.1
Analysis and testing	270	7.2	330	13.8	310	12.0	343	6.3	306	8.4	327	9.0
Construction supervision	370	10.5	351	21.7	362	18.6	409	15.5	(1)	(1)	387	19.8
Consulting, independent	(1)	(1)	407	26.0	407	22.0	502	25.5	420	35.0	460	30.0
Consulting, as employee of private firm	400	13.9	393	22.4	421	18.6	458	18.1	475	19.6	496	17.5
Design	359	6.8	342	19.0	353	12.9	365	11.0	(1)	(1)	361	14.6
Development	327	11.9	345	20.8	369	8.9	391	10.1	324	6.8	381	9.4
Drafting	(1)	(1)	270	9.8	273	7.7	275	7.3	(1)	(1)	295	12.0
Editing and writing	(1)	(1)	381	15.4	375	15.8	345	13.0	(1)	(1)	(1)	(1)
Estimating	(1)	(1)	379	23.2	329	15.8	342	10.7	(1)	(1)	338	18.8
Inspection	(1)	(1)	310	20.2	318	16.0	318	10.9	(1)	(1)	330	20.6
Installation	(1)	(1)	(1)	(1)	330	9.6	313	7.3	—	—	(1)	(1)
Maintenance	(1)	(1)	362	23.8	326	15.1	364	14.1	(1)	(1)	327	9.0
Operation	357	12.0	319	19.8	359	18.1	392	10.4	364	14.1	403	18.9
Patents	(1)	(1)	—	—	460	18.3	487	24.2	—	—	574	18.3
Personnel-labor problems	(1)	(1)	—	—	(1)	(1)	405	5.7	—	—	(1)	(1)
Production	339	6.5	(1)	(1)	324	7.0	336	9.0	312	8.5	348	10.4
Research in basic science	314	5.8	(1)	(1)	359	10.2	355	5.5	349	7.0	(1)	(1)
Research, applied	324	6.6	378	16.8	393	8.1	363	7.0	361	9.2	368	11.3
Safety engineering	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	366	17.0
Sales	408	11.6	364	20.3	407	17.4	409	14.7	405	12.0	399	15.7
Teaching, college	324	8.5	356	20.0	348	17.9	342	14.5	427	22.1	344	18.9
Any occupational status not specified above	320	8.0	306	17.5	336	10.0	395	11.1	433	17.5	369	19.8

[1] Insufficient reports to compute median.

jobs[5] as compared with technical administration-management work, where more than a quarter of the engineers in each of the major fields were employed in 1946. Earnings and length of experience of engineers engaged in administrative-management work were both well above the median for all engineers in each field of specialization. Although there were considerable differences, among the different fields of engineering, in median salaries earned in administrative work, it is obvious that these jobs represent the top of the financial ladder in every field.

Consulting engineers who were employees of private firms had relatively high monthly earnings, with median salaries from $25 to $86 higher than the medians for all engineers in their respective fields of engineering; however, their median years of experience were also higher. (Independent consulting work actually yielded the highest income of all the types of work, but only a part of the total income of men engaged in such work is reported as base monthly salary; therefore only annual income—which includes fees and bonuses—is meaningful for this category. See the part of this section on annual income, p. 67.)

College or university teaching yielded median monthly earnings in 1946 which varied from $324 for chemical engineers with a median of 8.5 years of experience to $427 for mining and metallurgical engineers with 22 years of experience. It should be borne in mind that base monthly salary of teachers probably represents only the pay received during the regular school term and does not include any income which may have been received from publications, special research work, consulting practice, or vacation employment.[6] Teaching apparently offers important compensations other than monetary considerations. An interview inquiry conducted for the President's Commission on Higher Education in 29 institutions revealed that faculty members felt secure in their positions, were reasonably certain of old-age security, were well pleased with the results they were achieving, and frankly recognized the high prestige value of the profession.[7] Nevertheless a report of a survey made in 1947 of 143 engineering schools has this to say concerning salaries of faculty members:[8]

> It is rather serious that the over-all median of average salaries of associate professors in all types of institutions is less than $4,000, of assistant professors is less than $3,400, and of instructors is less than $2,600. These can hardly be considered as satisfactory base incomes (even though for the academic year only) for professional men with the experience and competency required for the specific ranks.

Design work employs a sizable proportion of engineers in all the major fields of engineering except mining and metallurgical. In each field of engineering, earnings in design work are somewhat below the average, but median years of experience are also 2 or 3 years under the median for the field. The highest salaries for design work are paid in the mechanical engineering field; one-fifth of all mechanical engineers are so employed.

Some types of work are especially important in a particular branch of engineering. For example, nearly 18 percent of the civil engineers were engaged in construction supervision in 1946; the median salary of this group was about $350 per month, their median experience 22 years. About 17 percent of the chemical engineers were in development work; their median salary was $327, their median experience 12 years. About 16 percent of the mining and metallurgical engineers were engaged in applied research and averaged $361 per month (median experience, 9 years); chemical engineers, of whom 14 percent were in applied research, earned a median of $324 in this type of work (median experience about 7 years).

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[5] Examination of the reports from engineers reporting their field of employment as "nonengineering" indicates that a considerable number who were engaged in nontechnical administration-management classified their work as outside the engineering field, even though it may have been their training and experience as engineers which had qualified them for these top-flight administrative positions. The net result is that the proportion of nontechnical administration-management jobs for each field of engineering is probably understated; also the accompanying high salaries paid on this type of work were not included in the medians for the fields of engineering from which these executives came.

[6] Recognition of the fact that faculty members often have opportunities for additional income is made in reports such as that of the Minimum Salary Committee of the Georgia Society of Professional Engineers, Atlanta, Ga., 1948, in which the committee suggests that salaries of faculty members should be ⅚ of the normal minimum provided for 12 months continuous employment.

[7] President's Commission on Higher Education, *Staffing Higher Education,* Vol. IV, p. 49, December 1947, Superintendent of Documents, Washington 25, D. C. Price 25 cents.

[8] *Report on Present-Day Salaries of Members of the Instruction Staffs of Engineering Schools in United States and Canada,* Journal of Engineering Education, September 1947, p. 39.

It is clear that there is great variance in salaries of engineers by type of work performed. While a part of this is due to differences in length of experience, examination of the reports of engineers having approximately the same amount of experience shows a wide range of earnings, depending upon the occupational status. As table 10 shows, mechanical engineers engaged in administration, personnel work, and research earned relatively more, considering length of experience, than those engaged in drafting, college teaching, operation, inspection, and installation. Chemical engineers engaged in administration, sales, and design earned relatively more than those in analysis and testing, operation, and teaching. In civil engineering, administration and sales work paid more, considering experience, than inspection, operation, development, construction supervision, and maintenance work. Electrical engineers had relatively higher earnings in administration, consulting, sales, patents, research, and development than in inspection, maintenance, teaching, estimating, operation, and construction supervision. In mining and metallurgical engineering, those engaged in administration, sales, and research had higher earnings relative to their experience than those in operation, production, analysis and testing, and teaching.

In summary then, it is apparent that type of work performed has great influence on the earnings received in engineering. Length of experience is evidently an important factor in attaining certain types of jobs, while others are open to young engineers. Considering earnings in relation to experience, some variations are found among the fields of engineering, but, in general, administration-management, research, and sales jobs pay relatively better than such work as inspection, analysis and testing, operation, and college teaching.

Educational Level

That there are wide differences in the educational attainment of engineers among the major fields of engineering and also within a field has been shown in the earlier part of this report in table 6, page 36. In this section earnings are examined in relation to educational level, experience, and occupational status. Table 11 and chart 11 show that, by and large, earnings are higher for those with advanced degrees. In most fields differentials in earnings between holders of the master's degree and holders of the doctor's degree are considerably greater than between those with the bachelor's and master's degree. Because of the small numbers with advanced degrees in some fields, it is impossible to show salaries at all experience levels.

TABLE 11.—*Median base monthly salary rates for each field of engineering employment, by level of education and years of experience, 1946*

Years of experience	Doctor's degree	Master's degree	Bachelor's degree	Incomplete and no college
	CHEMICAL			
All engineers reporting	$472	$384	$345	$396
Less than 9 years	409	341	302	280
9–14 years	477	421	408	403
15–24 years	570	539	501	444
25 years and over	783	635	625	612
Median years of experience	13.1	8.8	7.7	15.0
	CIVIL			
All engineers reporting	$429	$414	$367	$354
Less than 9 years	330	312	290	314
9–14 years		364	353	314
15–24 years	485	416	386	343
25 years and over		480	446	381
Median years of experience	24.0	22.1	19.7	25.7
	ELECTRICAL			
All engineers reporting	$500	$425	$382	$395
Less than 9 years	420	355	302	323
9–14 years	513	430	375	360
15–24 years	505	475	436	409
25 years and over	665	490	529	471
Median years of experience	17.8	16.1	14.4	20.0
	MECHANICAL			
All engineers reporting	$524	$448	$394	$432
Less than 9 years	493	370	321	331
9–14 years		448	416	414
15–24 years	564	508	483	445
25 years and over		526	551	494
Median years of experience	19.0	15.4	11.0	20.7
	MINING AND METALLURGICAL			
All engineers reporting	$533	$448	$391	$423
Less than 9 years	460	319	302	283
9–14 years		440	392	407
15–24 years	715	511	500	427
25 years and over		537	595	538
Median years of experience	16.3	15.4	12.0	19.2
	OTHER			
All engineers reporting	$464	$469	$407	$397
Less than 9 years	410	349	315	314
9–14 years		394	383	366
15–24 years	500	518	454	406
25 years and over		576	551	449
Median years of experience	16.4	18.3	15.7	20.9

Chart 11.—Relation of Engineers' Earnings to Education

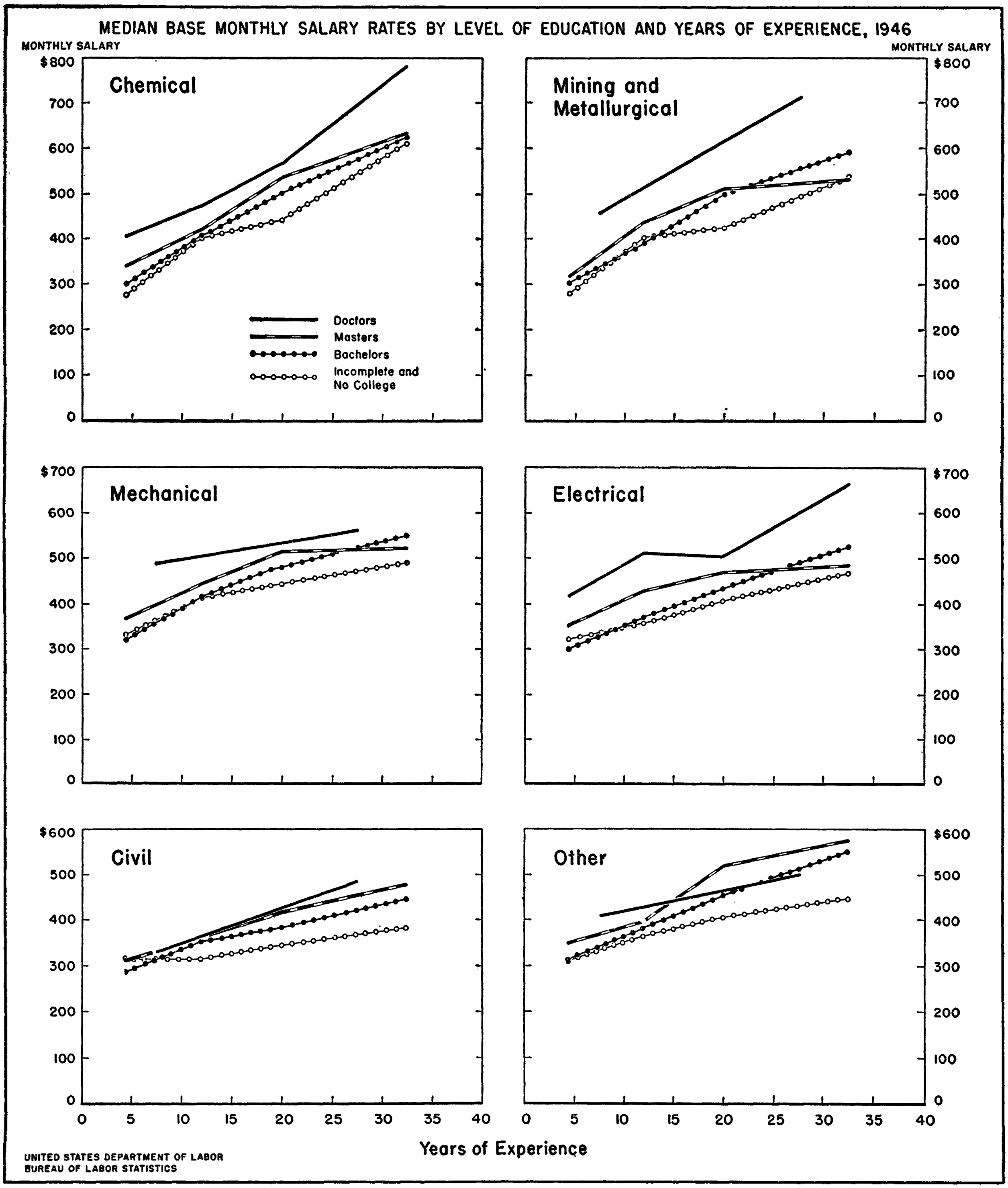


Table 12.—*Characteristics of engineers as related to occupational status, by field of engineering, 1946*

Occupational status	Percentage distribution	Median years of experience	Percent with advanced degrees in engineering	Percent with no degree in engineering	Median base monthly salary
CHEMICAL					
All engineers reporting	100.0	8.8	24.2	6.7	$363
Administration-management, nontechnical	2.0	20.0	20.4	14.8	750
Administration-management, technical	27.0	13.7	24.3	7.8	479
Analysis and testing	3.7	7.2	9.3	9.2	270
Consulting, employee	2.2	13.9	20.7	10.3	400
Design	7.7	6.8	33.5	4.9	359
Development	17.4	11.9	23.0	5.0	327
Operation	4.1	12.0	10.0	6.4	357
Production	8.2	6.5	16.0	4.6	339
Research in basic science	.9	5.8	43.5	-------	314
Research, applied	13.9	6.6	27.7	4.7	324
Sales	3.0	11.6	19.8	8.6	408
Teaching, college	2.5	8.5	67.2	-------	324
Retired, student, unemployed	3.3	-------	-------	-------	-------
All other occupational statuses	4.1	-------	-------	-------	-------
CIVIL					
All engineers reporting	100.0	21.6	11.0	23.2	$369
Administration-management, nontechnical	2.5	23.4	9.3	27.8	493
Administration-management, technical	27.4	24.5	10.3	23.8	448
Analysis and testing	1.1	13.8	10.9	17.4	330
Construction supervision	17.6	21.7	6.0	32.5	351
Consulting, independent	4.1	26.0	14.9	22.5	407
Consulting, employee	3.3	22.4	18.8	18.8	393
Design	20.4	19.0	10.4	18.9	342
Development	2.0	20.8	9.1	22.7	345
Drafting	2.4	9.8	2.8	19.8	270
Editing and writing	.7	15.4	22.6	3.2	381
Estimating	2.7	23.2	6.8	22.2	379
Inspection	2.0	20.2	7.8	26.7	310
Maintenance	3.5	23.8	3.3	30.4	362
Operation	1.2	19.8	4.0	24.0	319
Research, applied	1.3	16.8	36.2	10.3	378
Sales	1.3	20.3	9.4	7.5	364
Teaching, college	2.4	20.0	58.2	1.0	356
Retired, student, unemployed	.3	-------	-------	-------	-------
All other occupational statuses	3.8	-------	-------	-------	-------
ELECTRICAL					
All engineers reporting	100.0	15.9	13.9	17.4	$393
Administration-management, nontechnical	2.0	21.9	6.4	26.6	513
Administration-management, technical	26.3	20.3	14.3	20.2	493
Analysis and testing	2.8	12.0	5.5	18.0	310
Construction supervision	3.3	18.6	5.1	24.8	362
Consulting, independent	1.2	22.0	21.5	27.7	407
Consulting, employee	4.3	18.6	18.7	15.1	421
Design	16.5	12.9	10.6	15.3	353
Development	11.1	8.9	15.4	11.5	369
Drafting	.9	7.7	-------	22.5	273
Editing and writing	.8	15.8	8.1	29.7	3[illegible]5
Estimating	1.5	15.8	2.8	11.3	329
Inspection	1.2	16.0	6.9	20.7	318
Installation	1.4	9.6	9.5	15.9	330
Maintenance	3.2	15.1	4.6	31.6	326
Operation	3.7	18.1	4.1	28.7	359
Production	.9	7.0	-------	14.6	324
Research, applied	6.3	8.1	24.8	11.7	393
Sales	6.2	17.4	6.5	13.1	407
Teaching, college	2.8	17.9	70.7	.8	348
Retired, student, unemployed	.7	-------	-------	-------	-------
All other occupational statuses	2.9	-------	-------	-------	-------
MECHANICAL					
All engineers reporting	100.0	12.8	12.7	19.4	$409
Administration-management, nontechnical	2.5	17.4	7.7	27.4	576
Administration-management, technical	29.5	17.5	13.0	22.3	516
Analysis and testing	3.3	6.3	8.6	6.7	343
Construction supervision	1.9	15.5	12.4	24.8	409
Consulting, independent	1.4	25.5	19.2	27.2	502
Consulting, employee	3.8	18.1	16.6	17.9	458
Design	19.4	11.0	8.4	22.5	365
Development	7.8	10.1	12.1	16.9	391
Drafting	1.8	7.3	3.6	21.3	275
Estimating	1.1	10.7	7.2	25.7	342
Inspection	1.0	10.9	4.8	31.8	318
Installation	.8	7.3	5.9	9.8	313
Maintenance	2.2	14.1	7.0	19.0	364
Operation	1.8	10.4	7.1	17.7	392
Production	3.0	9.0	7.6	24.0	336
Research in basic science	1.0	5.5	24.6	3.2	355
Research, applied	5.9	7.0	21.3	9.1	363
Sales	5.5	14.7	6.4	16.0	409
Teaching, college	2.7	14.5	56.7	3.0	342
Retired, student, unemployed	.8	-------	-------	-------	-------
All other occupational statuses	2.8	-------	-------	-------	-------
MINING AND METALLURGICAL					
All engineers reporting	100.0	13.8	23.1	14.5	$417
Administration-management, nontechnical	2.7	23.3	17.7	17.6	570
Administration-management, technical	38.8	18.1	23.3	15.8	501
Analysis and testing	3.7	8.4	15.5	22.2	306
Consulting, independent	2.0	35.0	25.6	28.2	420
Consulting, employee	3.9	19.6	34.7	12.2	475
Development	5.9	6.8	19.0	5.4	324
Operation	5.6	14.1	8.2	20.5	364
Production	6.4	8.5	10.0	15.0	312
Research, basic science	2.0	7.0	23.1	7.6	349
Research, applied	16.3	9.2	33.7	9.0	361
Sales	2.3	12.0	3.3	13.3	405
Teaching, college	2.6	22.1	66.7	3.0	427
Retired, student, unemployed	.6	-------	-------	-------	-------
All other occupational statuses	7.2	-------	-------	-------	-------
OTHER					
All engineers reporting	100.0	17.3	13.5	25.8	$410
Administration-management, nontechnical	5.2	19.3	7.7	26.5	508
Administration-management, technical	33.1	20.1	15.0	26.3	496
Analysis and testing	1.9	9.0	2.4	9.8	327
Construction supervision	4.1	19.8	5.4	31.9	387
Consulting, independent	1.6	30.0	16.7	36.6	460
Consulting, employee	3.3	17.5	13.3	24.0	496
Design	5.6	14.6	7.8	31.2	361
Development	3.5	9.4	13.1	14.5	381
Drafting	1.0	12.0	-------	33.3	295
Estimating	1.8	18.8	7.2	35.7	338
Inspection	2.4	20.6	1.9	50.9	330
Maintenance	1.8	9.0	5.0	22.5	327
Operation	2.5	18.9	5.3	26.3	403
Patents	1.0	18.3	8.7	8.7	574
Production	3.8	10.4	3.6	13.1	348
Research, applied	5.4	11.3	35.1	12.8	368
Safety engineering	5.4	17.0	4.0	48.0	366
Sales	7.0	15.7	7.2	22.2	399
Teaching, college	2.9	18.9	66.2	4.6	344
Retired, student, unemployed	.4	-------	-------	-------	-------
All other occupational statuses	6.3	-------	-------	-------	-------

Examination of salaries for men with comparable amounts of experience shows that, in most cases, those with degrees earn considerably more in the long run than do those who did not complete college. Only in the lowest experience bracket do engineers with the least formal education have salaries comparable to graduates in the same field. The relatively high over-all median salary for those who did not complete college is obviously the result of the age composition of the group; it should be noted (table 11) that in every field the median years of experience, and therefore the age, is highest for those without degrees.

In chemical engineering—a field in which a relatively large number hold advanced degrees—those with the doctor's degree had a median base monthly salary about $100 above those with the bachelor's degree through the first 10 years of experience, and after 25 years in the profession the differential was about $160 a month.

Civil engineers had less spread in earnings than engineers in most other fields, but the fact that those with the master's and the bachelor's degree ultimately earned $100 and $65 more, respectively, than those with incomplete or no college education, is good evidence that academic training is an asset. Holders of doctor's degrees employed in electrical engineering had consistently higher salaries than those at other educational levels. Highest salaries in mechanical and mining and metallurgical engineering were also earned by those with doctors' degrees.

The factors discussed so far which appear to affect earnings—experience, type of work, and education—are brought together in summary fashion in table 12. The engineering student, in particular, will be interested in knowing in what types of work the most engineers are employed within an engineering specialty, and in which jobs it is most necessary to have an advanced degree. An appraisal of the average salary for various jobs, as related to both education and experience, can also be made from table 12.

Industry

The distribution of engineers by industry differs greatly by field of engineering as was seen earlier in the section of this report on employment trends. (See also table D–9 in the appendix.) Salaries also vary considerably for each field of engineering within an industry. The data available from the 1946 survey (table 13) show no industry which consistently pays either exceptionally high or exceptionally low salaries, to all types of engineers. The range of median earnings by industry is wide for all engineering specialties—particularly for "other," chemical, and civil engineering.

TABLE 13.—*Median base monthly salary rates for each field of engineering employment, by broad industry field, 1946*

Industry field	Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other
Agriculture and forestry	(1)	$344	(1)	(1)	(1)	$351
Mining	$420	380	$390	$445	$429	405
Construction	380	362	389	411	(1)	388
Manufacturing	368	402	390	412	413	422
Food and textiles	381	(1)	(1)	454	(1)	460
Lumber and paper	357	(1)	(1)	410	(1)	500
Printing and publishing	(1)	(1)	(1)	(1)	(1)	(1)
Chemicals	377	389	385	416	(1)	400
Petroleum and coal	357	400	348	415	(1)	419
Rubber, stone, clay, and glass products	343	440	366	388	(1)	368
Iron, steel, and nonferrous metals	390	408	395	413	422	415
Machinery	379	374	391	414	352	432
Transportation equipment	450	340	397	410	395	439
Other manufacturing	355	(1)	382	399	(1)	423
Transportation	(1)	378	364	410	(1)	420
Communications	(1)	(1)	436	410	(1)	484
Utilities	317	392	367	395	(1)	419
Other specified industry fields	312	369	368	395	428	392
Industry fields not specified	340	395	386	401	343	411

[1] Insufficient reports to compute median.

Chemical engineers are employed chiefly in the chemical and petroleum industries. In 1946, these two industries paid median salaries of $377 and $357, respectively. Highest earnings were in other industries, in which relatively few of these engineers find employment.

The construction industry, which furnishes employment for the great majority of civil engineers, showed median monthly earnings of $362 in 1946, or slightly below the median for all civil engineers. The few civil engineers in some manufacturing industries had the highest median salaries.

Highest median salary in the electrical engineering field ($436) was in the communications industry which includes telephone, telegraph, and the relatively new field of radio broadcasting and television. The other large industry for electrical engineers—machinery manufacturing—paid a median salary slightly below that of the entire group.

The branch of the profession in which there was least variation by industry was in mechanical engineering. The range was only from $388 to $454, with median salaries of $414 in the machinery manufacturing industry and $413 in the iron and steel industry, which together employed about a fourth of the mechanical engineers.

In two industries which employed most mining and metallurgical engineers—mining and the processing of iron, steel, and nonferrous metals—median salaries were $429 and $422 respectively.

The group of "other" engineers seemed to be less concentrated in one or two industries than were the members of any of the major fields. The median salaries in industries employing the largest numbers were lower than in several of the industries where only a few engineers were employed.

Altogether, on the basis of the evidence available in this survey, differentials in salary by industry seem to lack significance—industry in itself does not appear to be a determining factor in the amount of money an engineer earns. The effect of other factors upon earnings, such as length of experience, type of work done, and level of education, is so great that it is difficult to determine whether differences in earnings among industries are significant in themselves or can be ascribed to differences in the experience or education of the engineers employed in the industries, or in the types of work they do. The sample was not large enough to make it possible to examine earnings of comparable engineers in the various industries.

Class of Worker

Most engineers find employment with private firms, organizations or institutions. However, public employment is of special importance to civil engineers, one-half of whom were so employed in 1946. The field in which public employment was least important was chemical engineering; only about 5 percent of these engineers were employed by public agencies. Earnings vary considerably between private and public employment, as shown in table 14.

In private employment, besides the employee group, are the engineers in business for themselves—the employer and the independent consultant. While these men may allow themselves a specified amount as monthly salary, or may actually draw a salary from another employer, it is obvious that base monthly salary is no indication of their total income. A discussion of the income of self-employed engineers will be found under the section on annual income. (See p. 62.)

A comparison of monthly earnings of employees of private firms with those of government employees is interesting. (See table 14 and appendix table D–17.) Since it is known that length

TABLE 14.—*Percentage distribution of engineers by median years of experience, and median base monthly salary rates for each field of engineering employment, by class of worker, 1946*

Field of engineering	Total	Employers	Employees of private firms	Independent consultants	Government employees					Other [1]
					Federal	State	County	Municipal	Other	
Chemical:										
Percentage distribution	100.0	3.5	86.9	1.3	2.8	1.8	0.1	0.6	0.2	2.8
Experience (years)[2]	9	14	8	27	8	9	(3)	(3)	(3)	----------
Salary	$363	$427	$365	$500	$363	$314	(3)	(3)	(3)	----------
Civil:										
Percentage distribution	100.0	7.0	38.6	4.0	19.7	15.1	3.5	10.0	1.2	0.9
Experience (years)[2]	22	23	20	25	19	22	25	24	26	----------
Salary	$368	$496	$382	$406	$399	$319	$316	$345	$400	----------
Electrical:										
Percentage distribution	100.0	3.8	79.2	1.5	9.8	1.6	0.1	1.8	0.9	1.3
Experience (years)[2]	16	20	15	20	11	19	(3)	20	16	----------
Salary	$393	$465	$395	$350	$406	$358	(3)	$343	$343	----------
Mechanical:										
Percentage distribution	100.0	6.6	80.0	2.8	7.0	1.5	(4)	0.7	0.3	1.1
Experience (years)[2]	13	20	12	19	9	19	(3)	24	20	----------
Salary	$409	$574	$407	$496	$400	$339	(3)	$373	$370	----------
Mining and metallurgical:										
Percentage distribution	100.0	4.7	80.0	3.4	7.7	2.1	----------	0.1	0.2	1.8
Experience (years)[2]	14	22	12	35	16	21	----------	(3)	(3)	----------
Salary	$417	$495	$415	$440	$415	$378	----------	(3)	(3)	----------
Other:										
Percentage distribution	100.0	10.0	65.1	3.6	11.0	5.3	0.4	1.9	1.2	1.5
Experience (years)[2]	17	19	16	26	16	20	(3)	20	22	----------
Salary	$410	$558	$413	$495	$410	$349	(3)	$335	$413	----------

[1] Includes students, retired, etc.
[2] Rounded to the nearest full year.
[3] Insufficient reports to compute median.
[4] Less than 0.05 percent.

of experience affects earnings, it is important to take this factor into consideration when analyzing any aspect of earnings. Engineers employed by the Federal Government had median years of experience comparable to private firm employees for most fields, and, likewise, salaries were generally comparable. In civil and electrical engineering, however, median salaries in the Federal Government were a little higher than those in private employment despite the fact that median years of experience were less by 1 to 4 years.

Engineers employed by State governments had median monthly earnings averaging nearly $60 less than Federal employees, although on the average, they reported a greater amount of experience.

Only in civil engineering were the numbers employed by county and municipal governments of any consequence. These employees had lower than average earnings. The large proportion of civil engineers in State and local employment may explain, in part, the comparatively low over-all salaries in this field of engineering.

Employment Location

Table D–14, in the appendix, shows the median salaries and the distribution of engineers for the principal States where engineers were employed in 1946. The three Middle Atlantic States (New York, New Jersey, and Pennsylvania) furnished employment for a fourth or more of all engineers, with New York State having the largest number in all fields except mining and metallurgical engineering. The average salary in New York was higher in each field of engineering than the average for the entire group. This is probably due in large part to the high proportion of administration-management jobs in central offices located in New York.

Highest salaries were reported by engineers located in the District of Columbia. This may be a result of the many administrative positions held by engineer employees in the Federal Government. Because the District of Columbia is an entirely urban area, earnings of engineers employed there cannot be compared with States which include rural areas and small towns with diversified industries and relatively low living costs.

It was not possible to determine whether differences in salaries by States are significant in themselves, or whether they merely reflect differences in types of engineering positions, and in the length of experience of the engineers employed.

Income in Addition to Base Monthly Salary

Among the factors affecting the total income of engineers is the amount of money which they receive in addition to their regular base salaries, from such sources as overtime, fees, bonuses, and other services in both engineering and nonengineering work. In addition to their base monthly salary rates, engineers were asked in the 1946 survey to report two other types of data on their earnings:

1. Monthly salary rates inclusive of overtime payments, but exclusive of fees and bonuses.
2. Annual income from salaries or personal services in both engineering and nonengineering work, including fees and bonuses.

Overtime was of little significance in 1939 and 1946, but in 1943, a year of heavy war production, the overtime paid to engineers was considerable. Table 15 shows that the younger groups profited the most from overtime payments, with median monthly salaries being increased by as much as $45 to $50 in some fields at the 1-, 2-, and 3-year experience levels.

There were wide differences in the effect of overtime on earnings in the various fields of engineering. The increase in median monthly earnings ranged from $15 for civil engineers to $30 for mechanical engineers. The nature of the work performed and its relation to war production were no doubt important factors in the amount of overtime required in 1943. Since younger men were in the jobs in which overtime payments were important, the age composition of the men in a field of engineering also affected the average amount of overtime paid.

Certain sources of income, such as fees, bonuses, and other extra payments for engineering or nonengineering services, were not included in the reports on monthly salary. However, the engineers

Table 15.—*Comparison of median monthly salary rates excluding and including overtime for each field of engineering employment, by years of experience, 1943*

Years of experience	Median monthly salary and overtime, by field of engineering employment											
	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Excluding overtime	Including overtime	Excluding overtime	Including overtime	Excluding overtime	Including overtime	Excluding overtime	Including overtime	Excluding overtime	Including overtime	Excluding overtime	Including overtime
All engineers	$278	$303	$313	$328	$313	$335	$326	$356	$332	$348	$331	$351
Less than 1 year	177	214	183	204	186	214	179	219	203	219	193	218
1 year	208	237	198	243	204	238	211	252	198	213	213	234
2 years	222	252	220	259	219	268	235	285	216	236	239	271
3 years	244	270	231	254	240	275	259	305	233	255	256	284
4 years	254	282	241	259	247	277	272	308	251	262	255	265
5 years	265	300	246	263	265	305	281	315	295	302	273	312
6 years	279	301	302	313	269	307	291	325	267	287	273	304
7–8 years	307	324	259	275	284	308	314	343	314	327	294	310
9–11 years	346	361	272	302	307	332	344	369	338	358	320	338
12–14 years	382	397	296	314	320	337	355	388	385	417	336	349
15–19 years	406	428	307	321	352	374	400	426	414	429	360	373
20–24 years	456	483	333	347	399	419	429	452	430	440	390	403
25–29 years	581	577	355	367	450	471	429	458	520	520	471	475
30–34 years	595	620	372	378	482	490	456	479	526	520	477	496
35–39 years	507	558	390	394	497	508	477	488	583	595	490	504
40 years and over	650	665	408	423	494	512	601	614	520	533	475	487

were asked to include such income, as well as salary and overtime payments, in their reports on annual income. Annual income was reported for 1939 and 1943. (Since the survey took place during the year 1946, it was not possible to collect annual income data for that year.) The extent of income received from sources other than regular salary and overtime pay may be appraised by comparing the average annual income reported with the figure computed by multiplying monthly salary rates (including overtime) by 12—what might be called "annual earnings from salary and overtime." This comparison is shown in table 16.

Engineers in all fields and at virtually all levels of experience had an average annual income in excess of their annual earnings as thus computed. Income from fees, bonuses, and so forth, is therefore a significant factor in the earnings of engineers. The fact that annual income for some of the younger engineers is less than 12 times the

Table 16.—*Comparison of median total annual income [1] and median computed annual earnings from salary and overtime,[2] for each field of engineering employment, by years of experience, 1943*

Years of experience	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Total income[1]	Earnings[2] (salary and overtime)	Total income[1]	Earnings[2] (salary and overtime)	Total income[1]	Earnings[2] (salary and overtime)	Total income[1]	Earnings[2] (salary and overtime)	Total income[1]	Earnings[2] (salary and overtime)	Total income[1]	Earnings[2] (salary and overtime)
All engineers	$3,673	$3,636	$4,087	$3,936	$4,196	$4,020	$4,485	$4,272	$4,480	$4,176	$4,501	$4,212
Less than 1 year	2,509	2,568	2,467	2,448	2,523	2,568	2,580	2,628	2,667	2,628	2,522	2,616
1 year	2,800	2,844	2,825	2,916	2,869	2,856	3,023	3,024	2,733	2,556	2,883	2,808
2 years	2,984	3,024	3,031	3,108	3,203	3,216	3,400	3,420	3,000	2,832	3,350	3,252
3 years	3,260	3,240	3,133	3,048	3,280	3,300	3,667	3,660	3,111	3,060	3,467	3,408
4 years	3,378	3,384	3,300	3,108	3,438	3,324	3,737	3,696	3,350	3,144	3,473	3,180
5 years	3,578	3,600	3,200	3,156	3,541	3,660	3,933	3,780	3,525	3,624	3,760	3,744
6 years	3,624	3,612	3,800	3,756	3,748	3,684	3,937	3,900	3,564	3,444	3,564	3,648
7–8 years	3,932	3,888	3,324	3,300	3,838	3,696	4,309	4,116	4,104	3,924	3,800	3,720
9–11 years	4,660	4,332	3,770	3,614	4,189	3,984	4,637	4,428	4,314	4,296	4,146	4,056
12–14 years	4,871	4,764	3,816	3,768	4,259	4,044	4,854	4,656	5,000	5,004	4,557	4,188
15–19 years	5,247	5,136	3,951	3,852	4,681	4,488	5,229	5,112	5,256	5,148	4,732	4,476
20–24 years	6,107	5,796	4,314	4,164	5,156	5,028	5,808	5,436	5,775	5,280	5,400	4,836
25–29 years	7,800	6,924	4,713	4,404	5,756	5,652	5,869	5,496	7,950	6,240	5,963	5,700
30–34 years	7,850	7,440	4,703	4,536	6,075	5,880	6,325	5,748	7,350	6,240	6,390	5,952
35–39 years	6,360	6,696	4,984	4,728	6,600	6,096	6,500	5,856	7,650	7,140	6,300	6,048
40 years and over	8,100	7,980	5,220	5,076	6,240	6,144	7,629	7,368	7,125	6,396	6,525	5,844

[1] Includes income received from salaries, overtime, personal services, fees, and bonuses, both engineering and nonengineering work.

[2] Computed by multiplying median monthly salary, including overtime, by 12 (excludes fees, bonuses, and any income from nonengineering work).

monthly salary indicates that some engineers did not work the full 12 months.

Income from fees and bonuses appears to increase with additional experience. After about 5 years of experience engineers reported a noticeable amount of extra income, and in most cases it attained greatest importance for engineers who had about 25 to 35 years of experience. There is great variation among engineering fields in the amount received above salary. For example at the 25–29 year experience level the difference between median annual income as reported and median annual earnings including overtime as computed, ranges from about $100 for electrical engineers to $1,700 for mining and metallurgical engineers. Such differences may reflect the numbers engaged in consulting or other independent work in which fees and bonuses are significant.

It is interesting to see in what type of employment engineers earn the greatest amounts beyond their base salaries. Table 17 shows median annual income as reported for 1943 compared to base annual salary (computed without overtime) for engineers in private and those in public employment. As might be expected, those in private employment had somewhat more income from sources other than salary than did engineers in public employment. However, it is the employers and independent consultants who had the really significant additional income. Since men in these positions are known to be concentrated in the higher experience brackets, and therefore receive only a small amount of overtime pay (see table 15), it can be assumed that their additional income is derived largely from such sources as fees and bonuses. On page 59 of this report, it is pointed out that monthly salary for employers and consultants lacked significance. The annual incomes shown in table 17 are a more accurate reflection of the earnings of these engineers.

TABLE 17.—*Comparison of median total annual income [1] and median computed annual base salary [2] (excluding overtime) for each field of engineering employment, by class of worker, 1943*

Field of employment (class of worker)	Median annual income and median annual base salary											
	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Total income [1]	Base salary [2]	Total income [1]	Base salary [2]	Total income [1]	Base salary [2]	Total income [1]	Base salary [2]	Total income [1]	Base salary [2]	Total income [1]	Base salary [2]
Total	$3,673	$3,336	$4,087	$3,756	$4,196	$3,756	$4,485	$3,912	$4,480	$3,984	$4,501	$3,972
Private employment	3,705	3,372	4,701	4,152	4,377	3,876	4,642	4,020	4,528	4,008	4,721	4,152
Employer	6,000	4,860	10,088	6,204	7,950	6,264	10,200	7,440	7,500	5,360	8,550	7,092
Employee of a private firm	3,667	3,372	4,548	4,080	4,333	3,840	4,542	3,960	4,388	3,960	4,535	4,056
Independent consultant	(3)	(3)	5,438	4,500	5,500	4,716	9,100	6,240	9,700	3,840	6,960	5,196
Public employment	3,433	3,132	3,721	3,480	3,760	3,336	3,791	3,348	4,308	3,864	3,958	3,600
Employee of Federal Government	3,556	3,108	3,899	3,552	3,795	3,336	3,690	3,300	4,400	3,888	4,044	3,624
Employee of State government	3,150	3,096	3,414	3,312	3,889	3,456	4,120	3,756	3,960	3,804	3,633	3,492
Employee of county government	(3)	(3)	3,486	3,288	(3)	(3)	(3)	(3)	----	----	(3)	(3)
Employee of municipal government	(3)	(3)	3,819	3,612	3,611	3,348	4,250	3,960	(3)	(3)	3,667	3,480
Employee of other public authority	(3)	(3)	4,240	4,212	3,633	3,288	(3)	(3)	(3)	(3)	5,150	4,920

[1] Includes income received from salaries, overtime, personal services, fees, and bonuses in both engineering and nonengineering work.
[2] Computed by multiplying base monthly salary by 12 (excludes overtime, fees, bonuses, and any income from nonengineering work).
[3] Insufficient reports to compute median.

Trends in Earnings

The influence of general economic conditions on engineers' earnings is of interest to members of the profession and prospective students. Reports on remuneration and other pertinent data were collected for 1939 and 1943 as well as 1946 in the most recent survey made by the Bureau, and for 1929, 1932, and 1934 in the previous survey.[9] Thus the information available covers a period in which there were significant changes in the National economy—1929, a year in which earnings were high and there was little unemployment in any of the professions; 1932 and 1934, severe depression years with attendant low salaries, unemployment, and work relief; 1939, a year in which the country was recovering from the depression; 1943, a war year; and 1946, a postwar year with full employment and continuing shortages of technical manpower.

[9] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession 1929 to 1934*, Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

MONTHLY SALARIES, 1929–46

Since the earnings range of engineers is so wide, and so great a variety of factors affect those earnings, figures for fields of engineering employment are of limited significance. However, it is of interest to examine table 18 and note the general effect of economic conditions on average monthly salaries. From 1929 to 1934 engineers in all fields suffered decreases in median salaries ranging from $60 to $123 a month or about 22 to 38 percent, depending upon field of specialization. Engineers who were most dependent on manufacturing industries apparently had the greatest decreases. From 1934 to 1939 there was an upswing in earnings, but increases were not sufficient to bring average salaries back to 1929 levels. As a matter of fact, over the decade from 1929 to 1939 earnings decreased by from 8 percent to nearly 33 percent, depending on field of engineering.

Earnings advanced further after 1939 as first the defense production period and then the war boosted the demand for engineers. By 1943, average monthly salaries had advanced beyond the 1929 level for all but chemical and mining and metallurgical engineers.

By 1946, earnings had advanced further in all fields. From 1939 to 1946 they advanced by $125 to $150, or over 50 percent in every field. Over the entire 17-year period (1929–46) median monthly earnings increased by 11.3 percent for chemical engineers, 24.9 percent for mining and metallurgical engineers, 32.9 percent for civil engineers, 31.5 percent for mechanical engineers, and 42.9 percent for electrical engineers.

There is considerable evidence that earnings of engineers have increased since 1946. A survey of members of the Institute of Ceramic Engineers showed an increase from 1946 to 1947 of 6.3 percent in median base monthly salaries for that group.[10] Scattered reports from schools of engineering indicated that graduates in 1948 were receiving monthly salaries from $10 to $75 higher than those offered graduates in 1947. A survey made of business and industrial concerns in late 1948 regarding the employment of college and university graduates revealed that 121 companies paid an average monthly salary of $261 for starting engineers. A similar survey a year earlier indicated an average starting salary of approximately $235 per month.[11] Reports from a survey of Stanford University engineering graduates, who received degrees during the school year June 1947 to June 1948, showed average starting salaries of $261 a month for engineers with the bachelor's degree and $297 for those with the master's degree.[12] Most beginning engineers employed by the Federal Government received a salary increase from about $225 to $250 a month in 1948.

Eighty-six companies, employing large numbers of engineers, indicated that the percentage increase in salary that had occurred between August 1946 and the end of 1948 was 20 percent. It was believed that salaries of younger engineers increased by a greater percent than those of more experienced engineers.[13]

[10] *Economic Status of Ceramic Engineers, 1939 to 1947.* Mimeographed report available on request to the U. S. Department of Labor's Bureau of Labor Statistics, Washington 25, D. C.

[11] *Trends in the Employment of College and University Graduates in Business and Industry,* School and College Placement, March 1949, p. 57.

[12] Stanford University, *An Employment Survey of Stanford University Engineering Graduates Who Received Degrees During the School Year June 1947 to June 1948,* Stanford University, Calif., December 1948. Mimeographed. 12 pp.

[13] American Society of Engineering Education, *A Survey of Teachers' Salaries in Engineering Schools and a Comparison of These With Salaries Paid to Engineers in Nonteaching Employment,* June 1949, p. 31.

TABLE 18.—*Comparison of median base monthly salary rates, by field of engineering employment for specified years*

Field of engineering employment	Median monthly earnings						Amount of increase or decrease						Percentage increase or decrease					
	1929	1932	1934	1939	1943	1946	1929–34	1934–39	1939–46	1929–39	1934–46	1929–46	1929–34	1934–39	1939–46	1929–39	1934–46	1929–46
Chemical	$326	$251	$203	$220	$278	$363	−$123	$17	$143	−$106	$160	$37	−37.7	8.4	65.0	−32.5	78.8	11.3
Civil	277	229	205	244	313	368	−72	39	124	−33	163	91	−26.0	19.0	50.8	−11.9	79.5	32.9
Electrical	275	232	215	253	313	393	−60	38	140	−22	178	118	−21.8	17.7	55.3	−8.0	82.8	42.9
Mechanical	311	246	215	258	326	409	−96	43	151	−53	194	98	−30.9	20.0	58.5	−17.0	90.2	31.5
Mining and metallurgical	334	274	241	267	332	417	−93	26	150	−67	176	83	−27.8	10.8	56.2	−20.1	73.0	24.9

Chart 12.—How Engineers' Salaries Increased With Years of Experience Under Varying Economic Conditions

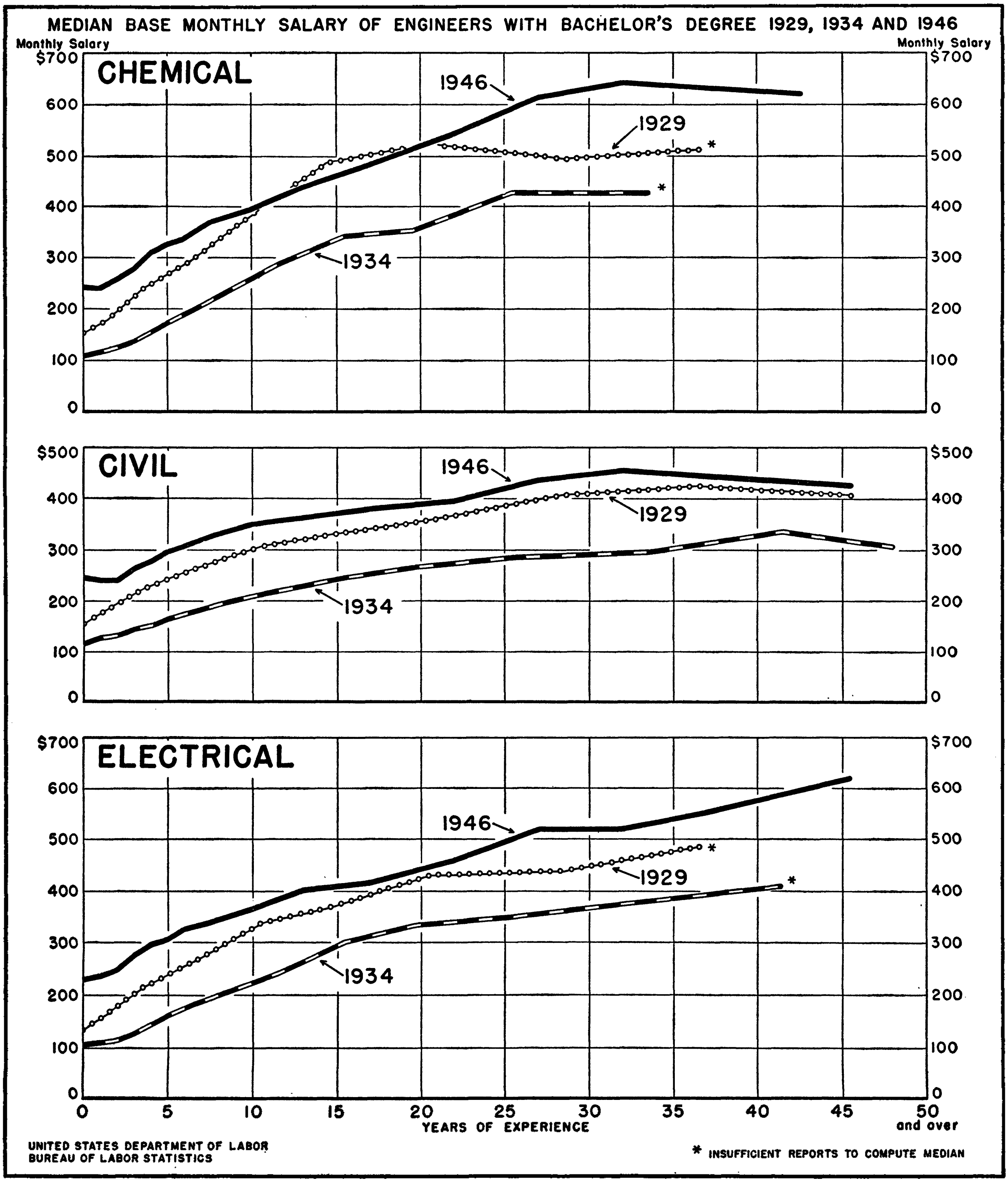
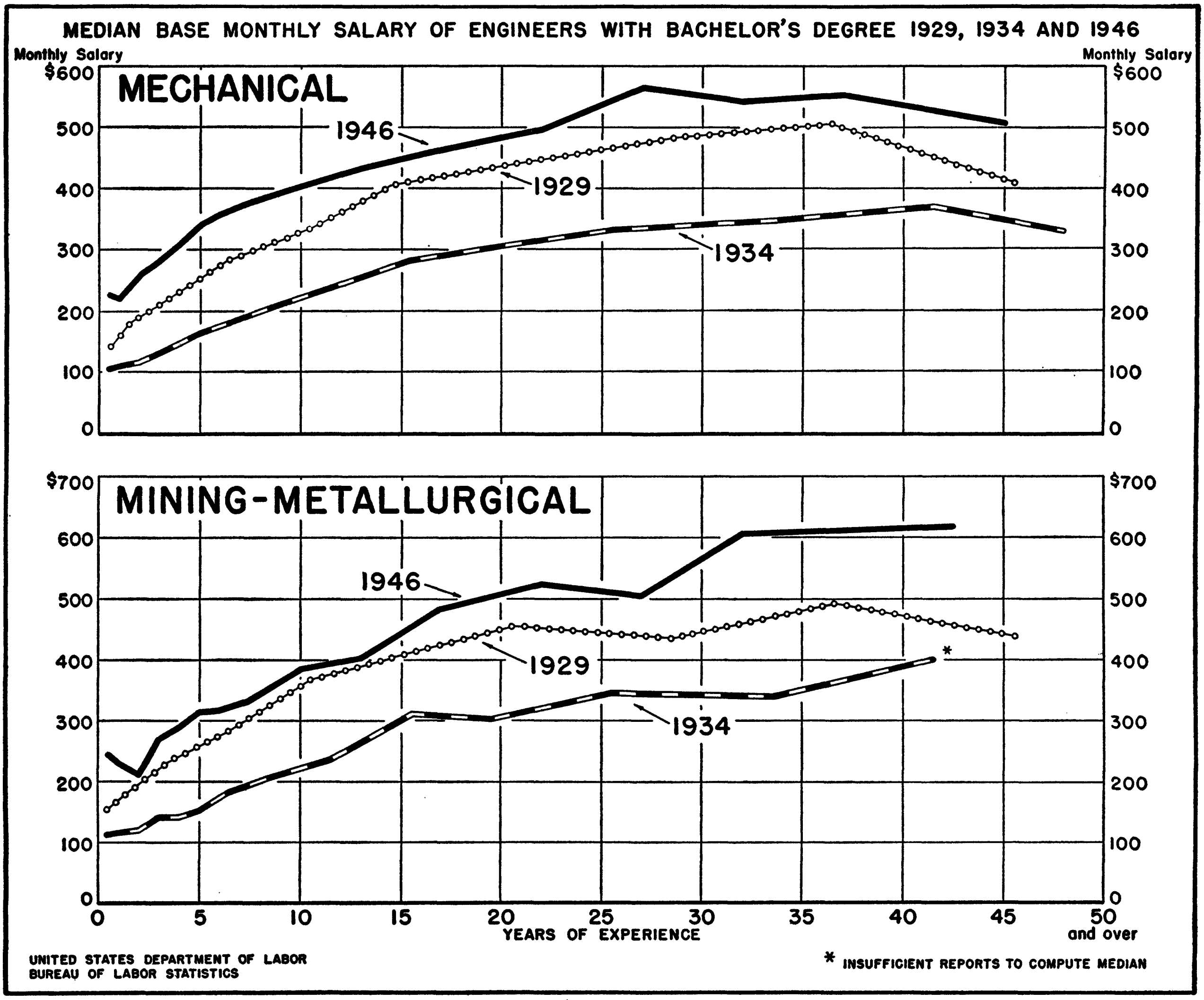


Chart 12.—How Engineers' Salaries Increased With Years of Experience Under Varying Economic Conditions—Continued



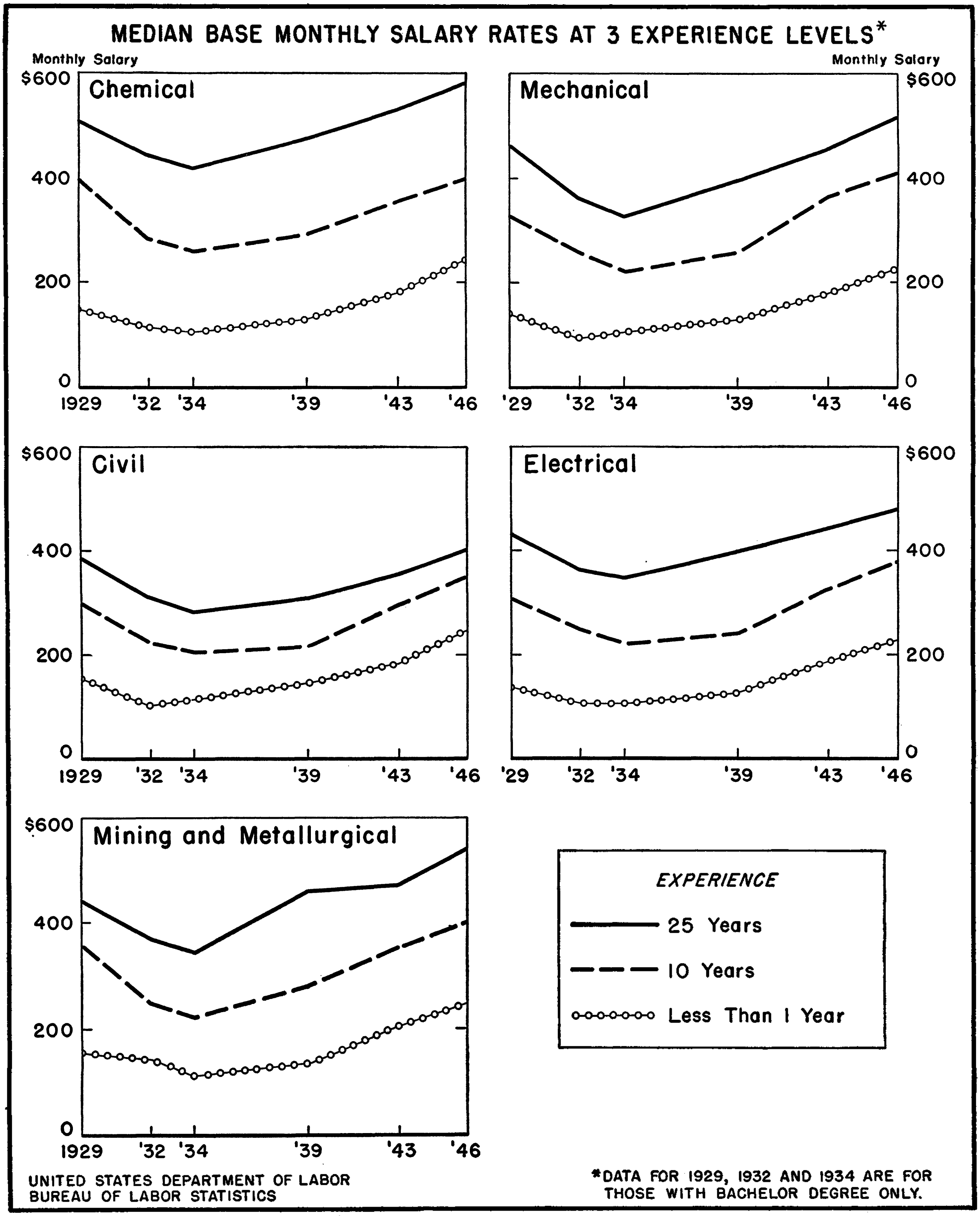
A more recent survey of industrial companies and governmental agencies concerning their 1949 employment programs for engineering graduates revealed the following median monthly starting rates, depending on field of engineering; bachelor's degree—$250 to $275, master's degree—$275 to $315, doctor's degree—$295 to $400. The same survey showed that engineering graduates who had been out of school for 10 years in late 1948 were receiving 20 percent higher salaries than graduates with similar experience in 1946.[14]

It has been mentioned earlier in this report that the educational level of engineers has risen noticeably in the last 15 or 20 years. In order to eliminate the possible bias in earnings data caused by differences in education, chart 12 (see also appendix table D-6) presents median base monthly salary for 1929, 1934, and 1946 for those engineers with the bachelor's degrees, the most common educational preparation among engineers. Because of the high proportion of engineers at this level of education, average salaries of those with the bachelor's degree differ very little from average salaries when engineers at all educational levels are combined.

The manner in which earnings of engineers at

[14] See footnote 4, p. 11.

Chart 13.—Engineers' Salaries Over a 17-Year Period



the different experience levels were affected by economic conditions is best demonstrated by chart 13. In all fields of engineering, beginner's salaries were cut less from 1929 to 1934, both in dollars and percentagewise (about $35 or 26 percent) than were those of more experienced engineers. Entrance salaries were also the first to regain their predepression level, and rose, from 1934 to 1946, by approximately $130 or over 100 percent.

Engineers at the 10-year experience level received, in 1934, approximately $100 or 30 percent less than similarly experienced engineers in 1929. In most fields it was a decade or more before salaries of engineers with 10 years of experience had risen to the 1929 average.

Economic conditions appear to have affected older engineers—those with 25 years of experience—in about the same manner as those at the 10-year level, although the percentage decrease in earnings from 1929 to 1934 was somewhat less in most fields for the more experienced group.

It should be pointed out that this discussion is limited to the effect of economic conditions on actual reported earnings at different experience levels. Unemployment imposed hardships on these groups in differing degrees. It is known that many graduates were not able to enter the profession during the thirties, thus salary data tell only a part of the depression story for the beginning group of engineers.[15]

ANNUAL INCOME, 1929–43

The trend in annual income over the 14-year period beginning in 1929 can be clearly seen in table 19. From 1929 to 1934 income decreased considerably in all major fields. Chemical engineers experienced the greatest decrease in median incomes (46 percent). Income of civil engineers declined least, both in dollar amount and percentagewise (30 percent). Annual incomes, particularly in the years 1932 and 1934, were affected considerably by periods of unemployment. By 1939, incomes had risen substantially in all fields but the averages were still less than they had been a decade earlier. In the next 4-year period (1939-43) increases of approximately $900 to $1,200 brought them above the 1929 medians, except for the chemical engineering field where the influx of young engineers kept the average income figure low in relation to other fields. It is evident that over the entire period covered by the two surveys, economic conditions caused earnings in all fields of engineering to move in the same general direction.

TABLE 19.—*Comparison of median annual income, by field of engineering employment, for specified years*

Field of engineering employment	Median annual income					Amount of increase or decrease						Percentage increase or decrease					
	1929	1932	1934	1939	1943	1929–34	1934–39	1939–43	1929–39	1934–43	1929–43	1929–34	1934–39	1939–43	1929–39	1934–43	1929–43
Chemical	$3,803	$2,625	$2,047	$2,756	$3,673	−$1,756	$709	$917	−$1,047	$1,626	−$130	−46.2	34.6	33.3	−27.5	79.4	−3.4
Civil	3,291	2,545	2,297	3,089	4,087	− 994	792	998	−202	1,790	796	−30.2	34.5	32.3	−6.1	77.9	24.2
Electrical	3,277	2,509	2,214	3,214	4,196	−1,059	996	982	−63	1,978	919	−32.3	44.9	30.6	−1.9	89.2	28.0
Mechanical	3,699	2,681	2,324	3,269	4,485	−1,375	945	1,216	−430	2,161	786	−37.2	40.7	37.2	−11.6	93.0	21.2
Mining and metallurgical	4,010	3,061	2,626	3,450	4,480	−1,384	824	1,030	−560	1,854	470	−34.5	31.4	29.9	−14.0	70.6	11.7

Implications for Guidance

The extent to which a prospective student is influenced in choosing a field of work by the monetary returns which he expects is not known, but there has always been a demand for this information from persons seeking vocational guidance. Certainly greater weight should be given to other more important considerations—such as general interest and ability—but a young person does want to know what he may expect in the way of a beginning salary and opportunities for advancement. Similarly, older engineers want information about prevailing rates for jobs at higher

[15] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934*, Bulletin 682,, pp. 92–119, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

levels, and such information sometimes is an important factor in job changes.

The section of this report which discusses earnings shows what has happened to the average income of engineers over a period of 17 years under varying economic conditions. It also demonstrates that earnings are affected by such factors as length of experience, education, kind of work done, type of employer, and that they vary sharply with general economic conditions.

While statistical surveys, such as those made in 1935 and 1946, are useful in showing what the average person may expect by way of remuneration in the engineering profession, caution should be exercised in applying such findings to individual cases. The salary range is great. Many engineers never advance beyond the earnings level of the average clerical or factory worker; in 1946, as many as one-fourth of the engineers with 6 to 11 years of experience averaged less than $330 monthly. On the other hand the highest paid 10 percent of the engineers with 5 years' or less experience had higher median earnings than the lowest 10 percent of the group with 30 years' or more experience. So it is evident that, while experience does increase earning capacity, it does not do so for everyone. It is perfectly possible for a man with a degree in engineering to remain in low salaried jobs.

Young people who are spending their time and money to attain a college education should know that they can gain an engineering degree without having the capacity to advance far up the professional ladder. If they give up the chance to be top-notch artisans, good foremen, or able salesmen merely to become mediocre engineers, they are paying a high price for their status as professional workers. Nor is it merely a matter of absolute incompetence. There are successive ceiling levels, and fairly considerable numbers who are capable of performing jobs at a higher level are bound to find themselves remaining in routine assignments. On the other hand, the top of the profession is so well rewarded both in terms of remuneration and job content that it is well worth sacrifice and struggle to attain it. Furthermore it is still possible, although increasingly difficult, for a man not trained in college to supply himself with a background of knowledge sufficient to gain a foothold and to advance in engineering.

In this report, little emphasis has been placed on the differences in earnings among the various fields of engineering. Many of these differences may be explained by the age distribution, educational level, or type of work done by engineers in each field. However, the supply and demand situation in the various fields has no doubt influenced earnings to a great extent. The rapid expansion of industries using certain types of engineers may create scarcities of experienced men and result in high salaries being paid by employers who are competing for the services of these men. So it must not be concluded that the pattern of differences in earnings among fields of engineering, as shown in the 1946 survey, will necessarily continue in the future.

Occupational Mobility of Engineers

What is the extent of occupational flexibility in engineering? Are engineers able to obtain employment in fields other than those in which they received their formal education? Do engineers shift among the different fields of specialization within engineering, as well as to and from occupations outside the field? To what extent do they move among industries and from one State to another? Finally, how often do they change functions within a field and what are the patterns of such shifts, if any?

These questions are of practical interest. The young man who is thinking of entering the profession may be interested in his ability to get a job in another branch of engineering if he should be unable to find employment in the branch in which he majors in college. Educators in the field may be concerned with the flexibility of the engineering force of the Nation—its ability to adapt to changing economic or military needs, and the implications, if any, for engineering education. To those responsible for recruitment and employment of technical personnel, information on the movement of engineers among industries may be of interest.

The 1946 Survey of the Engineering Profession provides some information on the occupational mobility of individuals between 1939 and the other two survey years, 1943 and 1946. From the point of view of assessing the mobility of engineers, these years are well chosen. The first was a year in which the Nation's economy had not yet recovered from a depression; the second, one of full mobilization for war; the third, a postwar year of high employment levels. The over-all demand for engineers greatly increased during the intervening 7 years, and the character of the demand shifted, with changing emphasis on the various types of engineering work. Following a peak in construction activity in 1942, needs for civil engineers dropped, to recover somewhat in 1946. The conversion of metalworking industries to production of munitions in late 1941 and early 1942 called for mechanical and electrical engineers—particularly the former—to do the required plant lay-out, design, and development work. The operation of new shipyards, and plants making aircraft, munitions, explosives, synthetic rubber, aviation gasoline, and many other products created many new jobs for mechanical, electrical, chemical, and metallurgical engineers, while the need to expand output of metals by the working of less profitable ores made for increased demand for mining engineers. Research on products such as weapons and drugs needed during the war called for highly trained engineers in certain specialties, as well as physicists, chemists, and other scientists.

These changing industrial needs resulted in shifts of men among engineering fields. As activity increased in certain industries and declined in others, and as plants and research centers were built in new locations—often far from prewar centers of manufacturing activity—the need arose for engineers to move from one industry or State to another.

Relationship Between Education and Employment

One of the more significant aspects of occupational mobility among engineers is the ability of some members of the profession to find employment in a branch of engineering other than the one in which they received their education. During their working lives, more than 20 percent had changed to a field of engineering employment other than that in which they were educated. These changes are made possible by the fact that the core of basic engineering training is common to all fields.

The educational background of the men employed in each field in 1946 is shown in table 20–A. As would be expected, the majority of those employed in each specific field were educated in that field. However, between 10 and 36 percent of the engineers employed in each field had received their education in some other field.

A greater proportion of those educated in mining or metallurgical engineering changed to some other employment field than did those educated in any other field. These changes appear to have been made easier by the fact that mining engineer-

TABLE 20–A.—*Percentage distribution of engineers within 1946 employment fields, by field of education*

Field of education	Total	Field of engineering employment						Nonengineering employment
		Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other	
Total reporting	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Chemical	14.5	90.5	1.4	.9	2.4	16.7	8.7	17.8
Civil	21.7	2.0	86.4	1.3	5.6	4.4	18.0	18.2
Electrical	22.9	.8	2.0	87.3	7.1	2.6	14.2	21.6
Mechanical	24.1	2.3	2.7	4.0	70.3	4.7	16.8	18.9
Mining and metallurgical	5.3	1.1	1.8	.2	1.3	64.2	4.6	6.4
Other engineering	7.1	1.0	1.5	2.0	9.1	3.3	30.9	9.9
Nonengineering [1]	4.4	2.3	4.2	4.3	4.2	4.1	6.8	7.2

[1] Includes respondents who indicated no college training in engineering but who may have had such training in a nonengineering field.

ing training and experience is so varied that it gives some men an opportunity to qualify for mechanical and civil engineering.

There was considerable movement out of chemical engineering but relatively less movement into that field. More than 26 percent of the respondents educated in chemical engineering were employed in other fields in 1946, principally in mining and metallurgical, "other", and mechanical engineering. In contrast, only 10 percent of the men employed in chemical engineering were educated in other fields. This may be explained in part by the fact that there were more graduates in chemical engineering than in any other single field, except mechanical, from 1941 to 1944. Perhaps another factor was the more comprehensive content of the chemical engineering curriculum, as compared to the relatively little background in chemical engineering given in the curricula for other fields.

The proportion of men with training in the same branch of engineering in which they were employed in 1946 was highest in chemical (90.5 percent), electrical (87.3 percent), and civil engineering (86.4 percent). Mechanical and mining and metallurgical engineering had relatively fewer men with training in their respective employment fields. Only 70 percent of the engineers employed in mechanical engineering had been educated in that field—the remainder having been drawn chiefly from among those educated in electrical, civil, or "other" engineering. This is explained in part by the great wartime and postwar demand for mechanical engineers and in part by the fact that industrial engineers were asked to report their field of employment as mechanical, while many such men who had received degrees in industrial engineering reported this under "other fields of education." Only 64 percent of those employed in mining and metallurgical engineering had been trained in these fields; nearly 17 percent had majored in chemical engineering.

A clear-cut analysis of the movements to and from "other" engineering and nonengineering fields of employment cannot be made because the manner in which the individual respondents classified themselves, if engaged in a specialized field of engineering, is not known. For example, a sanitary engineer may have regarded his field of employment either as civil engineering or as "other" engineering, making it difficult to establish the relationship between education and employment fields for this group. Likewise, it was found that some few engineers who had advanced to administration-management jobs classified themselves as in nonengineering employment, thus losing the relationship to their field of engineering education.

Schools of engineering may ask the question in another way: To what fields of engineering employment did the graduates of each course go? This is answered in table 20–B. Between 19 and 31 percent of the men trained in each field of engineering were employed in some other field in 1946.

The smallest proportion of transfers from a field of basic education to some other field of employment occurred among mechanical engineering majors, probably because of the great wartime demand in this field. Narrowing the discussion to the five major fields, chart 14 on page 72 shows the flow of engineers from the branch in which trained to other fields of employment.

TABLE 20-B.—*Percentage distribution of engineers educated in each field, by 1946 employment*

Field of education	Total	Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other	Nonengineering
Total reporting	100.0	11.8	19.3	20.4	27.8	5.7	10.2	4.8
Chemical	100.0	73.5	1.9	1.3	4.7	6.5	6.2	5.9
Civil	100.0	1.1	76.7	1.2	7.3	1.2	8.4	4.1
Electrical	100.0	.4	1.7	77.8	8.6	.6	6.3	4.6
Mechanical	100.0	1.1	2.2	3.4	81.3	1.1	7.1	3.8
Mining and metallurgical	100.0	2.6	6.4	.7	6.7	68.9	8.9	5.8
Other engineering	100.0	1.7	4.1	5.6	35.3	2.6	44.0	6.7
Nonengineering [1]	100.0	6.1	18.3	20.2	26.5	5.3	15.7	7.9

[1] Includes respondents who indicated no college training in engineering but who may have had such training in a nonengineering field.

Transfers Among Fields of Employment

Movement of the respondents from one field of engineering to another and between nonengineering and some engineering field reflects both the changing character of the demand for engineers and the extent to which the basic engineering education and actual experience in one field enable an engineer to carry on the work in another branch of the profession.

Only those reports with a general field of employment indicated for all three survey years were used for the analysis of movements between fields of employment, therefore all engineers with less than 7 years of experience were excluded. Reports from respondents who were in the armed forces or outside the continental United States were also excluded. The shifts that are shown to have taken place were notable in view of these exclusions, for it is likely that the younger engineers who were omitted were among the most mobile members of the profession.

The following tabulation indicates the net effect of the shifts that took place, by showing the percentage distribution of the engineers by field of employment in each of the 3 years.

Field of employment	*1939 Percent*	*1943 Percent*	*1946 Percent*
Chemical	9.0	9.0	8.9
Civil	23.0	21.4	21.5
Electrical	20.5	20.9	20.6
Mechanical	25.7	28.1	27.0
Mining and metallurgical	5.8	5.7	5.6
Other engineering	10.9	10.9	11.1
Nonengineering	5.1	4.0	5.3
Total reporting	100.0	100.0	100.0
Total number reporting	16,765	16,765	16,765

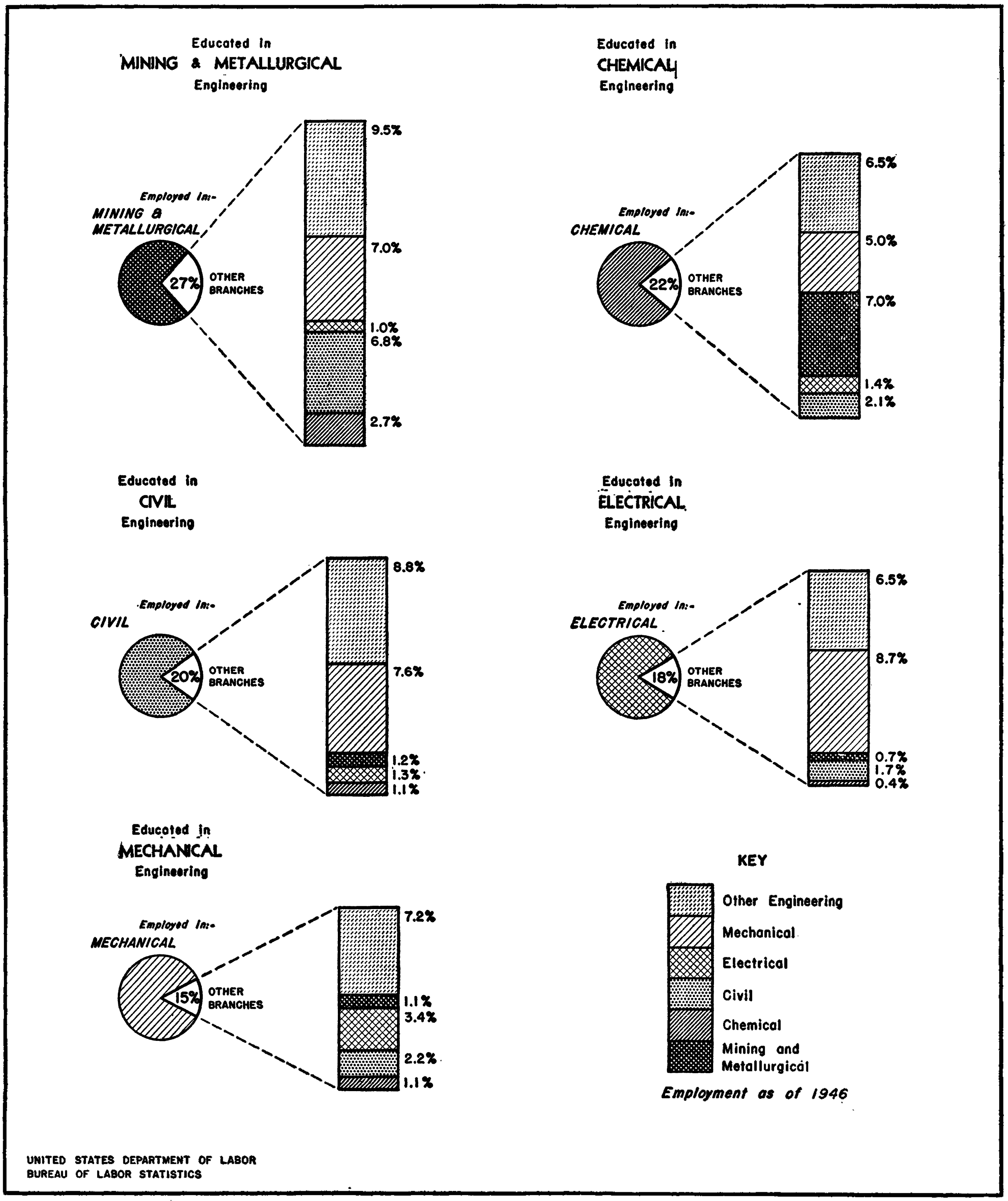
Employment in mechanical engineering gained the most between 1939, before preparation for national defense began, and 1943 when war production really began to roll. The field of electrical engineering also showed a slight net increase in employment by 1943. Civil engineering decreased considerably by 1943, by which time war construction had passed the peak and government controls had curtailed construction activities. The number employed in mining and metallurgical engineering also declined, and some respondents who had been in nonengineering work in 1939 had entered engineering employment by 1943.

From the war to the postwar period (1943–46) the net changes in employment field were not great. The mechanical engineering field showed some decrease, but the number leaving did not offset the increase between 1939 and 1943. The chemical, electrical, and mining and metallurgical fields of employment also showed slight net decreases from 1943 to 1946.

Field of employment	*Percent of respondents in 1939 who were in—* Same field all survey years—1939, 1943, 1946	Same field 1939 and 1946, but different field 1943	Different field each survey year
Total	86.5	2.1	0.9
Chemical	88.2	1.5	1.1
Civil	86.2	3.1	.9
Electrical	91.6	1.3	.4
Mechanical	92.1	.9	.5
Mining and metallurgical	85.8	1.5	1.1
Other engineering	80.7	2.7	1.3
Nonengineering	50.0	6.2	3.9

A summary of the shifts made by individuals is given in the preceding tabulation which shows the percent of those employed in 1939 who were in the same field in all three survey years, the percent

Chart 14.—Engineers Educated in One Branch of Engineering But Employed in Another



who moved to another field during the war but returned to their original field by 1946, and the percent who indicated three different employment fields.

While the great majority of the engineers remained in their prewar field of employment throughout the period, from 8 to 14 percent of those in each of the five major branches of engineering in 1939 transferred in one of the subsequent years. Among these only a small fraction—between 1 and 3 percent—returned to their prewar fields by 1946. The balance of those who shifted during the war remained in the fields to which they had transferred, except a small group who shifted among three or more different branches in the 7-year period. The greatest degree of stability was shown by those employed in mechanical and electrical engineering. These are the fields in which there was greatest expansion of the need for engineers during the war; those employed in them tended to remain there.

The changes in employment field are shown in greater detail in table 21. Of those who changed their field of employment between 1939 and 1943, the greatest percentage went into mechanical engineering, and the fewest left this branch. Very significant is the fact that there were some shifts made among all fields.

Some of the changes in field of employment between 1943 and 1946, as shown in the second section of table 21 represent what we can assume to be a return to an original field after the war, as presented in column 2 of the tabulation on page 71. Probably the most significant shifts were those into mechanical engineering. Despite the fact that the exodus from mechanical engineering (7.5 percent) was greater than that from any other of the five major fields, more of those who transferred out of other branches entered mechanical engineering than any other field of engineering. The greatest percent of those changing field

TABLE 21.—*Percentages of respondents*[1] *who shifted or remained in same field of employment, 1939, 1943, and 1946*

Field of employment	Total reporting	Engineering						Nonengineering
		Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other	
In 1939		*Field of employment in 1943*						
Total reporting	100.0	9.0	21.4	20.9	28.1	5.7	10.9	4.0
Chemical	100.0	91.8	.2	.4	2.8	1.4	1.6	1.8
Civil	100.0	.4	89.6	1.1	5.2	.3	2.1	1.3
Electrical	100.0	.2	.3	94.5	2.8	.1	1.2	.9
Mechanical	100.0	.5	.4	1.5	95.5	.1	1.2	.8
Mining and metallurgical	100.0	1.3	1.2	.5	3.4	90.5	2.0	1.1
Other engineering	100.0	.8	2.5	2.9	5.7	.7	85.2	2.2
Nonengineering	100.0	6.7	5.3	11.0	13.3	2.4	6.8	54.5
In 1943		*Field of employment in 1946*						
Total reporting	100.0	8.9	21.5	20.6	27.0	5.6	11.1	5.3
Chemical	100.0	94.7	.2	.4	1.1	.3	.9	2.4
Civil	100.0	(2)	95.3	.3	1.2	.3	1.3	1.6
Electrical	100.0	.1	.3	95.4	1.5	----------	1.0	1.7
Mechanical	100.0	.4	1.9	1.3	92.5	.3	1.6	2.0
Mining and metallurgical	100.0	.6	.7	.1	1.5	93.4	1.6	2.1
Other engineering	100.0	.7	2.3	1.0	1.6	.4	90.5	3.5
Nonengineering	100.0	2.3	3.8	2.3	3.0	.8	3.9	83.9
In 1939		*Field of employment in 1946*						
Total reporting	100.0	8.9	21.5	20.6	27.0	5.6	11.1	5.3
Chemical	100.0	89.7	.4	.5	2.6	1.4	2.3	3.1
Civil	100.0	.5	89.2	1.2	4.1	.3	2.3	2.4
Electrical	100.0	.2	.3	92.9	2.7	.1	1.5	2.3
Mechanical	100.0	.5	.6	1.6	93.0	.3	1.8	2.2
Mining and metallurgical	100.0	1.8	1.6	.5	3.2	87.3	2.8	2.8
Other engineering	100.0	.9	2.9	3.0	5.2	.8	83.4	3.8
Nonengineering	100.0	6.4	5.3	10.6	11.8	2.5	7.2	56.2

[1] Percentages based on 16,543 respondents who were employed in all 3 survey years.
[2] Less than 0.05 percent.

between 1943 and 1946 went to nonengineering employment.

Shifts made by individuals from their 1939 field of employment to their 1946 field of employment are shown in the third section of table 21. It appears that around 5 to 10 percent of those in each of the major engineering branches in 1939 had changed to one of the other engineering fields of employment by 1946, and that the changes made were similar to the changes made from field of basic engineering education to field of employment, but in smaller proportions. Of those who changed from their 1939 employment field by 1946, the greatest percent from most fields transferred to mechanical engineering. About 2 to 3 percent from each field of engineering went into nonengineering work over the period.

In summary, several points stand out in the analysis of shifts among fields of engineering employment:

1. It was possible for at least a few engineers to shift from each field to every other field. There is some transferability of basic engineering knowledge among all major fields.
2. Of those in each of the five major fields in 1939, between 8 and 14 percent had made a transfer by 1943 or 1946. Few of the engineers who shifted during the war had returned to their original field by 1946.
3. Mechanical engineering was the beneficiary of more of the shifting, both during and after the war, than any other major engineering field. Civil engineering lost the greatest proportion during the war, and by 1946 had gained few, aside from men who had been civil engineers in 1939.

Transfers Among Class-of-Worker Categories

The engineering profession, though originally composed largely of those in private practice, now consists mainly of salaried employees of private firms. Government employment of engineers has also assumed considerable importance.

Movement of engineers from 1939 to 1946 is discussed in this section on the basis of their reports on class-of-worker status. The percentage distribution of the respondents by class of worker for each survey year, showing the net result of the changes made by individuals, is as follows:

Class of worker [1]	*1939 Percent*	*1943 Percent*	*1946 Percent*
Private industry	73.5	74.5	75.6
Employers	4.9	4.8	6.6
Employees of private firms	66.5	68.0	66.1
Independent consultants	2.1	1.7	2.9
Public employment	21.7	22.5	20.1
Federal Government	8.9	12.7	9.9
State government	6.7	5.1	5.2
County government	1.1	.7	.9
Municipal government	4.0	3.2	3.3
Other public authority	1.0	.8	.8
Nonengineering	3.7	2.9	3.7
Student	.8	(2)	(2)
Retired	.1	.1	.3
Unemployed	.2	(2)	.3
Total reporting	100.0	100.0	100.0
Total number reporting	16,667	16,667	16,667

[1] Excludes those respondents having less than 7 years' experience, those in military service, and those who were off-continent.
[2] Less than 0.05 percent.

The proportion of engineers who were employees of private firms and of the Federal Government increased between 1939 and 1943, while in all other class-of-worker categories there were decreases. From war to postwar, 1943 to 1946, the proportion engaged as employers and independent consultants increased, while the employees of private firms decreased to slightly below the 1939 level. The proportion in public employment also decreased somewhat during the period, to a point below the 1939 level.

The following tabulation shows the much larger amount of transferring by individual engineers from one class-of-worker status to another which underlay the net changes just discussed.

From the first column it is evident that proportionately fewer engineers who were employed in private industry in 1939 changed from one class of worker to another during the years covered by the survey than did the engineers in public employment. Only 15 percent of the privately employed made changes, but as many as 37 percent of the public employees did so. Among engineers in private industry in 1939, the group classified as employees showed a greater degree of stability than the self-employed group. It is notable that, although employment of engineers in the Federal service increased during the war, as many as 33 percent of the engineers in this field in 1939 were out of it in one of the subsequent years, and only 1.6 percent had returned by 1946 after having been out of Federal service in 1943. Over 40 percent of the engineers on State and county engineering staffs in 1939 left for other employment, and only 4 to 6 percent of them had returned by 1946. This turnover undoubtedly was associated with salary levels (see appendix table D–17), as well as the falling off of construction activity during the war.

Class of worker	*Percent of engineers surveyed in 1939 who were in—* Same category in 1939, 1943, and 1946	Same category 1939 and 1946 but different category 1943	A different category each survey year
Total reporting	78.3	3.2	2.5
Private industry	85.3	3.0	1.1
Employers	75.4	6.4	3.5
Employees of private firms	86.8	2.5	.8
Independent consultants	59.7	11.0	7.2
Public employment	62.8	3.6	6.1
Federal Government	67.4	1.6	4.2
State government	58.4	6.2	6.7
County government	55.9	4.0	9.6
Municipal government	64.2	3.6	7.5
Other public authority	53.2	2.3	9.9
Nonengineering	54.0	6.4	5.5
Student	--	2.2	13.2
Retired	55.6	11.1	11.1
Unemployed	--	10.5	10.5

The second column indicates that 3 percent of the engineers changed their class-of-worker status during the war but returned to their prewar status by 1946. The proportions who did this were largest among independent consultants, employers, and State government employees.

The shifts from one class of worker to another made by individual engineers between 1939 and 1943, 1943 and 1946, and 1939 and 1946 are shown in table 22 (abridged from appendix table D–21). Of the engineers in each category of public employment in 1939 about one out of five went into private industry during the war, principally as employees of private firms. Relatively, the Federal Government made far greater inroads between 1939 and 1943 upon the engineering staffs of State and local government agencies (taking 13 percent of State government employees and similar proportions from other local government agencies) than it did upon the engineering staffs of private firms, only 5 percent of whom shifted to Federal employment. However, these percentages do not reveal the actual magnitude of movement of engineers between government and private industry. More than twice as many engineers in the sample moved from private industry to Federal Government as moved in the opposite direction (645 compared with 294), though in proportion to the total number of engineers employed in 1939, the Government's losses were much greater than those of private industry (20 percent and 5 percent, respectively).

TABLE 22.—*Percentages of respondents who shifted or remained in same class-of-worker status, 1939, 1943, and 1946*

[Abridged from appendix table D–21]

Source of employment (class of worker)	Total[1] reporting	Private industry: Total[1]	Private industry: Employees of private firms	Public employment: Total[1]	Public employment: Federal Government	Public employment: State government
In 1939		*Class of worker in 1943*				
Private industry	100.0	92.9	84.6	6.4	5.3	0.6
Employees of private firms	100.0	93.3	92.0	6.0	4.9	.6
Public employment	100.0	19.7	18.7	79.5	38.6	21.0
Federal Government	100.0	19.8	18.9	79.4	77.0	1.2
State government	100.0	18.9	18.4	80.4	13.0	65.0
In 1943		*Class of worker in 1946*				
Private industry	100.0	96.0	84.4	2.3	1.0	0.7
Employees of private firms	100.0	96.0	92.1	2.3	1.0	.7
Public employment	100.0	16.7	13.1	81.5	40.4	20.9
Federal Government	100.0	22.9	18.5	74.9	70.8	2.4
State government	100.0	9.5	7.0	89.5	1.6	86.0
In 1939		*Class of worker in 1946*				
Private industry	100.0	93.3	81.8	4.6	3.4	0.7
Employees of private firms	100.0	93.6	89.3	4.4	3.1	.6
Public employment	100.0	23.1	19.3	74.9	32.8	21.3
Federal Government	100.0	24.6	21.1	73.2	69.0	1.9
State government	100.0	20.9	17.8	76.9	8.3	64.7

[1] The selected items do not add to totals. See table D–21 for all components.

From 1943 to 1946 (second section of table 22), approximately 23 percent of the engineers in the Federal Government and from 6 to 10 percent of those in municipal, county, and State agencies went into private industry, mainly as employees.

In contrast, only about 2 percent of the engineers who were in private industry during the war changed to public employment after the war.

The changes made by engineers from 1939 to 1946 are shown in the third section of table 22. The engineers who were employees of private firms in 1939 were the most stable group over the 7-year period: nearly 90 percent of them were in this same category in 1946. One-fourth of the engineers in public employment in 1939 had moved to some other type of employment by 1946, principally becoming employees in private firms. While 69 percent of the engineers in the Federal Government in 1939 were also employed there in 1946, one out of five had become employees of private firms in 1946. This pattern of movement among engineers in the other categories of public employment was similar except that from 6 to 10 percent (8 percent for employees of State governments) had moved to Federal employment by 1946.

Transfers Among Industry Fields

The ability of engineers to move from one industry to another is of interest to those considering entering the profession who may want to know how widespread their employment opportunities are, and to what extent their future opportunities are limited by the prospects within a particular industry. It is also of interest in evaluating the ability of the engineering manpower of the country to adapt to changing industrial demands—particularly in a crisis such as war.

Distribution of engineers by industry of course varies from one branch of the profession to another, as indicated earlier in the report. (Also see appendix table D–9.) The wide dispersion of engineering employment makes possible the shifts among industries discussed in this section.

As a result of expanding war needs, the manufacturing industries claimed a greater proportion of the engineers in each field in 1943 than in 1939. Aircraft and parts manufacturing drew large numbers of mechanical engineers. The proportion of chemical engineers increased the most in the manufacturing of chemicals and allied products, and the proportion of electrical engineers increased the most in machinery manufacturing. At the same time there were decreases in the proportion of engineers in a number of other industry fields, notably mining, construction, utilities, and such manufacturing industries as food products and paper and allied products.

By 1946, as civilian production was being resumed, the proportion of engineers in manufacturing industries had declined somewhat from the 1943 level. However, with the exception of chemical engineers, the proportion of engineers in each branch of the profession engaged in manufacturing industries was greater in 1946 than in 1939.

The following tabulation, covering 16,453 engineers who reported employment in industry for 1939, 1943, and 1946, shows the proportion of the 1939 respondents who indicated the same industry all three survey years, those who changed to a different industry in 1943 but returned to their 1939 industry by 1946, and those who changed to

Industry field [1]	*Percent of respondents in 1939 who were in—* Same industry in 1939, 1943, and 1946	Same industry 1939 and 1946, different industry 1943	Different industry each survey year
Total reporting	75.5	3.6	4.3
Agriculture, forestry	61.5	2.2	8.9
Mining	80.4	1.4	3.4
Construction	75.6	4.6	3.4
Manufacturing	76.9	3.1	4.1
Food, textiles	65.0	3.8	7.0
Lumber, paper products	70.9	5.3	6.6
Printing and publishing	55.1	4.1	12.2
Chemicals and allied products	78.7	4.0	2.5
Petroleum and coal products	72.7	3.3	5.9
Rubber, stone, clay, and glass products	76.0	3.2	3.8
Iron, steel, nonferrous metal products	77.8	2.4	4.6
Machinery	80.5	3.2	3.3
Transportation equipment	78.7	1.7	2.5
Other manufacturing industries	72.6	3.9	5.2
Transportation	82.5	1.7	3.9
Communication	88.9	2.4	1.7
Utilities	74.4	2.8	5.1
Service industries	64.9	6.4	6.5
Other industry fields	69.9	3.6	5.6

[1] Excludes those respondents having less than 7 years' experience, those in military service, and those who were off-continent.

another industry by 1943 and to a third industry by 1946.

More than three-fourths of these engineers were employed in the same industry group in all three survey years. The greatest degree of stability was found in the communication industry which held 90 percent of its engineers throughout the 7-year period. Machinery, chemicals, transportation, and mining held more than 80 percent of their engineers throughout the period. On the other hand, such industries as food and textiles, printing and publishing, and service industries (such as ventilating and air conditioning installation firms) lost more than a third of the engineers working for them in 1939.

As would be expected, the amount of movement among industries was greater than among fields of engineering employment or class-of-worker categories. One-fourth of the engineers here considered made at least one industry change and 4 percent were employed in a different industry in each of the three survey years. A small proportion of those who had left their prewar industry by 1943 had returned to it by 1946.

Movement of individual engineers from one industry to another between the survey years is shown in table 23 (abridged from appendix table D-22). It can be seen that as employment in manufacturing industries increased during the war, engineers were drawn from all major industry fields. As many as 10 percent of the engineers in construction and utilities and nearly 20 percent of those in service industries in 1939 went into manufacturing industries by 1943. The manufacturing industries which expanded—the metalworking industries and chemicals—drew engineers not only from nonmanufacturing industries but from other manufacturing industries such as food and textiles, lumber and paper products, and coal and petroleum products. At the same time, however, there was some small shift in the opposite direction, from such industries as machinery and transportation equipment manufacturing to food, lumber, and service industries.

In the transition from war to postwar the shifts from one industry to another were not as numerous as during the period between 1939 and the war year 1943. However, a large number who

TABLE 23.—*Percentages of respondents who shifted or remained in same industry field, 1939, 1943, and 1946*

[Abridged from appendix table D-22]

Industry field	Total [1] reporting	Manufacturing: Total [1]	Manufacturing: Chemicals and allied products	Manufacturing: Petroleum and coal products	Manufacturing: Machinery	Manufacturing: Transportation equipment	Service industries
In 1939		*Industry field in 1943*					
Manufacturing	100.0	94.3	10.6	8.4	26.3	16.1	1.2
Chemical and allied products	100.0	94.6	84.7	1.0	2.1	.7	1.0
Petroleum and coal products	100.0	93.4	4.7	80.3	1.6	2.4	1.2
Machinery	100.0	93.8	.5	.4	85.6	4.7	1.5
Transportation equipment	100.0	96.7	.2	.2	3.7	89.7	.6
Service industries	100.0	19.7	1.8	.6	4.9	6.6	70.0
In 1943		*Industry field in 1946*					
Manufacturing	100.0	91.6	10.5	7.9	26.1	14.0	2.7
Chemicals and allied products	100.0	94.3	86.3	1.2	1.5	.4	2.7
Petroleum and coal products	100.0	93.0	1.7	87.5	1.4	.6	1.6
Machinery	100.0	93.9	.3	.5	89.4	.8	2.0
Transportation equipment	100.0	83.0	1.0	.6	4.6	69.2	5.6
Service industries	100.0	5.7	.8	.1	2.3	.8	88.8
In 1939		*Industry field in 1946*					
Manufacturing	100.0	91.4	10.5	8.2	26.3	13.3	2.8
Chemicals and allied products	100.0	93.9	82.6	1.1	2.6	.4	1.8
Petroleum and coal products	100.0	88.7	5.6	76.0	2.0	1.6	3.2
Machinery	100.0	91.4	.6	.3	83.8	2.8	3.3
Transportation equipment	100.0	90.6	.4	.4	4.7	80.2	2.4
Service industries	100.0	18.6	1.8	.6	6.1	3.7	71.2

[1] The selected items do not add to totals. See table D-22 for all components.

had been in transportation equipment manufacturing in 1943 had transferred to other manufacturing industries, construction, and service industries by 1946.

When the shifts made by the individual engineers are considered, it appears that about 20 percent of the respondents were in different industries in 1946 than in 1939. While there is no single pattern in these shifts, there was a tendency to move into durable-goods manufacturing industries. In 1946, the metalworking industries—machinery, iron and steel and nonferrous metal products, and transportation equipment—had a considerable number of engineers who had been in another industry in 1939.

Engineers appear to have changed their industry more readily than their general field of employment or their class-of-worker status. Most of the changes appeared to be in response to the shifting industrial demands of the war and postwar periods. At the same time there was some small movement of individual engineers away from the expanding industries to those which were, on the whole, losing engineers.

Changes in Employment Location

The war years were marked by great movements of population in response to the growth of defense industries and military establishments. These population movements followed long-term trends in migration.

Like other workers, engineers moved a great deal during this period in response to changing economic opportunities. Data on distribution of engineers by State for each branch of the profession in each of the three survey years are shown in appendix table D–10. The net changes in the distribution of engineers among the States are shown in table 24. As may be expected, there was expansion in the Pacific and South Atlantic regions (particularly in the District of Columbia), moderate decrease in the Great Plains States, particularly those in the West North Central region which also lost in general population. The great industrial region of the Middle Atlantic and East North Central States retained about the same number of these experienced engineers over the period.

TABLE 24.—*Percentage distribution of engineers, by State, 1939, 1943, and 1946* [1]

[Includes only those who indicated an employment location all three survey years]

Employment location	Engineers employed in—		
	1939	1943	1946
Total reporting—number	16,365	16,365	16,365
Total reporting—percent	100.0	100.0	100.0
Middle Atlantic	32.1	31.2	32.0
New York	16.8	15.7	16.7
Pennsylvania	10.1	9.8	9.8
New Jersey	5.2	5.7	5.5
East North Central	23.8	23.2	23.2
Ohio	7.7	8.1	8.0
Illinois	6.9	6.4	6.5
Michigan	4.3	4.0	4.1
Indiana	2.7	2.7	2.5
Wisconsin	2.2	2.0	2.1
Pacific	9.1	9.7	10.3
California	7.1	7.4	7.9
Washington	1.3	1.6	1.6
Oregon	.7	.7	.8
South Atlantic	8.7	10.5	10.0
District of Columbia	2.2	3.3	2.9
Maryland	1.6	1.7	1.7
Virginia	1.3	1.6	1.5
West Virginia	1.1	1.0	.9
Georgia	.7	.8	.9
North Carolina	.6	.6	.6
Florida	.5	.6	.6
Delaware	.4	.6	.6
South Carolina	.3	.3	.3
New England	8.1	7.7	7.8
Massachusetts	5.0	4.7	4.8
Connecticut	1.8	2.0	2.0
Rhode Island	.5	.4	.4
New England—Continued			
Maine	0.4	0.3	0.3
New Hampshire	.2	.2	.2
Vermont	.2	.1	.1
West North Central	6.4	5.7	5.6
Missouri	2.2	2.0	2.0
Minnesota	1.5	1.4	1.5
Iowa	1.0	.7	.8
Kansas	.8	.9	.7
Nebraska	.5	.5	.4
South Dakota	.2	.1	.1
North Dakota	.2	.1	.1
West South Central	6.0	6.1	5.9
Texas	3.7	3.8	3.8
Oklahoma	1.2	1.1	1.0
Louisiana	.8	.9	.8
Arkansas	.3	.3	.3
Mountain	3.0	2.8	2.7
Colorado	1.0	.9	1.0
Montana	.4	.3	.3
Utah	.4	.5	.4
Arizona	.4	.3	.3
New Mexico	.3	.3	.3
Idaho	.2	.2	.2
Wyoming	.2	.1	.1
Nevada	.1	.2	.1
East South Central	2.8	3.1	2.5
Tennessee	1.0	1.3	1.0
Kentucky	.8	.8	.8
Alabama	.7	.7	.5
Mississippi	.3	.3	.2

[1] Excludes those with less than 7 years in the profession, those in military service, and those outside the continental United States.

Engineers changed their employment location even more frequently than they changed the industries in which they were employed. Approximately 70 percent of these respondents reported themselves employed in the same State in all three survey years; the remaining 30 percent made one or more changes over the period. The proportion of those employed in a given State in 1939 who were in that State in 1943 and 1946 appears to have a direct relationship to the number of respondents employed in a State; i. e., in States where a relatively large number of engineers were employed, the proportion of engineers who stayed in the same State through 1946 was large, while in States where a relatively few engineers were employed in 1939 only one-half or less stayed in the same State through 1946.

The changes made by the 30 percent of the engineers who shifted employment location followed several patterns. Some 13.5 percent of all engineers moved to another State between 1939 and 1943 and remained there through 1946, while 5.9 percent of the engineers were in the same State in 1939 and 1943, but moved to a different State by 1946. About the same number (5.9 percent) were in a different State in each of the three survey years, and an additional 4.6 percent indicated a change in employment location between 1939 and 1943—possibly a war production job—but returned to their 1939 employment location by 1946.

The amount of shifting which lies behind the small net changes in the number of engineers in a State, as shown in table 24, may be illustrated by the movement of engineers into and out of Ohio between 1939 and 1943. The net increase of 66 engineers in the sample was brought about by the transfer of 280 engineers from 34 other States into Ohio, while 214 engineers transferred from Ohio to 32 other States. The majority of these changes were between Ohio and other States in the East North Central region and the neighboring Middle Atlantic region.

Summary

Mobility among members of the engineering profession is of many types; these occupational shifts are made in response to changing economic conditions, demands of employers, the engineers' personal wishes or needs, and other factors. Data on five types of movement of engineers have been presented in this report; namely, changes of employment location, industry, class of worker, field of employment, and from a specialized field of education to a different field of employment. A greater proportion of engineers—about 30 percent—moved from one employment location (State) to another, during the 7-year period covered by the 1946 survey, than were involved in any of the other changes analyzed. About 25 percent of the engineers changed industry field, 22 percent changed from one class-of-worker category to another, and about 14 percent transferred from one branch of engineering to another during the 7-year period. More than 20 percent of all respondents had made a change at some time during their working life to a field of employment other than the field in which they received their basic education.

Nearly a third of the engineers changed their employment location from one State to another between 1939 and 1946. More than twice as many engineers changed employment location in the 4-year period, 1939 to 1943, as moved during the 3-year period, 1943 to 1946. These movements were proportionately more numerous among those engineers located in States where a relatively smaller number of engineers had been employed in 1939, and conversely, the engineers in those States with a relatively large engineer population were less prone to change the State of their employment. The amount of shifting of employment location within a State is not known but may have been considerable in those States which furnish employment for large numbers of engineers.

The changes made by engineers among industry fields appear to reflect the high wartime demands and employment opportunities for engineers in the "heavy" or durable goods industries. Between 1939 and 1943 about a fifth of the engineers in the service industries shifted to manufacturing industries in response to curtailment of civilian goods production and the emphasis on war production. Between 1943 and 1946 the most significant movement was from transportation equipment manufacturing to service industries in response to the conversion to peacetime pursuits. Comparison of the prewar and postwar industry fields of individual engineers indicated that a fifth were in a different industry in 1946 from that re-

ported for 1939. Transfers to machinery, iron, steel, and nonferrous metals products manufacturing were fairly numerous. About 30 percent of the engineers in the service industries in 1939 had transferred out by 1943, but almost all of them were replaced by engineers from other industries by 1946.

Changes made by engineers among the class-of-worker categories during the period covered by the survey indicate to some extent the principal sources of employment for engineers during the war and postwar years. Between 1939 and 1943 the proportion of engineers who were employees of private firms and of the Federal Government increased at the expense of local government and other class-of-worker categories. About a fifth of the engineers in each category of public employment in 1939 had gone into private industry by 1943. On the other hand, only 5 percent of the engineers who had been in private industry in 1939 moved to Federal Government jobs; from 10 to 15 percent of those who had been in other types of public employment shifted to Federal Government jobs. However, while in percentage terms private industry made greater inroads upon Federal Government engineering staffs than vice versa, the actual number of engineers who shifted from private to Federal employment was twice as great as the number of Federal employees who went to private jobs.

As the war drew to a close and peacetime patterns were reestablished, about 23 percent of the engineers in Federal employment and from 6 to 10 percent of those in municipal, county, and State agencies in 1943 moved to private industry by 1946. In contrast, only about 2 percent of the engineers in private industry during the war shifted to public employment by 1946.

Over the entire period, 1939 to 1946, employees of private firms were the most stable group; nearly 90 percent of them reported no change in their status. About 30 percent of the engineers in Federal employment in 1939 had moved to some other class-of-worker status by 1946; 20 percent became employees of private firms. Engineers in the other categories of public employment followed a similar pattern, except that from 6 to 10 percent had moved to Federal employment by 1946.

There was some shifting of engineers among all the basic fields of engineering employment during the period 1939 to 1946. Between 8 and 14 percent of the members of each of the major fields of engineering in 1939 left their fields, and few had returned to their original fields by 1946. The greatest proportion of those who shifted from their 1939 employment field went into mechanical engineering by 1946. Civil engineering lost the greatest proportion during the war and regained few by the end of the survey period.

The ability of members of the profession to change from one field of engineering to another is also reflected in the fact that during their working lives as many as one out of five engineers had changed to a field of engineering employment other than that in which they were educated. As would be expected, the majority of those in each employment field were educated in that field. However, there were a number employed in each branch of engineering whose education had been in another field—ranging from 10 percent of those employed in chemical engineering to as high as 36 percent of those employed in mining and metallurgical engineering. Electrical and civil engineering employment included comparatively few (13 and 14 percent, respectively) whose education was in some other field. About 30 percent of those employed in mechanical engineering were educated in other fields—mainly electrical, civil, or "other" engineering.

Among those educated in each field, from 19 to 31 percent were employed in some other field in 1946. The greatest proportionate change was among the mining and metallurgical engineering majors who transferred mainly to civil, mechanical, or "other" engineering employment. More than 26 percent of those educated in chemical engineering had taken jobs in other fields, principally mining and metallurgical, mechanical, and "other" engineering. The smallest proportion of transfers to some other employment field was among those educated in mechanical engineering, possibly because of the wartime demand in this field. While it is not known at what time the survey respondents made the change from their basic field of education to a different field of employment, there is evidence that this condition is not necessarily one brought about during a period of shortages of engineers. A survey of members of engineering societies showed as many as 15 percent who had made such a change during their working lives up to 1939.[1]

Thus it appears that the engineering profession is a flexible one, offering opportunities to transfer from one field of specialization to another, from one industry and employer to another, and to various locations of employment. The significance of the movement which occurred during the 7-year period cannot be evaluated because there are no data on mobility in other periods which might provide norms for the engineering profession. Surveys of other occupations or future surveys of the engineering profession may provide some basis for evaluation of the volume and types of movement made by the respondents to the 1946 survey. Exploration of additional factors associated with mobility, such as age, years of experience, and educational level, in relation to the five types of occupational shifting considered in this report would help in understanding the mobility of engineers. Such information would be of value to engineers themselves, as well as to those interested in manpower utilization, training, and career guidance.

It is obvious that there are certain advantages in following an occupation in which there are opportunities for some movement. The individual may be able to satisfy his desires concerning the location of his employment and may be better able to adjust to changing economic conditions. There may also be adverse considerations in these changes, such as having to leave a community in which the engineer has become advantageously situated, or in having his home life and his children's schooling interrupted.

The young person contemplating entering the engineering profession should be aware of the amount and kind of movement possible. In order to equip himself to adjust more easily to changing conditions or to advance his career he may wish to acquire the broadest possible educational preparation consistent with an adequate background for the specialty he intends to follow. At the same time, however, he is faced with the conflicting trend toward a high degree of specialization in each field, accompanied by the demand for more graduate education. This presents an individual with a dilemma which he must try to resolve in terms of his own interests in a particular field and his desire for employment flexibility.

[1] *The Engineering Profession in Transition*, Engineers Joint Council, 33 West 39th St., New York, N. Y., 1947, p. 14.

Professional Societies and Organizations [1]

Many organizations have been formed over the past century which have as a basis a common interest in scientific and technical subjects or professional problems. Today it is estimated that more than 60 national and more than 70 independent State, regional, and local engineering organizations are functioning in the United States. Some are purely technical in nature; others are interested primarily in the economic, educational, or social aspects of engineering. In addition, there are many engineering clubs and various joint organizations of the council type.

Some of the major branches of engineering are represented by several national bodies, termed the "Founder Societies". Their names and dates of organization are as follows: American Society of Civil Engineers, 1852; American Institute of Mining and Metallurgical Engineers, 1871; American Society of Mechanical Engineers, 1880; and American Institute of Electrical Engineers, 1884.[2] In addition, an organization, representing another major branch of engineering, was founded in 1908; the American Institute of Chemical Engineers.[3] These 5 engineering societies are represented in another organization, The Engineers Joint Council, which was formed several years ago.

The Society for the Promotion of Engineering Education, now called the American Society for Engineering Education, was founded in 1893. This society, composed of teachers and representatives of engineering schools and industries, is interested mainly in the advancement of the standards and methods of professional training. Another organization, the National Council of State Boards of Engineering Examiners, founded in 1920, is a limited membership council, concerned with the certification and registration of engineers.

Together these seven bodies formed the Engineers' Council for Professional Development in 1932, which deals with professional problems of all branches of engineering and is interested in such questions as standards and ethics of the profession, student selection and guidance, and accreditation of engineering curricula and the stimulation of recent graduates to continue and expand their training.[4] The Engineering Institute of Canada is also a member of this organization.

The membership of the National Society of Professional Engineers (founded 1934) [5] is limited to those who are legally registered or licensed engineers. Emphasis in this organization is placed on the advancement of the professional status as well as the social and economic welfare of the engineer.

There are listed below some of the other national organizations to which many engineers belong, with their dates of organization; most of these consist of specialists in a particular industry or phase of engineering. They are active in advancing the science and techniques in their fields, and some have made notable contributions by establishing standards generally accepted in their industries. The list below is by no means complete but was selected to show the diversity of engineering interest.

American Chemical Society (1876).
American Water Works Association (1881).
National Association of Power Engineers (1882).
American Railway Bridge and Building Association (1891).
Society of Naval Architects and Marine Engineers (1893).
American Society of Heating and Ventilating Engineers (1894).
American Public Works Association (1894).
American Society for Testing Materials (1898).
American Railway Engineering Association (1899).

[1] Detailed descriptions and discussions of engineering organizations are found in the following publications: Esther Lucille Brown, *The Professional Engineer*, Russell Sage Foundation, 1936; *Organizations of Engineers in the United States of America*, a paper presented before International Technical Congress in Paris, France, September 1946 (C. E. Davies, Secretary, American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y.)

[2] All of these organizations are located at 25–33 West 39th St., New York, N. Y.

[3] Located at 50 East 41st St., New York, N. Y.

[4] This organization is located at 29 West 39th St., New York, N. Y.

[5] Located at 1121 15th St. NW., Washington, D. C.

Society of Automotive Engineers (1904).
American Society of Refrigerating Engineers (1904).
American Concrete Institute (1905).
Illuminating Engineering Society (1906).
American Society of Agricultural Engineers (1907).
Association of Iron and Steel Engineers (1907).
American Society of Sanitary Engineering (1908).
American Institute of Consulting Engineers (1910).
The Institute of Radio Engineers (1912).
American Association of Engineers (1915).
Society of Motion Picture Engineers (1916).
American Welding Society (1919).
American Society of Metals (1920).
American Society of Safety Engineers (1921).
Association of Consulting Management Engineers, Inc. (1929).
Institute of Traffic Engineers (1930).
American Society of Tool Engineers (1932).
Institute of Aeronautical Sciencies, Inc. (1932).
American Society of Photogrammetry (1934).
Society for the Advancement of Management (1936).
Institute of Ceramic Engineers (1938).
Society of Experimental Stress Analysis (1942).
National Association of Corrosion Engineers (1943).
American Society of Lubrication Engineers (1944).
American Society of Body Engineers, Inc. (1945).
American Institute of Industrial Engineers (1946).

Some engineers are members of unions, such as the International Federation of Technical Engineers, Architects and Draftsmen's Unions, AFL, and the United Office and Professional Workers of America, CIO. Also some are members of independent professional collective bargaining organizations.

Registration and Certification of Engineers[1]

To do some but not all kinds of engineering work a person must be a "registered engineer." There are laws providing for registration or licensing of engineers in all 48 States and five Territories (but not in the District of Columbia). In general, the purpose of the laws is to ensure that engineering work which involves the safeguarding of life, health, or property shall be done by registered engineers. Most of the laws provide for the registration of those qualified to practice engineering and forbid any other persons from practicing engineering or using any title or description tending to give the impression that they are "professional" engineers.

The various laws differ as to just who is required to be registered. In some States only civil or structural engineers are required to register. In others, only the engineer who approves or draws up the plans for the construction of a bridge or an electric light and power station is required to register. Subordinate engineers who work under the approving engineers and whose name would not be affixed to the plan or approval would not be required to register. At the present time, well over 100,000 engineers are registered by various boards—approximately a third of all engineers in the United States. Most of those registered now are civil engineers but registration of others is growing and in some States registration is virtually a requirement for public employment.

A general definition of "professional engineer" found in most State laws is, "a person who by reason of his special knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis and design, acquired by professional education and practical experience, is qualified to practice engineering, as attested by his legal registration as professional engineer." Professional education is obtained through graduation from an accredited curriculum or the equivalent. The amount of practical experience required varies by State, but usually is 4 years.

The term "practice of engineering" is usually defined as "any professional service or creative work requiring education, training, and experience and the application of special knowledge in the mathematical, physical, and engineering sciences to such professional services or creative work as consultation, investigation, evaluation, planning, design, and supervision of construction for the purpose of assuring compliance with specifications and design in connection with any public or private utilities, structures, buildings, machines, equipment, processes, works, or projects."

The registration laws are under constant change and improvement; the major engineering societies have from time to time attempted to set up "model" laws and definitions. The National Council of State Boards of Engineering Examiners was organized to assist the individual State boards which are established to administer the laws. This organization has established a National Bureau of Engineering Registration which facilitates interstate registration.

Detailed information on various registration laws, addresses of boards of examiners and other information may be obtained from either the National Council of State Boards of Engineering Examiners, Carolina Life Building, Columbia, S. C.; the National Society of Professional Engineers, 1121 Fifteenth Street NW., Washington, D. C.; or individual State boards of engineering examiners.

[1] Much of this section is based on the publication *Organization of Engineers in the United States of America*, a paper presented before the International Technical Congress, Paris, France, September 1946. (C. E. Davies, Secretary, American Society of Mechanical Engineers, 29 West 39th St., New York, N. Y.)

Appendix A. Census Data on Engineers

Throughout this report basic data on engineers as reported by the Bureau of the Census have been used. This source is the only one which gives numbers in the profession over a period of years, and also includes characteristics such as age and education. Most agencies, including the Engineers Joint Council,[1] have accepted the Census figures on engineers. However, the question has been raised whether the Census figures, which are based on the individual's report (or a relative's report) as to his occupation, are completely accurate. With respect to engineers, for example, it becomes important to evaluate whether there was any significant inaccuracy resulting from the natural tendency for people to overrate their status.

Every effort has been made by the Bureau of the Census to limit the technical engineer category to those engaged in or seeking work at the professional level. Enumerators were instructed in 1930 to "distinguish carefully the different kinds of engineers by stating the full descriptive titles, as civil engineer, electrical engineer, locomotive engineer, mechanical engineer, mining engineer, stationary engineer, etc." [2] Separate codes of classifications were assigned to these occupational returns so that it was possible to eliminate locomotive engineers, stationary engineers, and the like, from the group of technical engineers. A comparison of Census figures with those from the Interstate Commerce Commission on railroad employment for 1940, makes it apparent that locomotive engineers were not included in the professional engineer classification of the Census. In 1940, a further attempt was made to limit the group to professional workers by excluding all persons under 35 years old returned as technical engineers unless they had at least 4 years of college education.

The Bureau of the Census recognizes that it loses a considerable number of men who are trained professional engineers and who are doing engineering work, but are classified on the Census schedules as vice presidents, executives, managers, superintendents, builders, contractors, etc.[3] This same circumstance also affects many other professional occupations. Persons in the engineering profession usually view administrative and management positions as the highest possible attainment of an engineer, and do not consider that one who has advanced to such a position has left the profession. The reports of engineers to the 1946 survey substantiate this; approximately a third of all engineers employed in that year stated that they were in administrative positions. Since such men consider themselves to be engineers, a great many must have reported themselves as such to the Census also, and therefore are included in the basic data on employment trends and death and retirement rates as discussed in this report. Nevertheless, there is probably some loss to the engineering profession—as the profession is measured by Census data—resulting from advancement of men to administrative positions. An allowance for this loss, as well as other transfers out, is made in the section of this report on losses to the profession.

While Census material represents the only comprehensive data in the field of occupations, users of these data should realize their limitations, as indicated in the text and footnotes of the various Census publications. In comparing statistics of different census years, there are two important considerations which complicate the use of statistics on "experienced workers." These major factors are: (1) Differences between the "gainful

[1] *The Engineering Profession in Transition,* Engineers Joint Council, 33 West 39th St., New York, N. Y., 1947, pp. 57–60.

[2] *General Report on Occupations.* Fifteenth Census of the United States: 1930, U. S. Department of Commerce, Bureau of the Census, Washington 25, D. C., p. 30.

[3] *Comparative Occupation Statistics, 1870–1940,* U. S. Department of Commerce, Bureau of the Census, p. 24, Washington 25, D. C., 1943.

worker" concept of 1930 and previous censuses, and the "labor force" concept of the 1940 Census,[4] and (2) differences in classification of occupations.

The change in concept from "gainful workers" to "labor force" leads to a considerable difference in the treatment of seasonal workers, retired workers, new workers, and institutionalized persons. The net effect of these differences is that the "gainful worker" figures of the earlier censuses must be reduced by a relatively small amount and the "labor force" figures of 1940 raised slightly to make them comparable in concept. The Bureau of the Census has done this for the 1930 male and female labor force as a whole, but not by occupation. (For a detailed discussion of these adjustments, see Sixteenth Census of the United States: 1940, Population, *Comparative Occupation Statistics for the United States, 1870 to 1940*, pp. 11–16.)

While occupational classifications differed in relatively minor aspects in the earlier Censuses, the classification adopted for 1940 differed considerably for some occupations. Although adjustments have been made by the Bureau of the Census to take care of differences in classification insofar as possible, certain limitations nevertheless exist. One of these limitations, the exclusion of some engineers in administrative jobs, is discussed above. Another change in classification—that of excluding surveyors from the civil engineering group in 1940—was adjusted by the Bureau of Labor Statistics in the 1930 and earlier figures as explained in appendix B of this report.

[4] The principal difference between the concept of "gainful worker" and "labor force" is that "gainful workers" include all persons who were reported as usually following a gainful occupation, regardless of whether working or seeking work at the time of the Census; whereas "labor force" includes only persons working or seeking work as of a particular week to which the Census refers.

Appendix B. Analysis of Changes in the Engineering Profession, 1930–40

Appendix table B–1 presents an analysis of the movements both into and out of the engineering profession during the decade, 1930–40.

Column 1 is based on data from the 1930 Census of Population. The 1930 Census figures on engineers include surveyors; therefore the original number reported was adjusted to reduce the total to one comparable with 1940. This was accomplished by applying the 1940 ratio of surveyors to civil engineers to the 1930 civil engineer total.

The number of losses over the decade, owing to death and retirement (column 2), was then calculated by applying separation rates from the Bureau of Labor Statistics preliminary "tables of working life expectancy" to the 1930 age composition of the engineers. The separation rates used are those for all urban white males in the United States. It should be pointed out, however, that loss rates in the engineering profession, particularly those resulting from retirement, may be lower than those for the total urban white male population. The survivors in 1940, in their proper age brackets for that year, are shown in column 3 (column 1 minus column 2).

The total number of engineering graduates in the decade (see appendix table D–3), less those who died or retired, were then added to the engineers surviving to 1940 (column 4). Median age at graduation was assumed to be 23 years.

The computed labor force of engineers in 1940 (column 5, the sums of columns 3 and 4) can be compared to the actual labor force (including those employed and those unemployed) as shown by the 1940 Census. The last column of the table presents the differences between the computed and the actual labor force in 1940 at various age levels. The plus figures represent net transfers into the profession of persons other than graduates in the decade, and the minus figures, net transfers out of the profession. It should be emphasized that these are *net differences;* actually the number of transfers out in the age groups below 35 was *somewhat higher* than the 51,000 shown because some persons in these age groups probably transferred in at the same time. This also applies to the differences shown in the age groups above 35; the 26,000 shown represents a *minimum* of transfers between 1930 and 1940 in these age groups.

The last column suggests that *at least* 50,000 engineers and engineering graduates of the 1930–40 decade left the profession by 1940, and that *at least* 26,000 persons who were not engineers in 1930, and who were not graduated from engineering schools during the decade entered the profes-

TABLE B–1.—*Changes in the engineering profession, 1930–40* [1]

Age (in years)	Number of engineers in 1930 (gainful workers)[2] (1)	Deaths and retirements to 1940 of 1930 engineers (2)	Survivors in 1940 of 1930 engineers (by age in 1940) (3)	Graduates 1930–40 (less those who died or retired) (by age in 1940) (4)	Computed[3] labor force in 1940 (5)	Actual labor force in 1940[4] (6)	Difference (actual minus computed) (7)
Total	215,386	35,777	179,609	108,410	288,019	261,687	−26,332
20–24	23,744	926	----------	13,260	13,260	13,189	−71
25–29	38,424	1,806	----------	57,350	57,350	32,343	−25,007
30–34	34,508	2,519	22,818	37,800	60,618	34,348	−26,270
35–39	31,452	3,208	36,618	----------	36,618	45,503	+8,885
40–44	28,499	4,018	31,989	----------	31,989	39,071	+7,082
45–49	22,734	4,638	28,244	----------	28,244	34,195	+5,951
50–54	15,226	4,796	24,481	----------	24,481	28,730	+4,249
55–59	9,226	4,842	18,096	----------	18,096	18,054	−42
60–64	6,109	4,313	10,430	----------	10,430	9,550	−880
65–69	3,133						
70–74	1,410	4,682	6,782	----------	6,782	6,704	−78
75 and over	741						
Unknown	180	29	151	----------	151	----------	−151

[1] Sources of data and description of the table are presented in the accompanying text.
[2] See footnote 4, p. 86.
[3] Sum of columns 3 and 4.
[4] U. S. Department of Commerce, U. S. Bureau of the Census, Sixteenth Census of the United States, 1940, Population, vol. III, pt. 1, table 65.

sion by 1940. Inspection of the data on graduations and on the growth of the profession during the 1920's strongly suggests that the major part of the 26,000 or more entrants were persons who had not been graduated from engineering schools.

Several factors help to explain both types of movements. First, in the age groups below 35, the transfers out were in most cases the result of poor employment conditions existing during a great part of the thirties. The incidence of unemployment among young engineers was described in the section on civil engineers (see p. 15).

Most of those transferring in were probably men who were employed in subprofessional jobs in 1930, such as draftsmen, surveyors, and others who advanced to engineering positions by 1940. A smaller number of persons who held administrative or other professional positions in 1930, may also have entered the engineering profession by 1940.

Other types of transfers in the older age groups were the immigration of foreign-born engineers (examination of immigration data shows this to be a small factor) and the return of American engineers to the United States from foreign employment.

There are several technical factors which might affect the accuracy of these computations. First is the fact that the "gainful workers" concept of the 1930 census probably included some persons which the labor force concept of the 1940 census excluded—particularly older persons (appendix A). An adjustment for this difference would have the effect of increasing the "plus" figures slightly for some of the age groups over 35, in the last column. Secondly, the death and retirement rates for all white urban males may be slightly higher than those for engineers, as pointed out above. Any reasonable adjustment which might be made in these rates to make them applicable to engineers would have the effect of reducing the "plus" figures slightly for some of the age groups over 35, in the last column. These small differences would tend to offset each other.

Appendix C. Scope and Method of the 1946 Survey

Most of the statistical data on earnings and the economic status of engineers presented in this report are based on two surveys of the engineering profession made by the Bureau of Labor Statistics. The first, made in 1935 at the request of the American Engineering Council, covered the years 1929, 1932, and 1934.[1] This report described the economic status of engineers over a period in which general economic prosperity was followed by a serious depression. The second survey was made in 1946 in cooperation with the Engineers Joint Council, representing six leading engineering societies, and the National Roster of Scientific and Specialized Personnel. It covered the years 1939, 1943, and 1946; a period in which the economy of the country experienced first a recovery from the depression, then the war, and finally a postwar period of high employment levels. Thus information is available on the impact of a wide variety of economic conditions upon the status of the engineering profession. This section describes the scope and method of the 1946 survey.

The questionnaire for the survey was designed by the three cooperating agencies, drawing upon the experience of the previous survey as well as that gained in two surveys of the chemical profession in 1941 and 1943.[2] The questionnaire called for information on experience, earnings, employment status, and education (see facsimile of questionnaire, pp. 96 and 97). It was completely precoded to make it easy for the respondent to fill it out and to minimize clerical work in handling the completed questionnaires. In order to encourage the broadest response, the questionnaire was completely anonymous, with no way of identifying the respondent.

In order to obtain a representative cross section of the approximately 300,000 engineers in the United States in 1946, the files of the National Roster were used to provide a mailing list. The National Roster had approximately 200,000 persons registered as engineers. Their names had originally been obtained from the professional societies, State boards of engineering examiners, schools of engineering, and from the occupational questionnaires which were filled out in connection with Selective Service registration by all civilian men aged 18 to 64. All persons whose names had been obtained as being engineers or engineering graduates were sent National Roster registration forms, which called for information on education and professional experience. When these forms had been returned to the National Roster they were screened in order to make sure that every registrant was qualified as an engineer, for the purpose of establishing an active file of all persons who might be capable of doing professional work in connection with the war effort. (As it later developed when results of the survey were analyzed, some of these registrants were not employed in engineering; these were separately tabulated in the survey).

The 200,000 registrants in the Roster files were grouped for the purpose of the survey according to educational level, age, and engineering specialty, and 20 percent of the names in each cell were used as a mailing list for the survey. The Engineers Joint Council wished to obtain information on the economic status of all members of its six constituent societies and so the questionnaire was sent to its own mailing list of 86,900 society members. In order to avoid sending two questionnaires to the same person the sample selected from the National Roster files was matched against the Engineers Joint Council mailing list. Names found on both lists were eliminated from the National Roster mailing, but the questionnaires sent to these engineers were identified as being in the Roster sample, and, after their returns were

[1] U. S. Department of Labor's Bureau of Labor Statistics, *Employment and Earnings in the Engineering Profession, 1929 to 1934*, Bulletin No. 682, Superintendent of Documents, Washington 25, D. C., 1941. Price 25 cents.

[2] *The Economic Status of the Members of the American Chemical Society, 1942*, by Andrew Fraser, Jr. (available in Chemical and Engineering News, issues of October 25, November 25, December 10, and December 25, 1942, or in reprint form from the Mack Printing Co., Easton, Pa.

U. S. Department of Labor's Bureau of Labor Statistics, *Factors Affecting Earnings in Chemistry and Chemical Engineering*, Bulletin No. 881, Superintendent of Documents, Washington 25, D. C., 1946. (Reprinted from Monthly Labor Review, June 1946, with additional data.) Price 10 cents.

tabulated for the purposes of the Engineers Joint Council, they were included in the tabulations of the National Roster sample.

Altogether, approximately 42,000 questionnaires were mailed in September 1946 to persons registered with the National Roster. A total of 24,695 questionnaires were returned, representing a 58.8 percent response. A return as high as this to a voluntary questionnaire testifies to the interest of the members of the profession in such a survey and their willingness to cooperate. A similarly good response was obtained from the entire membership of the constituent societies of the Engineers Joint Council. The data on this group were published in a report by the Engineers Joint Council.[3] The data from the precoded schedules were transferred to punch cards and all basic tabulations were made by machine. Respondents who were in the armed forces, who were outside the continental United States, or who were engaged in nonengineering work for the year being tabulated were excluded except where indicated.

In order to determine how well the returns represented the entire engineering profession, two types of comparisons were made: The returns were compared with the National Roster mailing list, which was selected on a representative basis from the 200,000 registrants, to see if there was any bias in response to the survey; they were also compared with the data on engineers reported to the 1940 Census of Population, to determine how well they represent the entire profession.

[3] *The Engineering Profession in Transition,* prepared by Andrew Fraser, Jr., for the Engineers Joint Council, 1947. This report may be obtained from the Engineering Joint Council, 33 West 39th St., New York, N. Y.

Comparison of Returns With National Roster Mailing List

The distribution of the returns compared very closely with that of the mailing list with respect to general engineering field, as shown in the following tabulation.

General engineering field:	*Mailing list*	*Returns*
Chemical	11.8	12.4
Civil	23.8	20.3
Electrical	19.9	21.4
Mechanical	27.1	29.3
Mining and metallurgical	6.8	5.9
Other	10.6	10.7
Total percent	100.0	100.0
Total number	42,000	[1] 22,024

[1] Excludes 1,107 returns with field not reported, 1,118 reporting employment in nonengineering field, 215 in the armed services, and 231 off-continent.

The returns appear to have a small underrepresentation of civil and mining and metallurgical engineers and overrepresentation of mechanical and electrical engineers. However, information from the survey itself showed that there was some shifting of engineers from the civil and mining and metallurgical engineering fields into mechanical and electrical engineering during the period 1939–46, table 21. It is, therefore, to be expected that some men who were classified in the former fields at the time of registration with National Roster had shifted to mechanical and electrical engineering employment by 1946.

A comparison of the distributions by age group for each general field of engineering employment (table C–1 and chart C–1) also shows close correspondence between the returns and the mailing list. Proportionately, the number of returns from

TABLE C–1.—*Percentage comparison of mailing list and distribution of respondents in each field of engineering employment, by age group in 1946*

Age group	Total		Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Mailing list	Sample returns	Mailing list	Sample returns	Mailing list	Sample returns	Mailing list	Sample returns	Mailing list	Sample returns	Mailing list	Sample returns	Mailing list	Sample returns
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
29 years and under	19.2	20.1	45.1	40.2	7.9	9.3	16.8	19.2	22.8	24.4	17.4	20.6	11.8	11.8
30–39 years	30.4	32.0	34.0	35.7	23.1	24.2	31.3	33.2	32.0	35.5	34.1	35.5	34.7	34.3
40–49 years	29.3	26.7	13.5	15.3	35.9	34.1	35.2	31.0	26.0	22.2	24.1	21.3	32.7	32.6
50–59 years	13.6	14.1	5.6	6.3	19.7	20.4	11.6	12.4	12.7	12.4	14.1	15.2	14.5	16.0
60 years and over	7.5	7.1	1.8	2.5	13.4	12.0	5.1	4.2	6.5	5.5	10.3	7.4	6.3	5.3

Chart C–1.—Comparison of Mailing List and Respondents, by Age Group in 1946

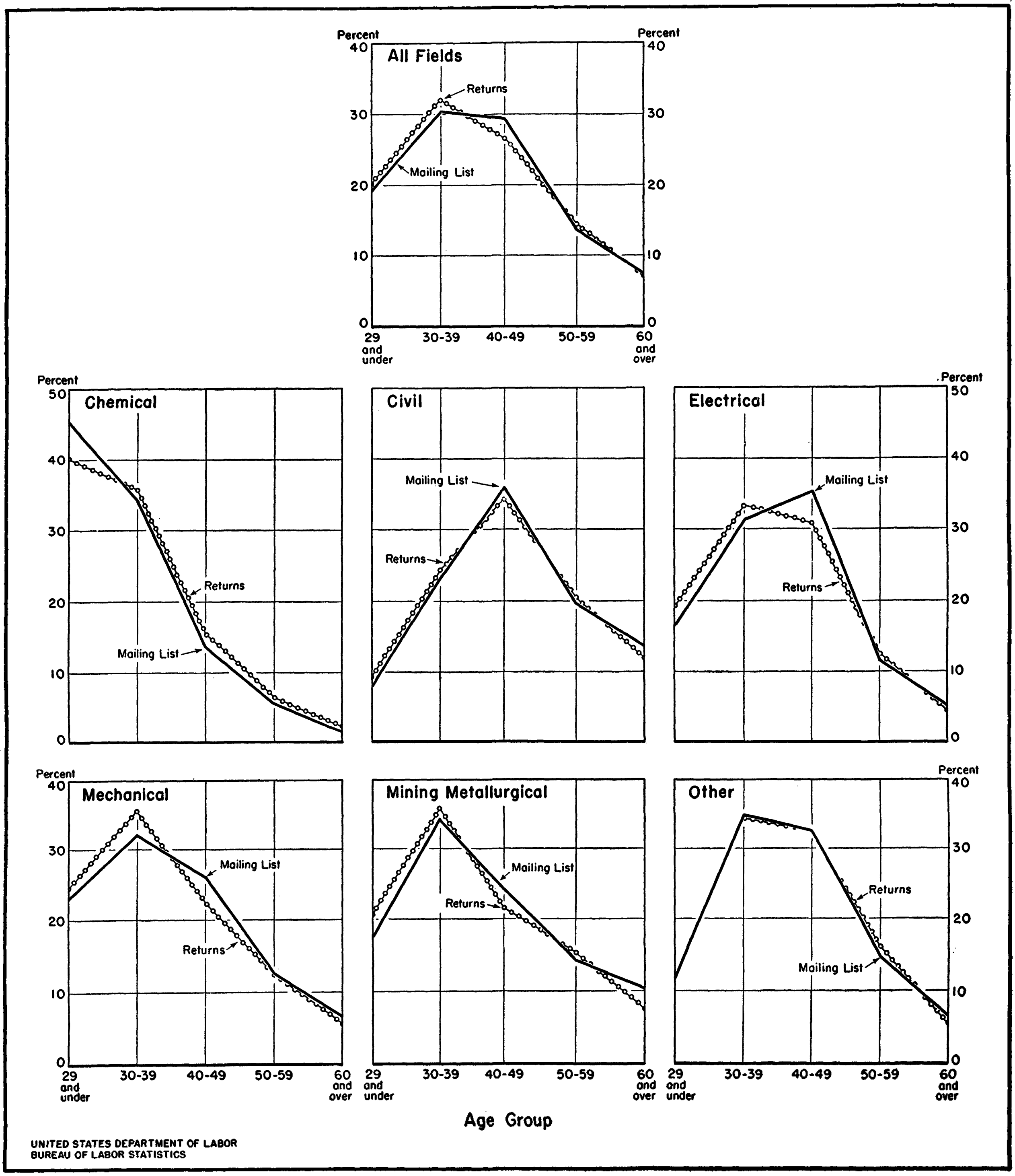


TABLE C–2.—*Percentage comparison of mailing list and respondents in each field of engineering employment, by educational level*

Engineering educational level	Total		Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Mailing list	Respondents	Mailing list	Respondents	Mailing list	Respondents	Mailing list	Respondents	Mailing list	Respondents	Mailing list	Respondents	Mailing list	Respondents
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Doctor's or master's degree	8.6	14.6	15.4	24.2	6.2	11.0	8.6	13.9	6.4	12.7	13.0	23.1	8 9	13.5
Bachelor's degree	66.8	66.7	71.2	69.1	64.3	65.7	69.7	68.8	66.3	67.9	68.3	62.4	62.5	60.6
Incomplete and no college	24.6	18.7	13.4	6.7	29.5	23.3	21.7	17.3	27.3	19.4	18.7	14.5	28.6	25.9

younger engineers in the civil, electrical, mechanical, and mining and metallurgical fields was slightly greater than their representation in the mailing list; whereas the number of returns from the older group of chemical and "other" engineers was the greater. The greatest deviation between proportions in the returns and in the mailing list was 4.9 percent in the 29-years-and-under age group for chemical engineers.

Comparison of the distribution by level of education for each of the fields (table C–2) shows the proportion of respondents with the bachelor's degree to be in agreement with the proportion of those showing the bachelor's degree on the mailing list. However, the returns from engineers with advanced degrees (doctor and master) were considerably higher than their representation in the mailing list, the excesses ranging from 4.6 percent for "other" engineers to 10.1 percent for mining and metallurgical engineers. The proportions of returns from those with incomplete or no college education were below the proportions in the mailing list by about the same amounts as the doctor and master returns were above the proportions in the mailing list.

The fact that the response to the survey represents a group with a higher proportion of advanced degrees than was shown in the mailing list may be accounted for, in part, by the method by which the Roster set up its registry. Many of the registrations were from college seniors who had not yet received their degrees. Although these registrants were recircularized by the Roster and requested to report any changes in status, such as additional education, it is possible that many did not respond and, therefore, continued to appear on the Roster files in the incomplete college group. When they returned their questionnaries for the survey, however, they indicated that they had a bachelor's or higher degree. Likewise, persons who registered before they received their advanced degrees may not have reported this change in educational level to the Roster. It may also be that those engineers with the greatest amount of training tend to have greater interest in the profession as a whole and respond better to surveys of the type made by the Bureau. The bias introduced by the overreporting of engineers with advanced degrees and the underreporting of those without degrees was not considered of sufficient magnitude to warrant weighting of the returns.

Comparison of Returns With Census Data

The 1940 Census of Population gives information on engineers which makes possible some comparisons with the data concerning their status in 1939 which was reported by engineers in the 1946 Survey of the Engineering Profession. Approximately 260,000 persons were classified by the census as engineers in 1940, and were grouped in 6 general engineering fields: Chemical, civil, electrical, mechanical, industrial, and mining and metallurgical. After eliminating from the census report those who would have been lost to the profession through death and retirement [4] from 1940 to 1946 (and would therefore not have reported in 1946), the comparison of the census distribution of engineers by field with that of the respondents to the 1946 Survey of the Engineering Profession (based on their reports as to their status in 1939) is as follows:

[4] Estimates of deaths and retirements based on preliminary tables of working life expectancy for urban white males prepared by the Bureau of Labor Statistics.

Field of engineering	*1940 Census survivors in 1946* Percent	*1946 Survey (1939 reports)* Percent
Chemical	4.6	9.5
Civil	33.6	24.9
Electrical	21.6	21.5
Mechanical and industrial	36.3	26.3
Mining and metallurgical	3.9	6.3
Other	—	11.5
All engineers	100.0	100.0

The chief reason for the differences in the above distributions is believed to lie in the methods used in classifying the engineers. In the 1946 Survey each respondent classified himself as being in one of the 5 fields shown above or in the broad category of "other" engineering, or in nonengineering. As many as 11.5 percent of the respondents classified themselves as "other" engineers, with no indication as to the type of engineering work done. For example, an agricultural, refrigerating, or automotive engineer may have classified himself among "other" engineers. In the census, each engineer reported his specialty in his own terms to the enumerator. When the enumerators' records were reviewed in the Bureau of the Census, classification of persons reported as engineers was done uniformly by clerks with specific rules in this regard. For example, all agricultural, refrigerating, and automotive engineers were classified as mechanical engineers; all "government" engineers (unless otherwise specified) were classified as civil engineers; ceramic engineers were classified as chemists.

The results of the analysis of the survey data cannot be much affected by the number of respondents in each field so long as each field is considered separately. However, presentation of data for the engineering profession as a whole may give a distorted picture if the component fields are not in proper proportion.

Another comparison which can be made between Census data and 1946 Survey data is that of age composition. Table C–3 and chart C–2 show the age distribution of the survey sample to be younger than the census distribution in all fields. The fact that the ages of engineers in the Census are as of April 1, 1940 and those of the survey as of about October 1939 would result in a slightly younger age distribution in the survey (in both cases, age at last birthday was requested). Another factor which may have tended to produce a bias toward older engineers in the Census is explained in the following excerpt from a Census publication:[5]

> At the 1940 Census, persons under 35 years old, returned as technical engineers, were not coded as technical engineers unless they had had at least 4 years of college education. An examination of a

[5] *Comparative Occupation Statistics for the United States, 1870 to 1940*, p. 24, U. S. Department of Commerce, Bureau of the Census, Washington 25, D. C., 1943.

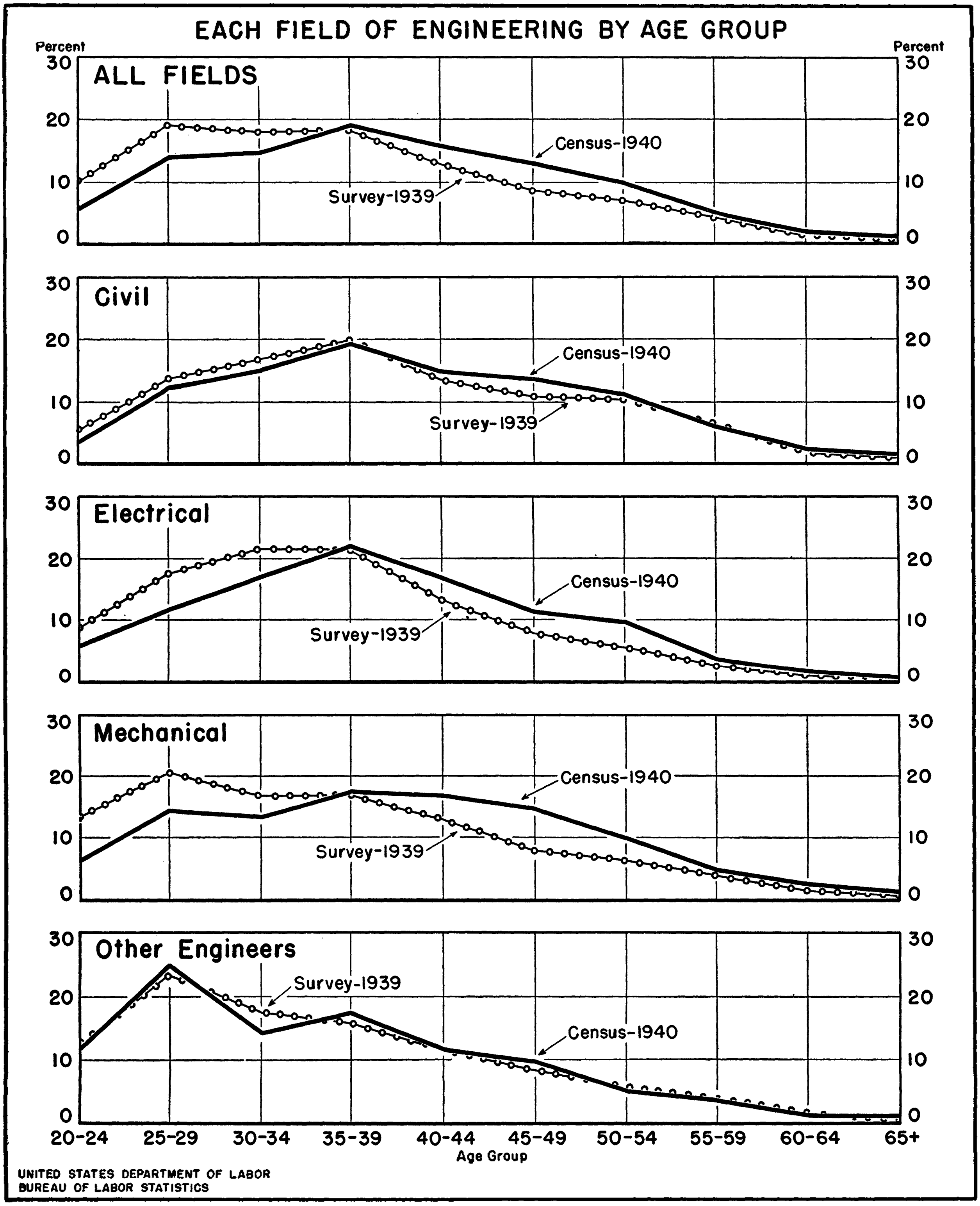
TABLE C–3.—*Percentage comparison of 1940 Census survivors [1] and 1946 Survey respondents, by age in 1939, for each field of engineering employment by age group*

Age groups	Percentage in field of engineering employment									
	Total		Civil		Electrical		Mechanical		Other	
	1940 Census survivors in 1946	1946 Survey (1939 reports)	1940 Census survivors in 1946	1946 Survey (1939 reports)	1940 Census survivors in 1946	1946 Survey (1939 reports)	1940 Census survivors in 1946	1946 Survey (1939 reports)	1940 Census survivors in 1946	1946 Survey (1939 reports)
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20–24 years [2]	5.8	10.1	3.8	5.7	5.8	8.9	6.2	13.4	11.7	12.6
25–29 years	14.0	19.0	12.1	13.8	11.7	17.5	14.6	20.6	25.0	23.4
30–34 years	14.7	18.0	14.9	16.7	16.9	21.6	13.1	16.9	14.2	17.4
35–39 years	19.0	18.2	19.3	19.9	22.0	21.3	17.2	16.7	17.3	15.8
40–44 years	15.8	12.8	15.0	13.5	16.9	13.2	16.7	12.9	11.6	11.6
45–49 years	13.0	8.6	13.6	10.9	11.2	7.9	14.5	7.7	9.5	8.1
50–54 years	9.8	6.9	11.2	10.4	9.6	5.5	9.7	6.1	5.0	5.6
55–59 years	4.8	4.2	6.1	6.2	3.7	2.6	4.7	3.9	3.6	3.8
60–64 years	2.0	1.4	2.4	1.9	1.6	1.0	2.2	1.3	1.1	1.3
65 years and over	1.1	.6	1.6	1.0	.6	.5	1.1	.5	1.0	.4

[1] 1940 Census figures minus the number of deaths and retirements to 1946 based on preliminary tables of working-life expectancy for urban white males, prepared by the Bureau of Labor Statistics.

[2] Those under 20 years of age were included in this age group, which added less than 0.5 percent to any one field.

Chart C–2.—Comparison of 1940 Census Survivors in 1946 and Survey Respondents for 1939



small sample of the coded schedules showed that the operation of this rule resulted in a considerable number—possibly as many as 12,000—of the persons who were returned as technical engineers not being coded as technical engineers.

College education of engineers was reported to the Census in two categories—those having 1 to 3 years of education and those with 4 or more years. Therefore, it is not possible to make strict comparisons with Survey educational data, which show highest degree received. The fact that amount of education was reported in the Survey as of 1946 also makes comparison with census material difficult. However, it is significant that only 62 percent of the engineers reporting to the census in 1940 had 4 or more years of college, while as many as 81 percent of the engineers included in the 1946 Survey reported degrees in engineering in 1946. The proportion of engineers with degrees did increase substantially from 1940 to 1946; some 95,000 engineers were graduated in this period and, allowing for deaths and retirements of older engineers, it may be estimated that at least 70 percent of the engineers in 1946 were graduates.

One reason for the survey showing higher educational attainment lies in the age composition, as discussed above. Since it is known that a higher portion of young engineers hold college degrees than do older engineers, it follows that a sample with an overrepresentation of those in the younger age groups also shows higher educational attainment.

Summary

In order to evaluate the accuracy of the survey as a measure of the economic status of engineers, comparison has been made of the responses with both the National Roster mailing list and Bureau of the Census data. It was found that the respondents in the survey include a slightly higher proportion of younger engineers than does the profession as a whole and a higher proportion of those with advanced degrees. It was also found that the respondents by field of engineering did not fully correspond to the Census and National Roster data. However, the methods employed in presenting the results of the survey completely eliminate the effect of the bias in the distribution by age and field of engineering—since most tables show each field of engineering separately and, in nearly every case, the data on earnings are tabulated separately for engineers with different lengths of experience. Some of the earnings tabulations are affected to a very small extent by the overrepresentation of graduate engineers. The effect of this bias upon earnings may be judged by table 11 which presents earnings by education. It is not likely that a presentation of earnings disregarding experience and education would be distorted to any extent, because the high proportion of younger and hence lower-paid engineers would probably be offset by the too-high proportion of graduate engineers who earn, on the average, more than those with less education.

Budget Approval No. 44—4626
Approval Expires 11/30/46

THE 1946 SURVEY OF THE ENGINEERING PROFESSION

Committee on the Economic
Status of the Engineer
ENGINEERS JOINT COUNCIL

in Cooperation With the

Bureau of Labor Statistics
U. S. DEPARTMENT OF LABOR
Washington 25, D. C.

NOTE 1.—Questions 2 to 6 inclusive require merely that you circle one and only one of the code numbers.

1. Age last birthday (in years): ......

2. Sex: Male 1
Female 2
(Circle one and only one of these two code numbers)

3. Year of entering profession: Indicate below the year in which you drew your first salary in your professional field.

1899 (or before)—

19—00	01	02	03	04	05	06	07	08	09
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46			

(Circle one and only one of these forty-eight code numbers)

4. Formal education in a nonengineering field: If you received education in a nonengineering field indicate below the highest educational level reached by you (excluding honorary degrees).

Doctor .... 1 | Master 2
Bachelor .... 3 | Incomplete college 4
(Circle one and only one of these four code numbers)

5. Formal education in a basic engineering field: Indicate below the highest educational level reached by you in a basic engineering field (excluding honorary degrees).

Basic engineering field	Educational level: Doctor	Master	Bachelor	Incomplete college training	No college training
Chemical engineering	11	12	13	14	15
Civil engineering	21	22	23	24	25
Electrical engineering	31	32	33	34	35
Mechanical engineering	41	42	43	44	45
Mining and metallurgical engineering	51	52	53	54	55
Any other engineering field	61	62	63	64	65

(Circle one and only one of these thirty code numbers)

6. Veteran status:
Are you a veteran of World War II? Yes .... 1 No 2
(Circle one and only one of these two code numbers)

NOTE 2.—In answering questions 7 to 10 inclusive, do not insert any code numbers for years prior to the one when you drew your first salary in your professional field which you circled in question 3.

7. Employment location: Insert in box for the appropriate year or years one and only one code number corresponding to the location in which you were employed for the major part of that year.

1946 [ ] 1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2)

State	Code No.	State	Code No.	State	Code No.	State	Code No.
Alabama	73	Iowa	52	Nevada	98	South Dakota	55
Arizona	96	Kansas	57	New Hampshire	32	Tennessee	72
Arkansas	61	Kentucky	71	New Jersey	02	Texas	64
California	43	Louisiana	62	New Mexico	95	Utah	97
Colorado	94	Maine	31	New York	01	Vermont	33
Connecticut	36	Maryland	22	North Carolina	25	Virginia	23
Delaware	21	Massachusetts	34	North Dakota	54	Washington	41
District of Columbia	89	Michigan	14	Ohio	11	West Virginia	24
Florida	28	Minnesota	51	Oklahoma	63	Wisconsin	15
Georgia	27	Mississippi	74	Oregon	42	Wyoming	93
Idaho	92	Missouri	53	Pennsylvania	03	U. S. Territories and Possessions	X6
Illinois	13	Montana	91	Rhode Island	35	Foreign Countries	R7
Indiana	12	Nebraska	56	South Carolina	26		

8. Annual income: (Respondents who circled one of the years 44 to 46 inclusive in question 3 will please omit question 8.) For the years 1939 and 1943 insert in box for the appropriate year or years the code number of the income bracket that contains your annual income from salaries or personal services in both engineering and nonengineering work, including fees and bonuses.

1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2)

Income bracket	Code No.	Income bracket	Code No.	Income bracket	Code No.	Income bracket	Code No.
Under $1,200	01	$2,600 and under $3,000	09	$6,000 and under $6,600	17	$12,000 and under $13,800	25
$1,200 and under $1,400	02	$3,000 and under $3,400	10	$6,600 and under $7,200	18	$13,800 and under $15,600	26
$1,400 and under $1,600	03	$3,400 and under $3,800	11	$7,200 and under 7,800	19	$15,600 and under $17,400	27
$1,600 and under $1,800	04	$3,800 and under $4,200	12	$7,800 and under $8,400	20	$17,400 and under $19,200	28
$1,800 and under $2,000	05	$4,200 and under $4,600	13	$8,400 and under $9,000	21	$19,200 and over	29
$2,000 and under $2,200	06	$4,600 and under $5,000	14	$9,000 and under $9,600	22		
$2,200 and under $2,400	07	$5,000 and under $5,400	15	$9,600 and under $10,200	23		
$2,400 and under $2,600	08	$5,400 and under $6,000	16	$10,200 and under $12,000	24		

9. Rate of earnings (monthly salary rates): Insert in box for the appropriate year or years one and only one code number of the salary bracket that contains your monthly salary rate for the time actually employed in engineering work. (a) Exclusive of fees, bonuses, and overtime payment; and (b) exclusive of fees and bonuses, but inclusive of overtime payment. *Important:* Repeat codes in (b) if (b) happens to be the same as (a).

(a) Exclusive of fees, bonuses, and overtime payment.

1946 [ ] 1943 [ ] 1939 [ ]

(Before inserting code numbers please refer to note 2)

(b) Exclusive of fees and bonuses, but inclusive of overtime payment.

1946 [ ] 1943 [ ] 1939 [ ]

(Before inserting code numbers please refer to note 2)

Salary bracket	Code No.	Salary bracket	Code No.	Salary bracket	Code No.	Salary bracket	Code No.
Under $100	01	$170 and under $180	09	$300 and under $320	17	$570 and under $620	25
$100 and under $110	02	$180 and under $190	10	$320 and under $340	18	$620 and under $680	26
$110 and under $120	03	$190 and under $200	11	$340 and under $370	19	$680 and under $750	27
$120 and under $130	04	$200 and under $220	12	$370 and under $400	20	$750 and under $850	28
$130 and under $140	05	$220 and under $240	13	$400 and under $440	21	$850 and under $1,000	29
$140 and under $150	06	$240 and under $260	14	$440 and under $480	22	$1,000 and over	30
$150 and under $160	07	$260 and under $280	15	$480 and under $520	23		
$160 and under $170	08	$280 and under $300	16	$520 and under $570	24		

(OVER)

10. Employment status: Insert in box for the appropriate year or years one and only one code number corresponding to your major activity during the year with respect to your (1) general field of employment; (2) class of worker; (3) industry field in which employed; and (4) occupational status.

(1) General field of employment: (If unemployed in any of these years insert the code number for the field in which seeking work):

1946 [ ] 1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2).

General field of employment	Code No.	*General field of employment*	Code No.
Chemical engineering	1	Mining and metallurgical engineering	5
Civil engineering	2	Any other engineering field	6
Electrical engineering (include radio)	3	Nonengineering field	7
Mechanical engineering (include aeronautical and industrial)	4		

(2) Class of worker:

1946 [ ] 1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2.)

Class of worker	Code No.
Engaged in engineering as:	
Employer	01
Employee of a private firm, organization or institution (exclude private consulting work)	11
Independent consultant	12
Employee of Federal Government	21
Employee of State government	22
Employee of county government	23
Engaged in engineering as—Continued	
Employee of municipal government	24
Employee of other public authority	25
Member of the armed forces	26
In nonengineering work as member of armed forces	27
In nonengineering work as civilian	31
Student	41
Retired	51
Unemployed	61

(3) Industry field in which employed:

1946 [ ] 1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2.)

Industry field in which employed	Code No.
Agriculture and forestry	100
Mining:	
Coal	201
Crude petroleum and natural gas	202
Ferrous	203
Nonferrous metals	204
Other mining industries not specified	205
Construction:	
Bridges	301
Buildings	302
Highways	303
Sewerage	304
Surveying	305
Waterways	306
Waterworks	307
Other construction not specified	308
Manufacturing:	
Food and kindred products	401
Textile mill products, excluding rayon and allied products	402
Lumber, furniture, and lumber products	410
Paper and allied products	411
Printing and publishing	420
Chemicals and allied products, including rayon and allied products	430
Petroleum and coal products:	
Petroleum refining	440
Other petroleum and coal products industries not specified	441
Rubber products	450
Stone, clay, and glass products	451
Iron and steel and their products:	
Blast furnaces, steel works, and rolling mills	460
Other iron and steel industries not specified	461
Nonferrous metals and their products	462
Manufacturing—Continued	
Machinery:	
Electrical machinery and equipment	470
Other machinery industries not specified	471
Transportation equipment:	
Aircraft and parts	480
Automobiles and automobile equipment	481
Other transportation equipment industries not specified	482
Other manufacturing industries not specified	490
Transportation:	
Railroads, including railroad repair shops	501
Other transportation industries not specified	502
Communication:	
Telephone (wire and radio)	601
Radio broadcasting and television	602
Telegraph (wire and radio)	603
Utilities:	
Electric light and power	701
Water and sanitary services	702
Gas works and steam plants	703
Other industry fields:	
Refrigerating, heating, and ventilating	801
Wholesale and retail trade	802
Insurance and appraisal	803
Finance, taxation, and real estate	804
Education	805
Legal	806
Professional and trade organization	807
Other service industries not specified	808
Any industry field not specified	900
Unemployed	001

(4) Occupational status:

1946 [ ] 1943 [ ] 1939 [ ] (Before inserting code numbers please refer to note 2.)

Occupational status	Code No.	*Occupational status*	Code No.
Administration-management, nontechnical	01	Patents	17
Administration-management, technical	02	Personnel-labor problems	18
Analysis and testing	03	Production	19
Construction, supervision	04	Research in basic science	20
Consulting, independent	05	Research, applied	21
Consulting, as employee of private firm	06	Retired	22
Design	07	Safety engineering	23
Development	08	Sales	24
Drafting	09	Student	25
Editing and writing	10	Teaching, college or university	26
Estimating	11	Teaching, other	27
Inspection	12	Unemployed	28
Installation	13	Any occupational status not specified	29
Library and information service	14		
Maintenance	15		
Operation	16		

(LS 47-582)

Appendix D. Supplementary Tables

Table D–1.—*Number of engineers in the United States, by field of engineering, 1910–48*

Year	Total	Civil	Electrical	Mechanical [1]	Other [2]
1910	84,177	46,737	15,125	15,385	6,930
1920	129,939	56,488	26,806	39,950	6,695
1930	215,386	88,540	57,259	57,617	11,970
1940	261,428	89,042	55,667	95,346	21,373
1948 [3]	350,000	90,092	73,647	130,436	56,843

[1] Includes industrial and aeronautical engineers.
[2] Includes chemical, mining and metallurgical engineers.
[3] Estimates by the Bureau of Labor Statistics (see appendix table D-2). Total rounded.

Source: U. S. Department of Commerce, Bureau of the Census, Civil engineers; data 1910 to 1930. Adjusted by Bureau of Labor Statistics to exclude surveyors.

Table D–3.—*Number of engineering degrees awarded in the United States, 1920–52 (Baccalaureate and first professional degree)*

Academic year ending June 30	U. S. Office of Education [1]	Journal of Engineering Education [2]	Estimated total [3]
1920	4,716	(*)	5,000
1921	5,855	(*)	6,100
1922	7,268	(*)	7,500
1923	7,496	(*)	7,700
1924	7,731	(*)	8,000
1925	7,558	(*)	7,800
1926	7,389	(*)	7,600
1927	7,510	(*)	7,800
1928	7,633	(*)	7,900
1929	7,513	(*)	7,800
1930	7,395	(*)	7,700
1931	8,885	(*)	9,200
1932	10,374	(*)	10,700
1933	10,897	(*)	11,300
1934	11,419	(*)	12,000
1935	11,024	8,847	11,600
1936	10,629	7,881	11,200
1937	10,834	8,245	11,400
1938	11,039	8,697	11,600
1939	12,694	12,408	13,300
1940	13,808	11,358	15,100
1941	14,318	12,709	15,200
1942	14,847	14,987	16,000
1943	14,450	14,145	15,300
1944	12,785	12,118	13,500
1945	(*)	7,645	8,500
1946	(*)	10,440	11,500
1947	(*)	18,592	21,000
1948	[5] 31,096	28,763	32,000
1949	[6] 43,604	(*)	44,000
1950	(*)	(*)	[4] 47,000
1951	(*)	(*)	[4] 36,000
1952	(*)	(*)	[4] 29,000

[1] From Biennial Surveys of Education in the United States, Statistics of Higher Education, U. S. Office of Education; data for uneven years estimated by the Bureau of Labor Statistics on the basis of a method used by the U. S. Office of Education.
[2] *Journal of Engineering Education*, annual statistics on engineering enrollments and graduates, Dec. 1935 to Feb. 1949.
[3] Graduates estimated by the Bureau of Labor Statistics with adjustment (approximately 5 percent) for schools not reporting each year.
[4] Estimates by the Bureau of Labor Statistics on the basis of enrollments reported in the Journal of Engineering Education, Feb. 1949, for the academic year 1948–49.
[5] Federal Security Agency, U. S. Office of Education, *Earned Degrees Conferred by Higher Educational Institutions, 1947–48*, Cir. No. 247, Nov. 1948, Washington 25, D. C.
[6] Federal Security Agency, U. S. Office of Education, *Higher Education*, Oct. 15, 1949.
*Not available.

Table D–2.—*Estimated changes in the engineering profession, 1940–48*

Item	Total	Civil	Electrical	Mechanical (including industrial and aeronautical)	Other (including chemical, mining and metallurgical)
Number of engineers, April 1940 [1]	261,428	89,042	55,667	95,346	21,373
Deduction for deaths and retirements, 1940–48 [2]	−43,000	−16,200	−7,700	−15,600	−2,500
Graduations, 1940–48 [3]	116,100	17,550	21,180	42,400	34,970
Excess of number of entrants without engineering degrees over number of engineers or engineering graduates leaving profession for other employment [4]	15,500	−1,300	4,500	9,300	3,000
Estimated number of engineers, April 1948 [5]	350,000	90,092	73,647	130,436	56,843
Percent increase, 1940–48	33.9	1.1	32.3	36.7	165.9

[1] Includes those employed, those seeking work and those on public emergency work. Source: Bureau of the Census.
[2] Calculated by Bureau of Labor Statistics from 1940 age composition (Census) by means of preliminary tables of working life expectancy for white males in urban communities.
[3] Table D-3, and table 8 on p. 39.
[4] Rough estimate on the basis of examination of data on occupational mobility of engineers from the 1946 survey of the engineering profession and other information at hand.
[5] Total rounded; the break-down by field of engineering which represents estimates only is shown to the last digit for the convenience of the reader in following the table.

Table D–4.—*Growth of the engineering profession and major industries employing engineers, and ratio of workers per engineer, 1890–1948*

Year	Number of engineers [1]	Manpower in selected industries [2]	Engineers per 100,000 workers	Workers per engineer
1890	26,833	7,800,000	344	290
1900	41,087	10,459,000	393	255
1910	84,177	14,461,000	582	172
1920	129,939	18,075,000	719	139
1930	215,386	19,949,000	1,080	93
1940	261,428	20,399,000	1,282	78
1948	350,000	24,300,000	1,440	69

[1] Gainful workers, 1890 to 1930 (adjusted for surveyors, see appendix B) labor force in 1940 (including 245,288 employed and 16,140 unemployed based on decennial census data; labor force in 1948 estimated by Bureau of Labor Statistics (see appendix table D-2).
[2] Manufacturing, mining, construction, transportation, and public utilities. All figures except 1948 based on decennial census data. Includes gainful workers, 1890 to 1930; labor force in 1940. Includes unemployed and self-employed as well as employees. Source for 1890 to 1940: Industrial Composition of Manpower in the United States, 1870–1940. Source for 1948: Bureau of Labor Statistics (adjusted to same basis as 1940).

TABLE D-5.—*Median age and median years of experience, by educational level for each field of engineering employment, 1946*

Educational level	Field of engineering employment											
	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Age	Experience	Age	Experience	Age	Experience	Age	Experience	Age	Experience	Age	Experience
Doctor	36	13.2	48	25.0	41	18.1	41	19.2	40	16.5	38	15.9
Master	31	8.8	45	22.6	39	16.5	39	15.8	40	15.9	42	18.8
Bachelor	31	7.7	42	19.8	38	14.5	34	11.4	36	12.3	39	15.7
Incomplete college	35	14.8	47	25.4	42	19.8	43	20.0	41	18.1	45	21.4
No college	41	22.5	51	28.1	44	20.2	47	24.9	48	26.1	44	19.1
Not reported	39	18.1	56	32.5	36	14.4	37	15.0	43	18.9	42	16.1

TABLE D-6.—*Percentage distribution, by educational level in each occupational status, for each field of engineering employment, 1946*

Occupational status	Total percent	Doctor	Master	Bachelor	Incomplete college	No college	Total percent	Doctor	Master	Bachelor	Incomplete college	No college
	CHEMICAL ENGINEERS						CIVIL ENGINEERS					
Total	100.0	5.7	18.5	69.1	5.8	0.9	100.0	1.2	9.8	65.8	19.4	3.8
Administration-management, nontechnical	100.0	5.6	14.8	64.8	11.1	3.7	100.0	1.9	7.4	62.9	24.1	3.7
Administration-management, technical	100.0	6.5	17.8	67.9	6.2	1.6	100.0	.8	9.5	65.9	20.6	3.2
Analysis and testing	100.0	3.1	6.2	81.5	8.2	1.0	100.0	---	10.9	71.7	8.7	8.7
Construction supervision	100.0	9.1	22.7	50.0	18.2	---	100.0	.7	5.3	61.5	25.8	6.7
Consulting, independent	100.0	10.0	20.0	46.6	16.7	6.7	100.0	1.7	13.2	62.6	17.0	5.5
Consulting, as employee of private firm	100.0	6.9	13.8	69.0	8.6	1.7	100.0	2.1	16.7	62.4	13.9	4.9
Design	100.0	4.4	29.1	61.6	4.4	.5	100.0	.8	9.6	70.7	16.3	2.6
Development	100.0	4.6	18.4	72.0	4.3	.7	100.0	---	9.1	68.2	19.3	3.4
Drafting	100.0	---	---	100.0	---	---	100.0	---	2.8	77.4	16.0	3.8
Editing and writing	100.0	---	---	83.3	16.7	---	100.0	---	22.6	74.2	3.2	---
Estimating	100.0	10.0	10.0	70.0	10.0	---	100.0	1.7	5.1	71.0	20.5	1.7
Inspection	100.0	---	14.3	85.7	---	---	100.0	---	7.8	65.5	25.6	1.1
Installation	100.0	---	---	100.0	---	---	100.0	---	---	70.0	30.0	---
Library and information service	100.0	33.3	33.3	33.4	---	---	---	---	---	---	---	---
Maintenance	100.0	---	5.6	83.3	11.1	---	100.0	1.3	2.0	66.3	25.0	5.4
Operation	100.0	---	10.0	83.6	5.5	.9	100.0	---	4.0	72.0	18.0	6.0
Patents	100.0	15.4	30.8	53.8	---	---	---	---	---	---	---	---
Personnel-labor problems	100.0	---	---	100.0	---	---	---	---	---	---	---	---
Production	100.0	.9	15.1	79.4	4.1	.5	100.0	---	12.5	62.5	25.0	---
Research in basic science	100.0	8.7	34.8	56.5	---	---	100.0	7.7	15.4	76.9	---	---
Research, applied	100.0	5.4	22.3	67.6	4.1	.6	100.0	3.4	32.8	53.5	8.6	1.7
Retired	100.0	---	---	60.0	40.0	---	100.0	---	---	80.0	20.0	---
Safety engineering	100.0	---	10.0	70.0	20.0	---	100.0	---	18.2	45.4	27.3	9.1
Sales	100.0	6.2	13.6	71.6	8.6	---	100.0	1.9	7.5	83.1	7.5	---
Student	100.0	2.3	29.5	50.0	18.2	---	100.0	---	---	66.7	33.3	---
Teaching, college or university	100.0	38.8	28.4	32.8	---	---	100.0	13.6	44.6	40.8	1.0	---
Teaching, other	---	---	---	---	---	---	100.0	---	100.0	---	---	---
Unemployed	100.0	6.3	---	87.5	6.2	---	100.0	---	9.1	72.7	9.1	9.1
Any occupational status not specified above	100.0	---	25.0	66.7	8.3	---	100.0	---	8.9	65.2	22.3	3.6

Table D-6.—*Percentage distribution, by educational level in each occupational status, for each field of engineering employment, 1946*—Continued

Occupational status	Total percent	Doctor	Master	Bachelor	Incomplete college	No college	Total percent	Doctor	Master	Bachelor	Incomplete college	No college
	ELECTRICAL ENGINEERS						MECHANICAL ENGINEERS					
Total	100.0	2.1	11.8	68.7	13.9	3.5	100.0	1.8	10.9	67.9	15.9	3.5
Administration-management, nontechnical	100.0	1.1	5.3	67.0	16.0	10.6	100.0	1.3	6.4	64.9	21.7	5.7
Administration-management, technical	100.0	1.9	12.4	65.5	17.2	3.0	100.0	1.9	11.1	64.7	18.9	3.4
Analysis and testing	100.0		5.5	76.5	14.1	3.9	100.0		8.6	84.7	6.2	.5
Construction supervision	100.0	1.3	3.8	70.1	17.2	7.6	100.0	2.5	9.9	62.8	22.3	2.5
Consulting, independent	100.0	4.6	16.9	50.8	18.5	9.2	100.0	3.2	16.0	53.6	20.0	7.2
Consulting, as employee of private firm	100.0	1.0	17.7	66.2	13.1	2.0	100.0	2.6	14.0	65.5	13.6	4.3
Design	100.0	.7	9.9	74.1	12.9	2.4	100.0	.7	7.7	69.1	17.9	4.6
Development	100.0	1.2	14.2	73.1	9.9	1.6	100.0	.6	11.5	71.0	14.4	2.5
Drafting	100.0			77.5	12.5	10.0	100.0	.9	2.7	75.1	18.6	2.7
Editing and writing	100.0		8.1	62.2	24.3	5.4	100.0	7.4	18.5	59.3	11.1	3.7
Estimating	100.0		2.8	85.9	8.5	2.8	100.0	2.9	4.3	67.1	24.3	1.4
Inspection	100.0	1.7	5.2	72.4	19.0	1.7	100.0	1.6	3.2	63.4	28.6	3.2
Installation	100.0		9.5	74.6	12.7	3.2	100.0		5.9	84.3	5.9	3.9
Library and information service	100.0			100.0			100.0			100.0		
Maintenance	100.0		4.6	63.8	23.7	7.9	100.0	1.4	5.6	74.0	14.1	4.9
Operation	100.0	.6	3.5	67.2	19.3	9.4	100.0	.9	6.2	75.2	12.4	5.3
Patents	100.0		18.2	77.3	4.5		100.0	4.3	17.4	65.3	8.7	4.3
Personnel-labor problems	100.0		20.0	60.0	20.0		100.0			95.7	4.3	
Production	100.0			85.4	12.2	2.4	100.0	2.2	5.4	68.4	20.7	3.3
Research in basic science	100.0	16.7	16.7	46.6	16.7	3.3	100.0	8.2	16.4	72.2	1.6	1.6
Research, applied	100.0	6.2	18.6	63.5	9.3	2.4	100.0	3.2	18.1	69.6	6.7	2.4
Retired	100.0		40.0	60.0			100.0		16.7	66.6	16.7	
Safety engineering	100.0		11.1	77.8	11.1		100.0	5.9		64.7	23.5	5.9
Sales	100.0		6.5	80.4	9.6	3.5	100.0	.5	5.9	77.6	14.0	2.0
Student	100.0		8.0	72.0	20.0		100.0		13.6	72.8	13.6	
Teaching, college or university	100.0	23.1	47.6	28.5		.8	100.0	11.7	45.0	40.3	1.8	1.2
Teaching, other	100.0		20.0	53.3	20.0	6.7	100.0		20.0	40.0	40.0	
Unemployed	100.0		41.7	50.0	8.3		100.0		9.4	59.3	18.8	12.5
Any occupational status not specified above	100.0		4.4	80.9	10.3	4.4	100.0	1.1	14.1	67.4	10.9	6.5

Occupational status	Total percent	Doctor	Master	Bachelor	Incomplete college	No college	Total percent	Doctor	Master	Bachelor	Incomplete college	No college
	MINING AND METALLURGICAL ENGINEERS						OTHER ENGINEERS					
Total	100.0	5.2	17.9	62.4	12.2	2.3	100.0	2.3	11.2	60.7	21.0	4.8
Administration-management, nontechnical	100.0		17.7	64.7	8.8	8.8	100.0	.9	6.8	65.8	21.4	5.1
Administration-management, technical	100.0	5.9	17.4	60.9	12.9	2.9	100.0	2.9	12.1	58.7	22.4	3.9
Analysis and testing	100.0	2.2	13.3	62.3	17.8	4.4	100.0		2.4	87.8	9.8	
Construction supervision	100.0		10.0	70.0	20.0		100.0	1.1	4.3	62.7	25.5	6.4
Consulting, independent	100.0	5.1	20.5	46.2	28.2		100.0	1.7	15.0	46.7	28.3	8.3
Consulting, as employee of private firm	100.0	10.2	24.5	53.1	12.2		100.0		13.3	62.7	17.3	6.7
Design	100.0		30.0	30.0	40.0		100.0		7.8	61.0	23.4	7.8
Development	100.0	1.4	17.6	75.6	5.4		100.0	2.6	10.5	72.4	13.2	1.3
Drafting	100.0					100.0	100.0			66.7	33.3	
Editing and writing	100.0	28.6	42.8	28.6			100.0	6.7	33.3	46.7	13.3	
Estimating	100.0			100.0			100.0	2.4	4.8	57.1	26.2	9.5
Inspection	100.0		5.9	70.5	11.8	11.8	100.0	1.9		47.2	39.6	11.3
Installation							100.0		25.0	50.0	12.5	12.5
Library and information service	100.0			100.0			100.0		50.0		50.0	
Maintenance	100.0		28.6	57.1	14.3		100.0	2.5	2.5	72.5	17.5	5.0
Operation	100.0		8.2	71.3	16.4	4.1	100.0		5.3	68.4	22.8	3.5
Patents							100.0		8.7	82.6	8.7	
Personnel-labor problems							100.0			80.0	10.0	10.0
Production	100.0		10.0	75.0	15.0		100.0	1.2	2.4	83.3	11.9	1.2
Research in basic science	100.0		23.1	69.3	3.8	3.8	100.0	28.6	28.6	42.8		
Research, applied	100.0	10.6	23.1	57.3	8.0	1.0	100.0	8.6	26.5	52.1	11.1	1.7
Retired	100.0			100.0								
Safety engineering	100.0			60.0	30.0	10.0	100.0		4.0	48.0	37.0	11.0
Sales	100.0		3.3	83.4	13.3		100.0	.6	6.6	70.6	16.8	5.4
Student	100.0		25.0	62.5	12.5		100.0		14.3	71.4		14.3
Teaching, college or university	100.0	18.2	48.5	30.3		3.0	100.0	12.3	53.9	29.2	4.6	
Teaching, other	100.0			100.0			100.0		14.3	57.1	28.6	
Unemployed	100.0			87.5	12.5		100.0		11.1	77.8	11.1	
Any occupational status not specified above	100.0		15.0	75.0	10.0		100.0	1.0	11.2	61.3	21.4	5.1

TABLE D–7.—*Percentage distribution for each field of engineering employment, by class of worker for each occupational status, 1946*

Occupational status	Total public and private	Private industry: Total	Private industry: Employers and independent consultants	Private industry: Employees of private firms	Public employees: Total	Public employees: Federal	Public employees: State	Public employees: County	Public employees: Municipal	Public employees: Other
	CHEMICAL ENGINEERS									
All chemical engineers	100.0	94.3	5.2	89.1	5.7	2.9	1.9	0.1	0.6	0.2
Administration-management, nontechnical	100.0	98.0	12.3	85.7	2.0	2.0				
Administration-management, technical	100.0	94.9	7.7	87.2	5.1	2.9	.6	.1	1.5	
Analysis and testing	100.0	91.3	2.2	89.1	8.7	2.2	4.3		1.1	1.1
Construction supervision	100.0	95.0	5.0	90.0	5.0	5.0				
Consulting, independent	100.0	100.0	100.0							
Consulting, as employee of private firm	100.0	100.0	5.7	94.3						
Design	100.0	99.0	1.6	97.4	1.0			.5	.5	
Development	100.0	97.2	1.7	95.5	2.8	2.4	.2			.2
Drafting	100.0	100.0		100.0						
Editing and writing	100.0	83.3		83.3	16.7	16.7				
Estimating	100.0	100.0		100.0						
Inspection	100.0	91.7		91.7	8.3		8.3			
Installation	100.0	100.0		100.0						
Library and information service	100.0	100.0		100.0						
Maintenance	100.0	78.6		78.6	21.4	14.3				7.1
Operation	100.0	98.1	2.8	95.3	1.9	1.0			.9	
Patents	100.0	83.3		83.3	16.7	16.7				
Personnel-labor problems	100.0	50.0		50.0	50.0					50.0
Production	100.0	97.5	.5	97.0	2.5	2.5				
Research in basic science	100.0	76.2		76.2	23.8	19.0	4.8			
Research, applied	100.0	90.8	2.9	87.9	9.2	6.2	2.4		.3	.3
Safety engineering	100.0	100.0		100.0						
Sales	100.0	100.0	8.3	91.7						
Student	100.0	100.0		100.0						
Teaching, college or university	100.0	56.7	1.7	55.0	43.3		41.7			1.6
Teaching, other										
Any occupational status not specified above	100.0	85.7		85.7	14.3		14.3			
	CIVIL ENGINEERS									
All civil engineers	100.0	49.2	11.0	38.2	50.8	19.7	15.7	3.8	10.3	1.3
Administration-management, nontechnical	100.0	55.1	21.4	33.7	44.9	14.3	13.3	4.1	11.2	2.0
Administration-management, technical	100.0	40.3	10.4	29.9	59.7	24.2	13.6	5.4	14.8	1.7
Analysis and testing	100.0	19.0		19.0	81.0	52.4	16.7		11.9	
Construction, supervision	100.0	49.2	7.8	41.4	50.8	13.0	21.4	5.2	10.0	1.2
Consulting, independent	100.0	98.0	96.5	1.5	2.0		.5	.5	.5	.5
Consulting, as employee of private firm	100.0	96.2	7.0	91.2	1.8	.9	.9			
Design	100.0	47.6	1.7	45.9	52.4	20.7	16.0	3.5	11.3	.9
Development	100.0	32.0	5.1	26.9	68.0	46.2	10.3	5.1	5.1	1.3
Drafting	100.0	60.4	5.5	54.9	39.6	6.6	16.5	3.3	9.9	3.3
Editing and writing	100.0	37.5	4.2	33.3	62.5	58.3			4.2	
Estimating	100.0	62.3	1.9	60.4	37.7	26.4	7.6	.9	2.8	
Inspection	100.0	17.1	1.3	15.8	82.9	27.6	34.2	4.0	14.5	2.6
Installation	100.0	44.4		44.4	55.6	22.3	11.1	11.1	11.1	
Library and information service										
Maintenance	100.0	47.5		47.5	52.5	12.4	29.2	2.2	8.0	.7
Operation	100.0	47.6		47.6	52.4	28.5	2.4	4.8	14.3	2.4
Patents										
Personnel-labor problems										
Production	100.0	75.0		75.0	25.0	25.0				
Research in basic science	100.0	8.3		8.3	91.7	75.0	16.7			
Research, applied	100.0	18.6		18.6	81.4	62.8	14.0		4.6	
Safety engineering	100.0				100.0	18.2	54.5		27.3	
Sales	100.0	97.6	4.8	92.8	2.4					2.4
Student										
Teaching, college or university	100.0	53.3	2.2	51.1	46.7		40.0		3.4	3.3
Teaching, other	100.0	100.0		100.0						
Any occupational status not specified above	100.0	25.5	4.2	21.3	74.5	37.2	20.2	3.2	12.8	1.1

TABLE D-7.—*Percentage distribution for each field of engineering employment, by class of worker for each occupational status, 1946*—Continued

Occupational status	Total public and private	Private industry: Total	Private industry: Employers and independent consultants	Private industry: Employees of private firms	Public employees: Total	Public employees: Federal	Public employees: State	Public employees: County	Public employees: Municipal	Public employees: Other
	ELECTRICAL ENGINEERS									
All electrical engineers	100.0	85.7	5.4	80.3	14.3	9.7	1.7	0.1	1.9	0.9
Administration-management, nontechnical	100.0	91.9	15.1	76.8	8.1	3.5			3.5	1.1
Administration-management, technical	100.0	85.9	6.6	79.3	14.1	10.5	.5	.1	1.8	1.2
Analysis and testing	100.0	84.1	1.8	82.3	15.9	11.5			.9	3.5
Construction supervision	100.0	79.7	7.7	72.0	20.3	10.5	1.4	.7	5.6	2.1
Consulting, independent	100.0	100.0	96.7	3.3						
Consulting, as employee of private firm	100.0	98.9	3.7	95.2	1.1		.5			.6
Design	100.0	85.1	1.3	83.8	14.9	10.7	.7	.2	2.9	.4
Development	100.0	89.1	.6	88.5	10.9	10.3			.2	.4
Drafting	100.0	87.9	3.0	84.9	12.1	3.0			9.1	
Editing and writing	100.0	85.7		85.7	14.3	11.4	2.9			
Estimating	100.0	94.7	1.7	93.0	5.3	3.5			1.8	
Inspection	100.0	59.6		59.6	40.4	36.6	1.9			1.9
Installation	100.0	83.1	6.8	76.3	16.9	13.5	1.7		1.7	
Library and information service	100.0	100.0		100.0						
Maintenance	100.0	84.9	5.0	79.9	15.1	5.8	1.4		5.0	2.9
Operation	100.0	83.1	3.9	79.2	16.9	6.5			7.1	3.3
Patents	100.0	73.7	15.8	57.9	26.3	21.0	5.3			
Personnel-labor problems	100.0	100.0		100.0						
Production	100.0	95.1	2.4	92.7	4.9	4.8				
Research in basic science	100.0	68.0	4.0	64.0	32.0	24.0	8.0			
Research, applied	100.0	76.6	1.9	74.7	23.4	21.5	1.9			
Safety engineering	100.0	88.9		88.9	11.1	11.1				
Sales	100.0	98.9	6.9	92.0	1.1	.4			.7	
Student	100.0	100.0		100.0						
Teaching, college or university	100.0	61.7		61.7	38.3		34.2		2.5	1.6
Teaching, other	100.0	66.7		66.7	33.3	13.3	6.7		13.3	
Any occupational status not specified above	100.0	75.4	5.2	70.2	24.6	21.1	3.5			
	MECHANICAL ENGINEERS									
All mechanical engineers	100.0	89.5	8.8	80.7	10.5	7.8	1.6	0.1	0.7	0.3
Administration-management, nontechnical	100.0	96.8	23.2	73.6	3.2	1.3			.6	1.3
Administration-management, technical	100.0	93.3	12.8	80.5	6.7	5.6	.5		.6	
Analysis and testing	100.0	85.2	2.0	83.2	14.8	14.3	.5			
Construction supervision	100.0	93.3	10.5	82.8	6.7	4.8	1.9			
Consulting, independent	100.0	99.2	95.1	4.1	.8				.8	
Consulting, as employee of private firm	100.0	98.2	4.4	93.8	1.8	1.8				
Design	100.0	91.0	2.7	88.3	9.0	7.4	.2		1.2	.2
Development	100.0	93.0	2.2	90.8	7.0	6.8				.2
Drafting	100.0	97.1	1.9	95.2	2.9	1.0			1.9	
Editing and writing	100.0	95.7	4.4	91.3	4.3	4.3				
Estimating	100.0	96.7	1.6	95.1	3.3	3.3				
Inspection	100.0	68.4	1.7	66.7	31.6	29.8	1.8			
Installation	100.0	89.1	4.3	84.8	10.9	6.5			2.2	2.2
Library and information service	100.0	75.0		75.0	25.0	25.0				
Maintenance	100.0	88.4	4.7	83.7	11.6	8.5		.8	1.5	.8
Operation	100.0	90.3	1.9	88.4	9.7	1.0			5.8	2.9
Patents	100.0	75.0	5.0	70.0	25.0	20.0	5.0			
Personnel-labor problems	100.0	95.2		95.2	4.8				4.8	
Production	100.0	99.4	3.1	96.3	.6	.6				
Research in basic science	100.0	24.1		24.1	75.9	72.4	3.5			
Research, applied	100.0	69.3	3.1	66.2	30.7	28.1	1.1	.3	.3	.9
Safety engineering	100.0	78.6		78.6	21.4	14.3	7.1			
Sales	100.0	99.4	10.4	89.0	.6	.6				
Student	100.0	100.0		100.0						
Teaching, college or university	100.0	50.3	1.2	49.1	49.7	.6	42.8	.6	1.9	3.8
Teaching, other	100.0	60.0	20.0	40.0	40.0		20.0			20.0
Any occupational status not specified above	100.0	78.4	6.8	71.6	21.6	17.1	4.5			

TABLE D-7.—*Percentage distribution for each field of engineering employment, by class of workers for each occupational status, 1946*—Continued

Occupational status	Total public and private	Private industry: Total	Private industry: Employers and independent consultants	Private industry: Employees of private firms	Public employees: Total	Public employees: Federal	Public employees: State	Public employees: County	Public employees: Municipal	Public employees: Other
	MINING AND METALLURGICAL ENGINEERS									
All mining and metallurgical engineers	100.0	87.9	10.8	77.1	12.1	9.3	2.5		0.1	0.2
Administration-management, nontechnical	100.0	80.0	80.0		20.0	20.0				
Administration-management, technical	100.0	85.2	16.5	68.7	14.8	13.2	1.2			.4
Analysis and testing	100.0	94.3	2.9	91.4	5.7	5.7				
Construction, supervision	100.0	100.0	12.5	87.5						
Consulting, independent	100.0	100.0	94.3	5.7						
Consulting, as employee of private firm	100.0	100.0	12.8	87.2						
Design	100.0	100.0		100.0						
Development	100.0	100.0	1.6	98.4						
Drafting	100.0	100.0		100.0						
Editing and writing	100.0	85.7		85.7	14.3	14.3				
Estimating	100.0	100.0		100.0						
Inspection	100.0	63.5		62.5	37.5	18.8	18.7			
Installation	100.0									
Library and information service	100.0	100.0		100.0						
Maintenance	100.0	100.0	16.7	83.3						
Operation	100.0	97.0	7.6	89.4	3.0	3.0				
Patents	100.0									
Personnel-labor problems	100.0									
Production	100.0	100.0	2.8	97.2						
Research in basic science	100.0	52.4		52.4	47.6	47.6				
Research, applied	100.0	84.5	1.5	83.0	15.5	13.9	1.6			
Safety engineering	100.0	55.6		55.6	44.4	44.4				
Sales	100.0	100.0		100.0						
Student	100.0	100.0		100.0						
Teaching, college or university	100.0	46.4	3.5	42.9	53.6		50.0			3.6
Teaching, other	100.0				100.0				100.0	
Any occupational status not specified above	100.0	78.6		78.6	21.4	21.4				
	OTHER ENGINEERS									
All other engineers	100.0	80.4	12.6	67.8	19.6	10.9	5.3	0.5	1.8	1.1
Administration-management, nontechnical	100.0	88.8	26.7	62.1	11.2	6.0	.9		3.4	.9
Administration-management, technical	100.0	81.5	15.5	66.0	18.5	11.4	3.3	.7	2.0	1.1
Analysis and testing	100.0	63.2		63.2	36.8	26.3	7.9		2.6	
Construction, supervision	100.0	78.3	12.0	66.3	21.7	14.5	3.6	1.2	1.2	1.2
Consulting, independent	100.0	100.0	94.5	5.5						
Consulting, as employee of private firm	100.0	94.0	11.9	82.1	6.0	1.5	1.5			3.0
Design	100.0	76.8	8.1	68.7	23.2	17.8	2.7		2.7	
Development	100.0	84.7	4.2	80.5	15.3	15.3				
Drafting	100.0	85.0		85.0	15.0	10.0	5.0			
Editing and writing	100.0	78.6		78.6	21.4	21.4				
Estimating	100.0	74.4		74.4	25.6	10.2	12.8		2.6	
Inspection	100.0	55.3		55.3	44.7	14.9	12.8	4.2	12.8	
Installation	100.0	100.0	12.5	87.5						
Library and information service	100.0				100.0	50.0			50.0	
Maintenance	100.0	82.4		82.4	17.6	5.8	5.9			5.9
Operation	100.0	89.9		88.9	11.1	5.6			3.7	1.8
Patents	100.0	73.9	17.4	56.5	26.1	17.4	8.7			
Personnel-labor problems	100.0	100.0		100.0						
Production	100.0	94.7	9.3	85.4	5.3	5.3				
Research in basic science	100.0	42.9		42.9	57.1	28.5	28.6			
Research, applied	100.0	72.6	1.8	70.8	27.4	17.7	8.8			.9
Safety engineering	100.0	84.4	4.9	79.5	15.6	10.7	4.1		.8	
Sales	100.0	98.7	12.0	86.7	1.3	1.3				
Student	100.0	100.0		100.0						
Teaching, college or university	100.0	36.7		36.7	63.3		50.0			13.3
Teaching, other	100.0	50.0		50.0	50.0		25.0		25.0	
Any occupational status not specified above	100.0	52.7	6.5	46.2	47.3	25.8	16.1	2.2	3.2	

TABLE D-8.—*Percentage distribution, by occupational status, for each field of engineering employment in 1939, 1943, and 1946*

Occupational status	Percentage in field of engineering employment																	
	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Administration-management, nontechnical	1.1	1.3	2.0	1.4	2.0	2.5	1.6	1.5	2.0	1.6	1.8	2.5	2.4	2.5	2.7	4.2	4.6	5.2
Administration-management, technical	19.5	21.9	27.0	19.8	25.6	27.4	19.2	21.9	26.3	20.3	24.5	29.5	27.7	34.2	38.8	22.4	28.2	33.1
Analysis and testing	12.8	5.8	3.7	1.3	1.0	1.1	4.9	3.9	2.8	3.6	4.9	3.3	8.1	5.5	3.7	2.6	2.6	1.9
Construction supervision	.6	1.2	.8	25.3	21.9	17.6	4.6	4.2	3.3	2.5	2.5	1.9	1.7	1.3	.8	4.8	4.4	4.1
Consulting, independent	1.2	.7	.7	3.4	3.0	4.1	1.0	.5	1.2	1.4	.8	1.4	4.1	2.5	2.0	2.4	1.7	1.6
Consulting as employee of private firm	1.6	1.6	2.2	1.9	2.5	3.3	3.3	3.3	4.2	3.1	3.0	3.8	2.4	3.3	3.9	2.8	3.0	3.3
Design	5.7	6.4	7.7	17.9	19.0	20.4	15.7	17.6	16.5	21.0	21.0	19.4	1.5	.5	.7	6.9	7.8	5.6
Development	13.4	16.9	17.3	1.8	1.8	2.0	9.3	11.1	11.1	6.9	7.8	7.8	5.0	5.8	5.9	2.9	3.7	3.5
Drafting	.6	.4	.4	4.7	3.2	2.4	2.7	1.4	.8	7.2	2.7	1.8	1.0	.2	.1	2.5	1.1	1.0
Editing and writing	.1	.2	.3	.4	.4	.7	.5	.8	.8	.3	.4	.4	.7	.7	.6	.5	.6	.7
Estimating	—	.3	.4	2.6	2.5	2.7	2.6	1.5	1.5	1.6	1.4	1.1	.2	.3	.6	2.7	1.9	1.8
Inspection	.5	.9	.5	5.6	3.0	2.0	2.2	2.6	1.2	1.3	1.9	.9	2.7	3.2	1.3	3.9	3.2	2.4
Installation	—	.2	.3	.4	.3	.2	1.6	1.5	1.4	1.0	1.1	.8	.1	.1	—	.9	.5	.3
Library and information service	—	(1)	.1	—	—	—	(1)	(1)	(1)	(1)	.1	.1	.1	—	.1	.1	.1	.1
Maintenance	.7	1.0	.7	3.3	3.8	3.5	5.6	3.8	3.2	3.8	3.2	2.2	.6	.5	.6	1.7	1.6	1.8
Operation	7.5	7.7	4.1	1.1	1.4	1.2	7.5	4.3	3.7	3.2	2.5	1.7	10.0	6.8	5.6	4.7	3.8	2.5
Patents	.5	.4	.5	—	—	—	.4	.3	.4	.4	.3	.4	—	—	—	.9	.7	1.0
Personnel-labor problems	—	.1	.1	—	(1)	—	(1)	.1	.1	.1	.3	.4	—	—	—	.3	.3	.4
Production	9.3	11.8	8.2	.3	.4	.4	1.1	2.0	.9	4.2	5.0	3.0	7.1	7.4	6.4	3.7	4.4	3.8
Research in basic science	.5	.5	.9	.3	.3	.3	.3	.3	.6	.5	.7	.9	1.0	1.3	2.0	.6	.4	.3
Research, applied	16.0	15.3	13.8	1.2	1.3	1.3	3.5	6.7	6.3	3.2	5.2	5.9	13.3	16.8	16.3	4.2	4.9	5.4
Retired	.1	.1	.2	(1)	(1)	.1	(1)	(1)	.1	(1)	(1)	.1	.1	.1	—	—	—	—
Safety engineering	.3	.3	.4	.3	.3	.3	.3	.3	.2	.3	.3	.3	.7	.8	.8	6.2	6.6	5.4
Sales	2.1	1.3	3.0	1.1	1.1	1.3	6.7	4.8	6.2	6.6	3.8	5.5	2.5	1.7	2.3	8.4	5.8	7.0
Student	1.2	.5	1.2	.3	.1	.1	.5	.2	.4	.8	.2	.3	.8	.2	.3	.2	—	.3
Teaching, college or university	3.2	2.2	2.5	2.1	2.5	2.4	3.0	3.3	2.8	3.2	2.8	2.7	3.7	2.5	2.5	3.3	2.5	2.8
Teaching, other	.2	.1	—	.1	.1	(1)	.3	.7	.3	.3	.3	.1	.1	—	.1	.4	.3	.3
Unemployed	.4	(1)	.2	.3	—	.1	.2	(1)	.2	.1	(1)	.3	.2	—	.3	.1	—	.1
Any occupational status not specified above	.9	.9	.8	3.1	2.5	2.6	1.4	1.4	1.5	1.5	1.5	1.5	2.2	1.8	1.6	5.7	5.3	4.3

[1] Less than 0.05 percent.

TABLE D-9.—*Percentage distribution of engineers, by industry field, for each field of engineering employment in 1939, 1943, and 1946*

Industry field	Percentage in field of engineering employment																	
	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Agriculture and forestry	.3	.3	.3	1.3	.9	1.3	.1	(1)	(1)	.1	.1	.1	—	—	.1	3.0	2.5	2.5
Mining	2.5	1.2	1.6	.8	1.0	.8	.7	.6	.6	1.0	.9	.7	44.2	37.4	40.4	6.1	5.8	6.4
Coal	.3	(1)	.1	.1	.2	.2	.3	.3	.3	.2	.2	.1	9.7	7.8	8.2	.2	.3	.2
Crude petroleum and natural gas	1.3	.7	.8	.5	.4	.4	.3	.2	.2	.3	.2	.3	8.6	7.4	8.9	5.4	5.0	5.7
Ferrous	—	—	—	(1)	.1	(1)	(1)	(1)	(1)	.1	.1	(1)	4.0	4.4	3.9	.1	.1	—
Nonferrous metals	.4	.1	.2	.1	.1	.1	.1	.1	.1	.3	.3	.2	17.7	13.7	14.5	.2	.3	.3
Other mining industries not specified	.5	.4	.5	.1	.2	.1	(1)	—	(1)	.1	.1	.1	4.2	4.1	4.9	.2	.1	.2
Construction	2.7	2.2	2.9	71.4	66.2	66.7	4.3	4.6	3.9	4.7	3.8	3.9	.6	.2	.3	14.1	13.1	12.4
Bridges	.1	.1	.2	8.2	5.4	6.5	.1	.1	.1	(1)	(1)	(1)	.1	—	—	.8	.4	.5
Buildings	.5	.3	.4	14.6	18.9	18.9	1.7	1.8	1.7	1.8	1.4	1.5	—	—	—	6.9	5.4	6.2
Highways	1.0	.4	.4	23.5	16.5	17.4	—	—	—	.1	.1	.1	—	—	—	1.6	1.2	1.2
Sewerage	.1	(1)	.1	3.4	3.1	3.7	.1	(1)	(1)	.1	(1)	.1	—	—	—	.1	.1	.2
Surveying	—	—	—	5.6	4.3	4.2	(1)	—	(1)	.1	(1)	(1)	—	—	—	.2	.1	.2
Waterways	.1	(1)	.1	4.9	3.3	4.0	.3	.1	.1	.3	.2	.3	.1	—	—	.2	.1	.2
Waterworks	.1	.2	.2	3.5	2.5	2.6	.1	.1	.1	.3	.2	.2	—	—	—	.8	.5	.4
Other construction not specified	.8	1.2	1.5	7.7	12.2	9.4	2.0	2.5	1.9	2.0	1.9	1.7	.4	.2	.3	3.5	5.3	3.5

[1] Less than 0.05 percent

TABLE D-9.—*Percentage distribution of engineers, by industry field, for each field of engineering employment in 1939, 1943, and 1946*—Continued

Industry field	Percentage in field of engineering employment																	
	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
Manufacturing	83.9	86.7	83.3	6.1	8.7	8.0	32.6	37.4	37.0	67.9	72.8	70.0	48.3	54.6	50.5	31.7	37.4	35.9
Food and kindred products	6.2	4.0	4.6	.2	.1	.2	.1	.1	.2	2.1	1.3	1.8	------	------	.1	1.0	1.1	1.2
Textile mill products (excluding rayon and allied products)	.7	.8	.9	------	------	(1)	.1	.1	.1	.8	.5	.8	------	------	.1	.9	.8	.8
Lumber, furniture, and lumber products	.2	.2	.2	.3	.3	.2	(1)	------	(1)	.7	.4	.6	------	------	------	.4	.3	.5
Paper and allied products	4.6	2.9	3.8	.1	.1	.2	.2	.1	.2	1.6	1.1	1.5	------	------	------	.8	1.0	.8
Printing and publishing	.3	.2	.2	.1	.1	.1	.1	.1	.1	.4	.2	.3	------	------	------	.3	.4	.5
Chemicals and allied products (including rayon and allied products)	33.1	39.1	36.3	.3	.6	.8	.6	1.0	1.1	3.0	2.8	3.2	.8	.4	.5	1.5	2.7	2.8
Petroleum and coal products	22.6	21.2	20.5	1.2	1.5	1.4	.5	.4	.6	3.7	2.8	3.0	.7	.7	.5	4.8	4.4	4.7
Petroleum refining	18.4	16.9	16.4	.7	1.1	.8	.4	.3	.5	2.5	1.9	2.1	.2	.3	.1	2.5	2.4	2.5
Other petroleum and coal products industries not specified	4.2	4.3	4.1	.5	.4	.6	.1	.1	.1	1.2	.9	.9	.5	.4	.4	2.3	2.0	2.2
Rubber products	3.8	5.4	5.2	(1)	.2	.1	.2	.3	.4	1.3	1.3	1.3	.1	.2	.1	.4	.7	.7
Stone, clay, and glass products	1.9	1.3	1.2	.3	.4	.5	.2	.2	.2	.6	.6	.7	.6	.3	.5	4.6	4.6	4.4
Iron and steel and their products	2.4	1.7	1.4	2.5	2.8	2.6	1.4	1.4	1.0	8.1	7.2	6.8	26.1	26.9	24.5	3.8	4.0	3.9
Blast furnaces, steel works and rolling mills	1.1	.7	.5	1.0	1.2	1.2	1.0	.8	.6	3.1	2.7	2.4	17.4	16.2	14.4	1.4	1.7	1.4
Other iron and steel industries not specified	1.3	1.0	.9	1.5	1.6	1.4	.4	.6	.4	5.0	4.5	4.4	8.7	10.7	10.1	2.4	2.3	2.5
Nonferrous metals and their products	2.0	2.8	2.0	.2	.3	.3	.6	.7	.5	1.7	2.0	1.9	12.6	15.1	14.7	1.0	1.3	1.4
Machinery	1.8	2.0	2.8	.2	.6	.7	24.6	26.6	26.6	21.7	18.6	20.1	3.2	4.4	4.1	5.0	6.1	6.0
Electrical machinery and equipment	.6	.7	1.0	.1	.2	.1	23.9	25.9	25.6	4.4	4.6	4.6	1.2	2.2	1.9	2.5	3.0	3.2
Other machinery industries not specified	1.2	1.3	1.8	.1	.4	.6	.7	.7	1.0	17.3	14.0	15.5	2.0	2.2	2.2	2.5	3.1	2.8
Transportation equipment	1.0	1.5	.9	.4	1.3	.5	2.0	3.6	3.1	17.0	28.4	21.5	3.1	5.3	3.9	4.0	6.1	4.7
Aircraft and parts	.1	.9	.2	.1	.7	.2	.7	2.3	1.9	9.6	23.0	15.4	.9	3.5	1.4	.8	2.9	1.8
Automobiles and automobile equipment	.8	.5	.6	.1	.1	.1	.6	.5	.5	5.2	2.8	4.0	1.8	1.3	2.0	1.5	.8	1.2
Other transportation equipment industries not specified	.1	.1	.1	.2	.5	.2	.7	.8	.7	2.2	2.6	2.1	.4	.5	.5	1.7	2.4	1.7
Other manufacturing industries not specified	3.3	3.6	3.3	.3	.4	.4	2.0	2.8	2.9	5.2	5.6	6.5	1.1	1.3	1.5	3.2	3.9	3.5
Transportation	.5	.4	.5	6.0	6.5	6.0	2.0	1.8	1.8	2.1	2.2	2.1	.2	.4	.3	2.7	3.2	3.1
Railroads, including railroad repair shops	.4	.3	.3	5.1	5.5	5.1	1.5	1.0	1.1	1.0	.8	.8	------	.2	.2	1.3	1.1	1.1
Other transportation industries not specified	.1	.1	.2	.9	1.0	.9	.5	.8	.7	1.1	1.4	1.3	.2	.2	.1	1.4	2.1	2.0
Communication	.2	.2	.3	.2	.2	.3	21.7	21.7	22.4	1.3	1.6	1.5	.5	.5	.6	5.2	4.7	4.5
Telephone (wire and radio)	.1	.1	.3	.2	.2	.3	14.4	14.6	14.5	1.1	1.3	1.1	.5	.4	.5	4.7	4.4	4.2
Radio broadcasting and television	.1	.1	(1)	------	------	(1)	5.8	5.8	6.6	.1	.3	.3	------	.1	.1	.4	.3	.2
Telegraph (wire and radio)	------	------	------	------	------	------	1.5	1.3	1.3	.1	(1)	.1	------	------	------	.1	------	.1
Utilities	2.3	1.2	1.3	6.7	7.2	7.3	29.9	21.1	21.4	5.9	3.5	4.1	.2	.3	.1	7.4	6.1	5.7
Electric light and power	.5	.1	.2	2.4	2.6	2.7	29.6	21.0	21.1	3.6	2.1	2.5	.1	.1	.1	3.5	2.7	2.4
Water and sanitary services	.3	.2	.2	4.0	4.1	4.0	.2	.1	.2	.3	.2	.3	------	.1	------	1.4	1.6	1.6
Gas works and steam plants	1.5	.9	.9	.3	.5	.6	.1	(1)	.1	2.0	1.2	1.3	.1	.1	------	2.5	1.8	1.7
Other industry fields	4.5	3.6	5.0	4.1	4.5	5.0	5.8	5.9	6.4	13.1	9.4	11.6	4.6	3.8	4.9	20.1	16.3	18.6
Refrigerating, heating and ventilating	.5	.2	.3	.1	------	(1)	.1	.3	.4	7.0	4.2	5.9	------	.1	.1	4.6	3.4	4.1
Wholesale and retail trade	------	(1)	.2	.1	.1	.1	.8	.4	.7	.6	.3	.5	.1	.1	.2	1.2	.6	1.4
Insurance and appraisal	------	------	.1	.3	.3	.3	.3	.3	.2	.4	.3	.3	------	------	------	6.4	4.7	4.7
Finance, taxation, and real estate	------	------	------	.4	.4	.4	------	------	------	.1	.1	.1	.4	.3	.3	.7	.6	.6
Education	3.2	2.4	3.2	2.2	2.4	2.4	3.5	3.8	3.6	3.8	3.3	3.1	3.6	2.5	2.9	3.5	3.3	3.4
Legal	------	------	(1)	(1)	.1	.1	.1	.1	.1	.1	.1	.1	------	------	.1	.4	.1	.3
Professional and trade organization	.3	.4	.5	.5	.5	.9	.2	.2	.3	.4	.4	.6	.4	.3	.5	.7	1.0	1.4
Other service industries not specified	.5	.6	.7	.5	.7	.8	.8	.8	1.1	.7	.7	1.0	.1	.5	.8	2.6	2.6	2.7
Any industry field not specified	3.1	4.2	4.8	3.4	4.8	4.6	2.9	6.9	6.5	3.9	5.7	6.0	1.4	2.8	2.8	9.7	10.9	10.0

[1] Less than 0.05 percent.

TABLE D-10.—*Percentage distribution of engineers, by employment location, for each field of engineering employment in 1939, 1943, and 1946*

Employment location	Percentage in field of engineering employment																	
	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
New England	6.4	5.5	6.0	6.1	5.6	5.6	9.2	10.2	8.8	9.1	8.6	8.9	4.8	5.2	5.3	8.0	8.5	7.8
Maine	.4	.2	.2	.6	.5	.5	.4	.3	.3	.2	.2	.2	—	.1	—	.3	.2	.2
New Hampshire	.1	(1)	.1	.3	.2	.3	.1	.1	.1	.1	.1	.1	.1	—	—	.2	.2	.1
Vermont	.2	(1)	(1)	.2	.1	.1	.2	.1	.2	.1	.1	.1	—	.3	.2	.1	.1	.1
Massachusetts	4.3	3.6	4.3	3.5	3.2	3.3	6.4	7.5	6.2	5.4	4.4	4.9	2.5	2.8	3.1	4.8	5.0	4.6
Rhode Island	.3	.3	.2	.5	.6	.4	.4	.3	.2	.5	.5	.4	.3	.2	.4	.6	.4	.4
Connecticut	1.1	1.4	1.2	1.0	1.0	1.0	1.7	1.9	1.8	2.8	3.3	3.2	1.9	1.8	1.6	2.0	2.6	2.4
Middle Atlantic	34.4	32.8	34.7	25.2	24.0	24.4	39.5	40.7	40.9	33.7	32.1	33.3	30.0	30.8	30.6	28.2	27.5	27.7
New York	13.9	12.2	13.7	14.3	13.2	14.6	23.3	21.6	22.9	17.4	16.0	17.4	7.8	7.9	8.5	15.5	13.4	14.3
New Jersey	10.0	11.0	11.1	2.5	2.9	2.7	5.4	7.9	7.6	6.0	6.6	6.3	4.9	5.9	5.7	4.6	4.8	5.0
Pennsylvania	10.5	9.6	9.9	8.4	7.9	7.1	10.8	11.2	10.4	10.3	9.5	9.6	17.3	17.0	16.4	8.1	9.3	8.4
East North Central	24.5	22.5	22.4	20.9	20.3	20.9	21.2	18.8	19.6	29.5	28.1	27.8	22.5	26.0	25.0	21.5	20.2	20.5
Ohio	8.3	7.5	8.0	7.0	7.5	7.4	6.2	6.0	6.2	9.3	10.7	10.6	8.7	10.2	9.4	6.8	6.8	6.2
Indiana	3.3	3.0	2.9	2.4	2.3	2.2	2.8	2.7	2.5	3.1	3.1	2.6	2.6	2.9	2.6	2.3	2.4	2.8
Illinois	7.0	6.1	6.1	6.1	5.8	6.2	6.7	5.4	6.2	8.4	6.6	6.6	4.8	5.3	5.4	6.8	6.1	6.3
Michigan	4.7	4.1	3.8	2.8	2.9	2.8	3.5	3.0	2.8	5.9	5.4	5.4	4.6	5.6	5.4	4.2	3.3	3.6
Wisconsin	1.2	1.8	1.6	2.6	1.8	2.3	2.0	1.7	1.9	2.8	2.3	2.6	1.8	2.0	2.2	1.4	1.6	1.6
West North Central	4.1	3.6	3.6	9.4	8.7	8.7	5.4	4.6	4.1	4.8	4.6	3.7	5.1	5.2	4.6	7.4	6.7	6.8
Minnesota	.5	.9	.9	2.4	2.1	2.3	1.1	1.3	1.1	1.4	1.3	1.2	2.2	2.2	2.0	1.5	1.3	1.4
Iowa	.7	.3	.5	1.6	1.2	1.3	.5	.3	.4	.7	.5	.5	.2	.2	.2	1.5	1.2	1.4
Missouri	1.3	1.4	1.3	2.8	2.5	2.7	2.1	1.9	1.5	1.8	1.7	1.4	1.4	1.7	1.6	2.7	2.2	2.5
North Dakota	.1	(1)	.1	.3	.3	.2	.1	(1)	.1	.1	(1)	(1)	—	—	—	.1	.1	.1
South Dakota	.1	(1)	(1)	.2	.2	.3	.1	.1	.1	.1	(1)	(1)	.5	.2	.3	.2	.3	.2
Nebraska	.1	.1	.1	1.1	1.2	1.0	.6	.3	.3	.2	.3	.1	—	.1	—	.5	.6	.5
Kansas	1.3	.9	.7	1.0	1.2	.9	.9	.7	.6	.5	.8	.5	.8	.8	.5	.9	1.0	.7
South Atlantic	10.4	11.6	10.8	10.2	12.4	11.6	8.2	10.0	10.3	7.4	8.5	8.6	7.1	7.9	8.9	9.7	12.6	11.3
Delaware	2.5	2.5	2.9	.2	.4	.3	.1	.2	.2	.2	.3	.4	.1	.2	.2	.2	.4	.3
Maryland	1.3	2.2	1.5	1.6	1.6	1.6	1.4	1.9	2.0	1.9	2.0	2.1	1.8	1.5	1.5	1.5	1.9	1.9
Virginia	1.8	1.9	1.7	1.2	1.9	1.7	1.0	1.1	1.1	1.4	2.0	2.0	.9	.7	.9	1.8	1.9	1.8
West Virginia	3.0	2.6	2.4	1.2	1.1	1.0	.7	.5	.6	.6	.5	.4	2.3	1.9	2.1	.7	1.0	.7
North Carolina	.5	.4	.3	.8	.7	.9	.6	.4	.6	.5	.4	.5	.1	—	.2	.8	.9	.9
South Carolina	.1	.2	.1	.6	.7	.6	.5	.4	.3	.1	.1	.1	.1	—	.1	.4	.4	.3
Georgia	.2	.4	.5	.9	1.1	1.0	1.0	1.0	1.0	.6	.5	.6	—	—	.1	.9	1.2	1.1
Florida	.5	.4	.5	.8	1.2	1.0	.6	.6	.5	.2	.3	.3	.2	.2	.2	.5	.7	.6
District of Columbia	.5	1.0	.9	2.9	3.7	3.5	2.3	3.9	4.0	1.9	2.4	2.2	1.6	3.4	3.6	2.9	4.2	3.7
East South Central	2.5	5.1	3.7	4.4	4.6	3.5	2.5	2.7	2.1	1.6	1.8	1.5	3.2	2.0	2.0	3.5	3.4	3.1
Kentucky	.9	1.9	1.2	1.3	1.1	1.0	.5	.5	.5	.6	.5	.4	1.0	.6	.6	.7	.8	.6
Tennessee	.7	1.4	1.8	1.7	2.2	1.5	1.0	1.4	1.1	.5	.7	.6	.6	.3	.4	1.3	1.4	1.6
Alabama	.8	1.6	.6	.8	.8	.6	.7	.6	.4	.4	.4	.3	1.5	1.1	1.0	.8	.7	.5
Mississippi	.1	.2	.1	.6	.5	.4	.3	.2	.1	.1	.2	.2	.1	—	—	.7	.5	.4
West South Central	9.0	10.8	10.1	7.8	7.6	7.4	4.5	3.7	3.6	3.4	3.5	3.2	7.0	7.2	6.6	10.1	9.9	10.1
Arkansas	.5	.6	.2	.7	.6	.6	.3	.3	.2	(1)	.1	(1)	.7	.6	.2	.5	.5	.3
Louisiana	1.5	2.1	1.9	.9	1.0	.7	.4	.4	.3	.6	.6	.4	.8	.7	1.1	1.5	1.5	1.7
Oklahoma	2.0	1.8	1.8	1.0	1.0	.8	.9	.6	.7	.7	.7	.5	1.8	1.6	1.4	2.4	2.0	2.2
Texas	5.0	6.3	6.2	5.2	5.0	5.3	2.9	2.4	2.4	2.1	2.1	2.3	3.7	4.3	3.9	5.7	5.9	5.9
Mountain	1.4	1.3	1.6	5.2	4.6	4.7	2.5	1.7	2.2	.8	1.0	1.1	11.5	9.4	10.3	2.3	1.7	2.3
Montana	.2	.1	.1	.7	.3	.3	.3	.1	.1	.1	.1	.1	1.8	1.4	1.4	.4	.2	3
Idaho	.1	—	—	.5	.4	.6	.4	.3	.2	(1)	(1)	(1)	.7	.6	.8	.1	.1	.1
Wyoming	.1	.2	.2	.3	.2	.2	.1	.1	(1)	(1)	—	(1)	.3	.1	.2	.2	.1	.1
Colorado	.6	.5	.6	1.5	1.3	1.5	1.0	.7	1.1	.4	.5	.7	2.4	1.8	2.5	.8	.7	1.0
New Mexico	.1	.1	.4	.8	.7	.7	.2	.1	.3	(1)	(1)	.1	.4	.6	.9	.2	.2	.3
Arizona	.1	.1	.1	.7	.7	.7	.2	.1	.1	(1)	.1	.1	2.2	1.6	1.5	.2	.1	.2
Utah	.1	.1	.1	.6	.9	.6	.2	.2	.3	.2	.2	.1	2.5	2.1	1.9	.3	.3	.3
Nevada	.1	.2	.1	.1	.1	.1	.1	.1	.1	.1	.1	(1)	1.2	1.2	1.1	.1	—	—
Pacific	7.3	6.8	7.1	10.8	12.2	13.2	7.0	7.6	8.4	9.7	11.8	11.9	8.8	6.3	6.7	9.3	9.5	10.4
Washington	1.0	.7	.9	1.6	2.4	2.2	1.1	1.4	1.6	1.2	1.8	1.4	1.0	1.0	1.0	1.5	1.5	1.4
Oregon	.1	.1	.3	1.1	1.0	1.5	.7	.9	.9	.5	.4	.3	.4	.3	.4	.7	.5	.8
California	6.2	6.0	5.9	8.1	8.8	9.5	5.2	5.3	5.9	8.0	9.6	10.2	7.4	5.0	5.3	7.1	7.5	8.2

(1) Less than 0.05 percent.

TABLE D-11.—*Distribution of engineers in each field of employment, by base monthly salary bracket, 1946*

Salary bracket	Number in field of engineering employment: Chemical	Civil	Electrical	Mechanical	Mining and metallurgical	Other
All engineers reporting	2,659	4,273	4,615	6,247	1,257	2,252
Under $100	35	52	52	58	18	27
$100 and under $110	7	9	7	13	3	7
$110 and under $120	3	4	5	7	1	3
$120 and under $130	4	6	5	10	--------	2
$130 and under $140	1	3	5	7	--------	2
$140 and under $150	3	4	8	5	--------	4
$150 and under $160	4	8	12	12	2	4
$160 and under $170	7	8	12	14	5	5
$170 and under $180	14	13	8	21	2	2
$180 and under $190	8	9	18	10	4	5
$190 and under $200	9	20	26	36	8	7
$200 and under $220	67	101	94	103	21	37
$220 and under $240	104	106	89	153	30	51
$240 and under $260	144	206	199	231	48	61
$260 and under $280	146	185	204	246	52	76
$280 and under $300	143	238	217	237	58	88
$300 and under $320	238	404	343	363	95	189
$320 and under $340	194	300	270	358	55	103
$340 and under $370	263	487	472	586	97	211
$370 and under $400	210	355	339	483	74	179
$400 and under $440	265	509	560	779	133	257
$440 and under $480	158	254	323	443	73	144
$480 and under $520	138	291	333	466	109	163
$520 and under $570	99	172	229	316	69	116
$570 and under $620	77	138	199	284	59	110
$620 and under $680	64	90	158	229	43	70
$680 and under $750	47	73	95	129	36	55
$750 and under $850	59	79	108	179	48	86
$850 and under $1,000	37	27	77	115	26	45
$1,000 and over	111	122	148	354	88	143

TABLE D-12.—*Comparison of percentile levels of base monthly salary rates for each field of engineering employment, by years of experience, 1946*

Reported years of experience	90 percent made more than—	75 percent made more than—	50 percent made more than—	25 percent made more than—	10 percent made more than—	90 percent made more than—	75 percent made more than—	50 percent made more than—	25 percent made more than—	10 percent made more than—
	CHEMICAL					MECHANICAL				
All engineers	$240	$294	$363	$471	$666	$255	$322	$409	$527	$880
Under 6 years	213	245	288	329	368	212	246	294	349	406
6-11 years	286	326	379	436	501	282	329	390	460	545
12-19 years	314	379	461	573	755	309	376	450	584	795
20-29 years	332	417	566	792	[2]	318	400	500	672	[2]
30 years and over	[1]	435	653	986	[2]	302	388	521	796	[2]
	CIVIL					MINING AND METALLURGICAL				
All engineers	$248	$304	$368	$468	$607	$253	$313	$417	$560	$826
Under 6 years	206	234	270	310	350	209	246	285	320	364
6-11 years	246	290	333	385	439	250	306	364	442	536
12-19 years	256	309	366	432	523	303	367	437	547	729
20-29 years	268	318	392	486	610	331	423	529	708	[2]
30 years and over	257	325	431	570	806	355	481	607	910	[2]
	ELECTRICAL					OTHER				
All engineers	$252	$311	$393	$503	$633	$262	$319	$410	$547	$807
Under 6 years	203	246	290	339	404	208	240	297	347	405
6-11 years	254	318	354	424	503	266	309	361	440	554
12-19 years	287	344	415	506	631	289	347	425	551	744
20-29 years	302	372	466	596	883	304	368	462	620	896
30 years and over	307	409	518	771	[2]	283	395	538	818	[2]

[1] Insufficient reports to compute median. [2] Over $1,000.

TABLE D-13.—*Median base monthly salary rates for each field of engineering employment, by years of experience, 1939, 1943, and 1946*

Years of experience	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
All engineers	$220	$278	$363	$244	$313	$368	$253	$313	$393	$253	$326	$409	$267	$332	$417	$259	$331	$410
Less than 1 year	130	177	242	144	183	247	127	186	228	129	179	226	134	203	247	141	193	231
1 year	154	208	241	155	198	240	153	204	237	154	211	225	156	198	(1)	168	213	(1)
2 years	165	222	255	158	220	247	159	219	249	163	235	264	175	216	(1)	182	239	283
3 years	180	244	278	167	231	263	174	240	277	184	259	285	196	233	272	190	256	290
4 years	191	254	310	177	241	278	177	247	303	200	272	308	211	251	290	203	255	311
5 years	221	265	327	183	246	297	207	265	315	208	281	342	227	295	313	209	273	310
6 years	227	279	344	189	302	307	206	269	325	220	291	360	205	267	327	214	273	330
7-8 years	263	307	375	207	259	327	215	284	347	235	314	380	256	314	337	243	294	356
9-11 years	299	346	399	218	272	345	240	307	366	261	344	408	284	338	404	251	320	370
12-14 years	310	382	452	235	296	356	279	320	409	291	355	442	316	385	417	271	336	396
15-19 years	374	406	474	271	307	369	318	352	418	320	400	455	335	414	478	315	360	443
20-24 years	438	456	552	302	333	382	367	399	454	381	429	492	440	430	516	366	390	445
25-29 years	491	581	598	316	355	407	421	450	502	401	429	518	483	520	570	404	471	501
30-34 years	545	595	655	337	372	427	423	482	513	423	456	514	488	526	608	423	477	528
35-39 years	(1)	507	640	387	390	428	520	497	545	500	477	534	440	583	592	(1)	490	539
40 years and over	(1)	650	680	370	408	438	513	494	509	(1)	601	520	(1)	520	650	(1)	475	580
Median years of experience	5.9	6.6	8.8	15.2	19.7	21.6	12.4	14.1	15.9	11.1	10.9	12.8	10.7	11.7	13.8	12.5	15.1	17.3

[1] Insufficient reports to compute median salary.

TABLE D-14.—*Percentage distribution and median base monthly salary for each field of engineering employment, by employment location, 1946*

Employment location	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	Percent	Median base monthly salary	Percent	Median base monthly salary	Percent	Median base monthly salary	Percent	Median base monthly salary	Percent	Median base monthly salary	Percent	Median base monthly salary
Total	100.0	$363	100.0	$368	100.0	$393	100.0	$409	100.0	$417	100.0	$410
New York	13.7	396	14.6	385	22.9	424	17.4	426	8.5	504	14.3	461
New Jersey	11.1	356	2.7	376	7.6	407	6.3	403	5.7	430	5.0	439
Pennsylvania	9.9	361	7.1	402	10.4	389	9.6	409	16.5	442	8.4	418
Ohio	8.0	350	7.4	347	6.2	382	10.6	406	9.4	400	6.2	409
Illinois	6.1	379	6.2	377	6.2	412	6.6	422	5.4	388	6.3	436
Indiana	2.9	357	2.2	345	2.5	364	2.6	404	2.6	338	2.8	393
Michigan	3.8	387	2.8	397	2.8	409	5.4	425	5.4	413	3.6	423
Wisconsin	1.6	325	2.3	321	1.9	365	2.6	391	2.2	340	1.6	407
District of Columbia	.9	430	3.5	483	4.0	431	2.2	438	3.6	510	3.7	480
Maryland	1.5	377	1.6	377	2.0	347	2.1	430	1.5	(1)	1.9	395
Virginia	1.7	402	1.7	405	1.1	364	2.0	365	.9	(1)	1.8	393
West Virginia	2.4	368	1.0	361	.6	370	.4	400	2.1	429	.7	(1)
North Carolina	.3	(1)	.9	353	.6	348	.5	385	.2	(1)	.9	318
Georgia	.5	(1)	1.0	400	1.0	355	.6	420	.1	(1)	1.1	390
Massachusetts	4.3	375	3.3	341	6.2	375	4.9	370	3.1	385	4.6	379
Connecticut	1.2	381	1.0	330	1.8	374	3.2	386	1.6	500	2.4	465
California	5.9	369	9.5	399	5.9	386	10.2	420	5.3	407	8.2	428
Washington	.9	317	2.2	372	1.6	374	1.4	395	1.0	(1)	1.4	400
Minnesota	.9	290	2.3	328	1.1	383	1.2	373	2.0	370	1.4	340
Missouri	1.3	330	2.7	387	1.5	405	1.4	402	1.6	440	2.5	385
Louisiana	1.9	312	.7	350	.3	(1)	.4	389	1.1	(1)	1.7	340
Oklahoma	1.8	374	.8	347	.7	332	.5	350	1.4	(1)	2.2	379
Texas	6.2	349	5.3	342	2.4	379	2.3	402	3.9	448	5.9	387
Kentucky	1.2	316	1.0	340	.5	348	.4	363	.6	(1)	.6	(1)
Tennessee	1.8	347	1.5	383	1.1	358	.6	385	.4	(1)	1.6	385
Colorado	.6	(1)	1.5	373	1.1	365	.7	358	2.5	318	1.0	349
All other States	7.6	---------	13.2	---------	6.0	---------	3.9	---------	11.4	---------	8.2	---------

[1] Insufficient reports to compute median.

TABLE D-15.—*Median base monthly salary of engineers with the bachelor's degree, by field of engineering and by years of experience, 1929, 1932, 1934, and 1946*

Years of experience	Chemical	Civil	Electrical	Mechanical	Mining and metallurgical
			1929		
Under 1 year	$150	$155	$137	$141	$156
1-2 years	179	187	167	180	183
3-4 years	236	220	213	224	235
5-8 years	295	260	264	285	284
9-12 years	395	305	338	337	370
13-16 years	487	328	368	405	405
17-24 years	523	358	428	440	458
25-32 years	493	407	438	483	437
33-40 years	510	424	484	506	493
41 years and over	(1)	408	(1)	410	440
			1934		
Under 1 year	$107	$116	$106	$106	$113
1 year	114	126	109	110	118
2 years	122	131	114	118	120
3 years	134	143	127	132	143
4 years	153	150	145	149	143
5 years	170	163	162	165	153
6-7 years	198	179	180	180	183
8-9 years	228	198	205	207	207
10-13 years	287	218	240	239	237
14-17 years	340	244	300	283	311
18-21 years	350	263	333	303	302
22-29 years	425	285	349	333	347
30-37 years	426	296	379	346	340
38-45 years	(1)	331	408	370	400
46 years and over	(1)	306	(1)	330	(1)

Years of experience	Chemical	Civil	Electrical	Mechanical	Mining and metallurgical
			1932		
Under 1 year	$116	$103	$106	$97	$143
1 year	124	134	118	120	114
2 years	144	149	136	137	143
3 years	149	164	152	152	149
4-5 years	185	187	178	175	162
6-7 years	223	208	202	211	206
8-11 years	273	232	243	250	239
12-15 years	324	262	309	301	300
16-19 years	418	289	330	327	314
20-27 years	443	307	353	351	374
28-35 years	420	334	420	390	356
36-43 years	(1)	367	415	416	420
44 years and over	(1)	336	(1)	420	(1)
			1946		
Under 1 year	$242	$246	$229	$226	$244
1 year	240	240	236	222	230
2 years	257	240	247	262	214
3 years	277	263	276	281	270
4 years	309	278	298	310	290
5 years	323	297	308	340	315
6 years	336	306	327	359	318
7-8 years	368	324	339	377	334
9-11 years	393	348	365	403	385
12-14 years	437	361	400	435	404
15-19 years	481	379	415	464	483
20-24 years	540	395	458	496	526
25-29 years	613	435	518	565	507
30-34 years	640	453	520	543	608
35-39 years	620	444	551	555	620
40 years and over		427	620	507	

[1] Insufficient reports to compute median.

TABLE D-16.—*Median monthly salary, including overtime, for each field of engineering employment, by years of experience, 1939, 1943, and 1946*

Years of experience	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
Total	$218	$303	$364	$244	$328	$377	$253	$335	$400	$254	$356	$415	$262	$348	$418	$259	$351	$413
Less than 1 year	132	214	245	146	204	260	129	214	238	133	219	233	135	219		146	218	
1 year	155	237	245	154	243	253	154	238	242	155	252	232	157	213	247	167	234	236
2 years	166	252	261	158	259	260	161	268	254	165	285	268	181	236		181	271	
3 years	180	270	284	169	254	267	174	275	281	189	305	301	194	255	274	188	284	322
4 years	189	282	313	178	259	285	177	277	308	203	308	340	211	262	297	203	265	314
5 years	219	300	329	181	263	305	208	305	320	209	315	349	229	302	313	210	312	312
6 years	226	301	349	188	313	311	205	307	336	222	325	369	213	287	327	220	304	351
7-8 years	258	324	376	207	275	338	218	308	356	236	343	387	265	327	345	248	310	360
9-11 years	299	361	401	218	302	352	242	332	375	262	369	413	281	358	412	251	338	375
12-14 years	313	397	452	238	314	362	279	337	415	306	388	449	314	417	422	276	349	395
15-19 years	381	428	481	272	321	375	304	374	424	320	426	469	345	429	483	316	373	451
20-24 years	440	483	554	304	347	390	371	419	459	381	453	495	433	440	519	361	403	447
25-29 years	504	477	604	316	367	412	426	471	506	409	458	532	489	520	576	409	475	512
30-34 years	505	620	660	336	378	437	424	490	518	428	479	526	493	520	601	436	496	518
35-39 years	850	558	650	404	394	428	525	508	548	500	488	549	410	595	599	(1)	504	576
40 years and over	(1)	665	698	370	423	452	513	512	516	(1)	614	523	(1)	533	640	(1)	487	585

[1] Insufficient reports to compute median.

TABLE D–17.—*Median base monthly salary rates for each field of engineering employment, by class of worker, 1939, 1943, and 1946*

Class of worker	Chemical			Civil			Electrical			Mechanical			Mining and metallurgical			Other		
	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946	1939	1943	1946
Total private and public	$220	$278	$363	$244	$313	$368	$253	$313	$393	$253	$326	$409	$267	$332	$417	$259	$331	$410
Total private	225	281	367	275	346	390	258	323	396	255	335	413	268	334	418	266	346	420
Employer	378	405	427	496	517	496	355	517	465	495	620	574	413	480	495	404	591	558
Employee of a private firm	222	281	365	264	340	382	256	320	395	251	330	407	261	330	415	257	338	413
Independent consultant	355	490	500	322	375	406	263	392	350	333	520	496	310	320	440	348	433	495
Total public	189	261	348	230	290	356	218	278	387	240	279	384	264	322	409	243	300	375
Federal Government employee	177	259	363	224	296	399	215	278	406	213	275	400	273	324	415	243	302	410
State government employee	190	258	314	218	276	319	240	288	358	267	313	339	260	317	378	237	291	349
County government employee	(1)	(1)	(1)	228	274	316	(1)	(1)	(1)	(1)	(1)	(1)	------	------	------	(1)	(1)	(1)
Municipal government employee	(1)	(1)	(1)	261	301	345	218	279	343	287	330	373	(1)	(1)	(1)	249	290	335
Other public authority employee	(1)	(1)	(1)	258	351	400	220	274	343	(1)	(1)	370	(1)	(1)	(1)	290	410	413

[1] Insufficient reports to compute median.

TABLE D–18.—*Comparison of median base monthly salaries for engineers in the same field of employment all 3 survey years, by years of experience, 1946*

Years of experience in 1946	Median base monthly salary			Dollar amount of increase in median base monthly salary			Percentage increase in median base monthly salary		
	1939	1943	1946	1939 to 1946	1939 to 1943	1943 to 1946	1939 to 1946	1939 to 1943	1943 to 1946
	CHEMICAL								
7–8 years	$143	$263	$385	$242	$120	$122	169.2	83.9	46.4
9–11 years	178	297	409	231	119	112	129.8	66.9	37.7
12–14 years	230	347	459	229	117	112	99.6	50.9	32.3
15–19 years	303	388	488	185	85	100	61.1	28.1	25.8
20–24 years	345	440	554	209	95	114	60.6	27.5	25.9
25–29 years	424	493	599	175	69	106	41.3	16.3	21.5
30–34 years	480	583	650	170	103	67	35.4	21.5	11.5
35–39 years	513	595	692	179	82	97	34.9	16.0	16.3
40 years and over	650	650	733	83	----------	83	12.8	----------	12.8
	CIVIL								
7–8 years	$154	$248	$338	$184	$94	$90	119.5	61.0	36.3
9–11 years	168	265	352	184	97	87	109.5	57.7	32.8
12–14 years	181	270	358	177	89	88	97.8	49.2	32.6
15–19 years	218	300	369	151	82	69	69.3	37.6	23.0
20–24 years	254	315	385	131	61	70	51.6	24.0	22.2
25–29 years	287	338	403	116	51	65	40.4	17.8	19.2
30–34 years	309	361	431	122	52	70	39.5	16.8	19.4
35–39 years	333	379	432	99	46	53	29.7	13.8	14.0
40 years and over	363	402	443	80	39	41	22.0	10.7	10.2
	ELECTRICAL								
7–8 years	$142	$255	$357	$215	$113	$102	151.4	79.6	40.0
9–11 years	171	278	372	201	107	94	117.5	62.6	33.8
12–14 years	207	308	413	206	101	105	99.5	48.8	34.1
15–19 years	241	330	426	185	89	96	76.8	36.9	29.1
20–24 years	305	372	458	153	67	86	50.2	22.0	23.1
25–29 years	357	430	508	151	73	78	42.3	20.4	18.1
30–34 years	408	470	521	113	62	51	27.7	15.2	10.9
35–39 years	432	494	550	118	62	56	27.3	14.4	11.3
40 years and over	480	508	558	78	28	50	16.3	5.8	9.8
	MECHANICAL								
7–8 years	$137	$276	$394	$257	$139	$118	187.6	101.5	42.8
9–11 years	181	311	417	236	130	106	130.4	71.8	34.1
12–14 years	217	347	455	238	130	108	109.7	59.9	31.1
15–19 years	263	378	468	205	115	90	77.9	43.7	23.8
20–24 years	308	409	497	189	101	88	61.4	32.8	21.5
25–29 years	366	461	541	175	95	80	47.8	26.0	17.4
30–34 years	397	456	527	130	59	71	32.7	14.9	15.6
35–39 years	417	495	541	124	78	46	29.7	18.7	9.3
40 years and over	468	513	563	95	45	50	20.3	9.6	9.7
	MINING AND METALLURGICAL								
7–8 years	$137	$259	$351	$214	$122	$92	156.2	89.1	35.5
9–11 years	201	313	416	215	112	103	107.0	55.7	32.9
12–14 years	235	340	429	194	105	89	82.6	44.7	26.2
15–19 years	290	376	483	193	86	107	66.6	29.7	28.5
20–24 years	334	433	516	182	99	83	54.5	29.6	19.2
25–29 years	379	480	572	193	101	92	50.9	26.6	19.2
30–34 years	493	545	644	151	52	99	30.6	10.5	18.2
35–39 years	511	570	604	93	59	34	18.2	11.5	6.0
40 years and over	470	553	715	245	83	162	52.1	17.7	29.3
	OTHER								
7–8 years	$157	$262	$364	$207	$105	$102	131.8	66.9	38.9
9–11 years	194	287	377	183	93	90	94.3	47.9	31.4
12–14 years	214	312	396	182	98	84	85.0	45.8	26.9
15–19 years	258	361	458	200	103	97	77.5	39.9	26.9
20–24 years	290	360	437	147	70	77	50.7	24.1	21.4
25–29 years	336	414	491	155	78	77	46.1	23.2	18.6
30–34 years	423	513	573	150	90	60	35.5	21.3	11.7
35–39 years	438	500	564	126	62	64	28.8	14.2	12.8
40 years and over	520	587	608	88	67	21	16.9	12.9	3.6

TABLE D-19.—*Median annual income for each field of engineering employment, by years of experience, 1939 and 1943*

Years of experience	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	1939	1943	1939	1943	1939	1943	1939	1943	1939	1943	1939	1943
Total	$2,756	$3,673	$3,089	$4,087	$3,214	$4,196	$3,269	$4,485	$3,450	$4,480	$3,339	$4,501
Less than 1 year	1,608	2,509	1,718	2,467	1,585	2,523	1,642	2,580	1,700	2,667	1,822	2,522
1 year	1,879	2,800	1,910	2,825	1,894	2,869	1,936	3,023	1,909	2,733	2,088	2,883
2 years	1,991	2,984	1,957	3,031	1,997	3,203	2,040	3,400	2,120	3,000	2,229	3,350
3 years	2,176	3,260	2,075	3,133	2,189	3,280	2,330	3,667	2,360	3,111	2,240	3,467
4 years	2,400	3,378	2,171	3,300	2,197	3,438	2,510	3,737	2,558	3,350	2,495	3,473
5 years	2,813	3,578	2,225	3,200	2,545	3,541	2,600	3,933	3,000	3,525	2,588	3,760
6 years	2,765	3,624	2,341	3,800	2,485	3,748	2,800	3,937	2,600	3,564	2,716	3,564
7–8 years	3,325	3,932	2,564	3,324	2,595	3,838	3,111	4,309	3,514	4,104	3,125	3,800
9–11 years	3,538	4,660	2,742	3,770	3,071	4,189	3,291	4,637	3,400	4,314	3,211	4,146
12–14 years	3,646	4,871	2,970	3,816	3,469	4,259	3,667	4,854	3,943	5,000	3,475	4,557
15–19 years	4,700	5,247	3,345	3,951	3,925	4,681	4,181	5,229	4,540	5,256	4,040	4,732
20–24 years	6,050	6,107	3,776	4,314	4,733	5,156	4,909	5,808	6,050	5,775	4,615	5,400
25–29 years	6,514	7,800	3,996	4,713	5,176	5,756	5,206	5,869	6,150	7,950	5,057	5,963
30–34 years	7,500	7,850	4,238	4,703	5,367	6,075	5,387	6,325	5,914	7,350	5,120	6,390
35–39 years	(1)	6,360	4,838	4,984	6,450	6,600	6,386	6,500	6,500	7,650	(1)	6,300
40 years and over	(1)	8,100	5,167	5,220	5,800	6,240	(1)	7,629	(1)	7,125	(1)	6,525

[1] Insufficient reports to compute median.

TABLE D-20.—*Median annual income, by occupational status, for each field of engineering employment, 1939 and 1943*

Occupational status	Chemical		Civil		Electrical		Mechanical		Mining and metallurgical		Other	
	1939	1943	1939	1943	1939	1943	1939	1943	1939	1943	1939	1943
Administration-management, nontechnical	$4,500	$6,000	$5,067	$5,775	$5,000	$5,550	$4,800	$7,450	$7,800	$8,100	$5,400	$5,957
Administration-management, technical	4,867	5,088	4,231	4,959	4,746	5,397	5,225	6,015	5,217	5,316	4,545	5,412
Analysis and testing	1,972	2,946	2,267	3,086	2,411	3,530	2,171	3,564	2,467	3,300	2,450	3,236
Construction supervision	(1)	(1)	2,987	3,981	3,178	4,219	3,660	4,867	(1)	(1)	3,231	4,460
Consulting, independent	(1)	(1)	4,900	6,300	5,333	6,000	5,520	9,000	6,600	9,600	6,600	8,400
Consulting, as employee of private firm	3,600	4,600	3,880	5,167	4,050	5,071	4,425	5,525	4,800	5,400	4,075	5,467
Design	3,000	3,838	3,034	3,839	3,113	3,980	3,012	4,097	(1)	(1)	3,171	4,400
Development	2,529	3,235	2,580	3,378	3,272	4,091	3,109	4,331	3,025	3,675	3,171	3,886
Drafting	(1)	(1)	2,179	3,043	2,069	3,046	2,057	3,216	(1)	(1)	2,300	3,350
Estimating	-------	(1)	3,137	3,950	2,734	3,800	2,800	3,787	(1)	(1)	2,756	3,667
Inspection	(1)	(1)	2,405	3,240	2,320	3,384	2,350	3,693	2,133	3,567	2,618	3,547
Installation	-------	(1)	(1)	(1)	2,867	3,675	3,073	3,686	(1)	(1)	(1)	(1)
Maintenance	(1)	(1)	3,215	3,713	2,542	3,567	2,971	3,883	(1)	(1)	2,514	3,900
Operation	2,562	3,376	2,525	3,343	2,693	3,714	3,306	4,238	3,075	3,711	3,164	4,089
Patents	(1)	(1)	-------	-------	(1)	(1)	5,400	4,800	-------	-------	(1)	(1)
Production	2,536	3,451	(1)	(1)	2,525	3,720	2,810	4,236	2,785	4,000	2,450	3,914
Research in basic science	(1)	(1)	(1)	(1)	(1)	(1)	2,600	3,500	(1)	(1)	(1)	(1)
Research, applied	2,486	3,289	3,334	3,720	3,627	3,869	3,011	3,823	3,341	3,809	2,975	4,029
Safety engineering	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	3,056	3,741
Sales	4,700	5,800	4,400	5,080	3,650	4,730	4,012	5,645	3,900	5,700	3,667	5,500
Teaching, college or university	3,360	3,920	3,711	4,400	3,575	4,213	3,296	4,286	3,960	5,600	3,150	4,440
Any occupational status not specified above	(1)	(1)	2,174	3,362	2,700	3,467	3,140	4,092	3,050	4,150	3,111	3,900

[1] Insufficient reports to compute median.

TABLE D-21.—*Percentages of respondents who shifted or remained in same class-of-worker status, 1939, 1943, and 1946*

Class of worker	All reports	Engineering employment: All engineering	Private industry: Total	Private industry: Employers	Private industry: Employees of private firms	Private industry: Independent consultants	Public employment: Total	Public employment: Federal Government	Public employment: State government	Public employment: County government	Public employment: Municipal government	Public employment: Other public authority	Nonengineering work	Student	Retired	Unemployed
In 1939		*Class of worker in 1943*														
All reports	100.0	97.0	74.5	4.8	68.0	1.7	22.5	12.7	5.1	0.7	3.2	0.8	2.9	(1)	0.1	(1)
All engineering	100.0	99.3	76.2	5.0	69.5	1.7	23.1	12.9	5.3	.8	3.3	.8	.7	(1)	(1)	(1)
Private industry	100.0	99.3	92.9	6.2	84.6	2.1	6.4	5.3	.6	(1)	.3	.2	.7	(1)	(1)	------
Employers	100.0	99.5	91.0	78.5	11.6	.9	8.5	7.2	.5	------	.4	.4	.5	------	------	------
Employees of private firms	100.0	99.3	93.3	1.0	92.0	.3	6.0	4.9	.6	(1)	.3	.2	.7	(1)	(1)	------
Independent consultants	100.0	99.7	83.9	1.5	19.3	63.1	15.8	13.6	.5	.3	.8	.6	.3	------	------	(1)
Public employment	100.0	99.2	19.7	.7	18.7	.3	79.5	38.6	21.0	3.3	13.6	3.0	.8	------	(1)	------
Federal Government	100.0	99.2	19.8	.6	18.9	.3	79.4	77.0	1.2	.2	.9	.1	.7	------	.1	------
State government	100.0	99.3	18.9	.2	18 4	.3	80.4	13.0	65.0	.9	1.3	.2	.6	------	------	0.1
County government	100.0	98.3	21.5	1.7	19.8	------	76.8	11.3	2.3	60.5	2.2	.5	1.7	------	------	------
Municipal government	100.0	98.8	19.0	1.1	17.6	.3	79.8	10.0	1.2	.1	68.4	.1	.9	------	.3	------
Other public authority	100.0	99.4	22.9	1.8	19.9	1.2	76.5	14.6	1.1	------	.6	60.2	.6	------	------	------
Nonengineering work	100.0	41.3	31.4	1.6	29.3	.5	9.9	8.0	.7	------	.7	.5	58.7	------	------	------
Student	100.0	91.9	80.3	4.5	75.8	------	11.6	8.0	2.9	------	------	.7	3.7	4.4	------	------
Retired	100.0	44.4	33.3	------	22.2	11.1	11.1	11.1	------	------	------	------	------	------	55.6	------
Unemployed	100.0	97.4	57.9	5.3	52.6	------	39.5	36.9	------	------	------	2.6	2.6	------	------	------
In 1943		*Class of worker in 1946*														
All reports	100.0	95.7	75.6	6.6	66.1	2.9	20.1	9.9	5.2	0.9	3.3	0.8	3.7	(1)	0.3	0.3
All engineering	100.0	98.2	77.6	6.8	67.8	3.0	20.6	10.1	5.4	.9	3.4	.8	1.2	(1)	.3	.3
Private engineering	100.0	98.3	96.0	8.3	84.4	3.3	2.3	1.0	.7	.2	.3	.1	1.2	0.1	.3	.3
Employers	100.0	97.8	96.7	93.7	2.2	.8	1.1	.3	.4	.1	.3	------	1.3	------	.4	.5
Employees of private firms	100.0	98.3	96.0	2.4	92.1	1.5	2.3	1.0	.7	.2	.3	.1	1.2	(1)	.2	.3
Independent consultants	100.0	97.8	95.0	2.9	4.8	87.3	2.8	1.0	1.0	------	.8	------	.4	------	1.4	.4
Public employment	100.0	98.2	16.7	1.8	13.1	1.8	81.5	40.4	20.9	3.5	13.7	3.0	1.2	(1)	.2	.4
Federal Government	100.0	97.8	22.9	2.4	18.5	2.0	74.9	70.8	2.4	.5	1.0	.2	1.6	(1)	(1)	.6
State government	100.0	99.0	9.5	1.2	8.0	1.3	89.5	1.6	86.0	.8	1.0	.1	.9	------	.1	------
County government	100.0	100.0	6.4	.8	4.8	.8	93.6	.8	1.6	90.4	.8	------	------	------	------	------
Municipal government	100.0	98.8	5.9	.6	3.8	1.5	92.9	.2	.7	.4	91.4	.2	.6	------	.4	.2
Other public authority	100.0	98.6	16.2	1.5	11.7	3.0	82.4	2.1	------	.7	------	79.6	.7	------	.7	------
Nonengineering work	100.0	12.5	10.7	.6	9.0	1.1	1.8	.6	.6	.2	.4	------	86.9	.2	.2	.2
Student	100.0	100.0	42.9	------	42.9	------	57.1	28.5	14.3	------	------	14.3	------	------	------	------
Retired	100.0	8.3	8.3	------	8.3	------	------	------	------	------	------	------	------	------	91.7	------
Unemployed	100.0	------	------	------	------	------	------	------	------	------	------	------	------	------	------	100.0
In 1939		*Class of worker in 1946*														
All reports	100.0	95.7	75.6	6.6	66.1	2.9	20.1	9.9	5.2	0.9	3.3	0.8	3.7	(1)	0.3	0.3
All engineering	100.0	97.9	77.3	6.8	67.5	3.0	20.6	10.0	5.4	.9	3.4	.9	1.5	(1)	.3	.3
Private industry	100.0	97.9	93.3	8.1	81.8	3.4	4.6	3.4	.7	.1	.3	.1	1.5	(1)	.3	.3
Employers	100.0	98.6	92.3	81.7	8.7	1.9	6.3	5.2	.4	.1	.4	.2	.7	------	.1	.6
Employees of private firms	100.0	98.0	93.6	2.8	89.3	1.5	4.4	3.1	.6	.1	.3	.3	1.6	------	.2	.2
Independent consultants	100.0	97.8	88.8	4.1	14.1	70.6	9.0	6.3	1.5	.5	.7	------	1.2	------	.7	.3
Public employment	100.0	98.0	23.1	2.1	19.3	1.7	74.9	32.8	21.3	3.9	14.0	2.9	1.5	(1)	.2	.3
Federal Government	100.0	97.8	24.6	2.5	21.1	1.0	73.2	69.0	1.9	.6	1.6	.1	1.7	0.1	.1	.3
State government	100.0	97.8	20.9	1.5	17.8	1.6	76.9	8.3	64.7	2.1	1.6	.2	1.6	------	.2	.4
County government	100.0	99.5	24.3	3.3	19.8	1.2	75.2	6.4	4.6	59.6	4.1	.5	.5	------	------	------
Municipal government	100.0	98.2	21.6	2.1	17.0	2.5	76.6	6.4	1.1	.4	67.9	.8	1.1	------	.4	.3
Other public authority	100.0	97.1	28.0	2.9	21.0	4.1	69.1	10.0	1.8	.6	1.1	55.6	2.3	------	.6	------
Nonengineering work	100.0	38.9	31.6	1.8	28.7	1.1	7.3	4.9	1.3	------	.9	.2	60.3	------	.3	.5
Student	100.0	93.4	78.7	7.3	71.4	------	14.7	6.6	5.8	------	------	2.3	3.6	2.1	------	.8
Retired	100.0	33.3	33.3	------	33.3	------	------	------	------	------	------	------	------	------	66.7	------
Unemployed	100.0	84.2	57.9	5.2	52.7	------	26.3	23.6	------	------	------	2.7	2.6	------	2.6	10.6

1 Less than 0.05 percent.

TABLE D-22.—*Percentages of respondents who shifted or remained in same industry field, 1939, 1943, and 1946*

Industry field	All reports	Agriculture, forestry	Mining	Construction	Manufacturing											Transportation	Communication	Utilities	Service industries	Other industry fields	Unemployed
					Total	Food, textiles	Lumber, paper products	Printing and publishing	Chemicals and allied products	Petroleum and coal products	Rubber, stone, clay, and glass products	Iron, steel, and nonferrous metals products	Machinery	Transportation equipment	Other manufacturing industries						
In 1939		*Industry field in 1943*																			
All reports	100.0	0.6	4.0	18.4	45.5	1.6	1.2	0.2	5.0	3.8	2.0	7.4	12.3	8.8	3.2	3.0	6.0	9.0	8.1	5.3	0.1
Agriculture, forestry	100.0	64.4	.7	16.3	11.2	.7	.7		1.5			2.3	2.3	2.3	.7	.7	.7	3.7	.7	2.3	
Mining	100.0		84.5	3.0	9.8	.4	.3		1.8	.6	.6	2.0	11.0	2.5	.6	.1		.6	.6	1.4	
Construction	100.0	.1	.6	81.6	10.1	.1	.2	.1	.8	.6	.5	1.8	1.5	3.6	.9	1.0	.4	1.6	2.0	2.5	.1
Manufacturing	100.0	(1)	.2	1.3	94.3	3.6	2.7	.5	10.6	8.4	4.3	15.5	26.3	16.1	6.3	.4	.6	.4	1.2	1.6	(1)
Food, textiles	100.0		.6	3.5	91.5	70.4	.6	.3	4.8	1.6	1.0	2.6	2.5	4.5	3.2	.6	.6	1.3	.6	1.3	
Lumber, paper products	100.0			3.5	90.8	.9	75.3		4.9	.4	.9	1.8	.4	4.4	1.8	.9		.4	2.2	2.2	
Printing and publishing	100.0			2.0	89.8			59.2	4.1		2.0	2.0	6.2	14.3	2.0				2.0	6.2	
Chemicals and allied products	100.0		.3	1.0	94.6	.8	.4	.1	84.7	1.0	1.0	2.7	2.1	.7	1.1		.8	.4	1.0	1.9	
Petroleum and coal products	100.0	.1	.6	1.2	93.4	.6	.1		4.7	80.3	2.2	1.0	1.6	2.4	.5	.5	.5	.6	1.2	1.9	
Rubber, stone, clay, and glass products	100.0			1.0	97.6		.3	.3	3.8	1.3	80.1	3.5	2.6	3.8	1.9		.3		.3	.6	
Iron, steel, nonferrous metals products	100.0		.3	2.1	93.8	.3	.2	.1	1.4	.2	.4	83.6	2.6	3.9	1.1	.4	.4	.1	1.4	1.5	
Machinery	100.0		(1)	.8	93.8	.4	.2	(1)	.5	.4	.2	1.2	85.6	4.7	.6	.5	1.2	.7	1.5	1.6	
Transportation equipment	100.0		.2	.5	96.7	.1	.1		.2	.2	.1	.8	3.7	89.7	1.8	.3	.3	.1	.6	1.0	.1
Other manufacturing industries	100.0			.9	94.4	.2	.2		.9	.7	.5	1.4	2.3	8.2	80.0	.7	.2	.4	1.1	2.3	
Transportation	100.0			4.3	5.1					.5		.5	1.1	3.0		86.4	.2	.6	1.7	1.5	.2
Communication	100.0				4.1			.1			.1	.1	2.1	1.1	.6	.2	92.0	.1	1.0	2.6	
Utilities	100.0	.1	.2	4.3	10.7	.3	.1		1.3	.5	.5	1.6	3.1	2.4	.9	.6	1.4	78.8	1.9	1.9	.1
Service industries	100.0	(1)	.5	2.5	19.7	.4	.1		1.8	.6	.6	2.7	4.9	6.6	2.0	.7	1.8	1.3	70.0	3.4	.1
Other industry fields	100.0	.1	.4	3.9	12.8	.3	.1		1.4	.7	.6	1.8	2.0	4.9	1.0	1.0	1.7	.8	3.1	76.2	
Unemployed	100.0		4.2	14.1	49.4	1.4	2.8		2.8	2.8	4.2	8.5	9.9	11.3	5.7	2.8	2.8	2.8	12.7	4.2	7.0
In 1943		*Industry field in 1946*																			
All reports	100.0	0.7	3.9	18.2	43.9	1.9	1.4	0.3	5.1	3.7	2.0	7.1	12.6	6.6	3.2	3.0	6.0	9.0	9.4	5.4	0.5
Agriculture, forestry	100.0	93.7		2.1	3.2	1.1		1.1				1.0							1.0		
Mining	100.0	.1	90.8	2.5	2.9	.3	.3		.1	.5		.6	.8		.3	.3	.1	.5	1.4	.6	.8
Construction	100.0	.3	.5	89.5	3.7	.3	.3		.7	(1)	.1	.6	.9	.4	.4	.9	.1	1.2	1.9	1.4	.5
Manufacturing	100.0	.1	.2	2.2	91.6	3.9	2.9	.5	10.5	7.9	4.3	14.9	26.1	14.0	6.6	.2	.4	.7	2.7	1.5	.4
Food, textiles	100.0	.8		.7	95.8	88.3	.7		2.6		1.5	.4	1.9		.4			.4	.8	1.5	
Lumber, paper products	100.0	.5		1.4	96.1	.5	89.6	.5	2.0		.5	.5	2.0		.5	.5		.5	1.0		
Printing and publishing	100.0				91.9			86.5	2.7					2.7					2.7	5.4	
Chemicals and allied products	100.0	.1	.2	1.1	94.3	1.6	.8	.2	86.3	1.2	.5	1.1	1.5	.4	.7	.1		.1	2.7	1.0	.4
Petroleum and coal products	100.0	.2	1.0	1.6	93.0	.6	.2		1.7	87.5	.5	.3	1.4	.6	.2	.2		.6	1.6	.8	1.0
Rubber, stone, clay, and glass products	100.0			1.5	94.6	1.2	.3		2.1	2.1	85.0	.9	1.8	.6	.6			.6	1.8	.9	.6
Iron, steel, nonferrous metals products	100.0		.3	1.8	93.8	.5	.7	.1	1.6	.4	.7	86.3	2.2	1.0	.3	.1	.1	.7	1.9	.9	.4
Machinery	100.0	.2	.1	1.2	93.9	.8	.1	(1)	.3	.5	.2	.9	89.4	.8	.9	(1)	.6	.7	2.0	1.1	.2
Transportation equipment	100.0	.1	.1	5.3	83.0	.6	.9	.1	1.0	.6	.5	1.8	4.6	69.2	3.7	.6	.7	.9	5.6	2.9	.8
Other manufacturing industries	100.0			2.9	89.4	1.1	.4	.4	1.9	.6	.6	.8	3.6	2.1	77.9	.2	.7	.7	3.0	2.5	.6
Transportation	100.0		.6	3.0	4.4	.2			.8	.2		.4	1.4	1.0	.4	87.5	.6	1.2	1.9	.6	.2
Communication	100.0			.1	3.2	.1			.4		.1	.1	1.6	.4	.5	.1	93.1	.5	1.9	1.0	.1
Utilities	100.0	.1	.3	1.7	2.5	.3	.1		.4	.1	.2	.3	.9	.1	.1	.1	.1	92.3	1.7	.9	.3
Service industries	100.0	.1	.2	1.5	5.7		.1		.8	.1	.2	1.0	2.3	.8	.4	.5	.6	.7	88.8	1.6	.3
Other industry fields	100.0	.1	.2	4.0	10.0	.6	.2	.4	1.0	.7	.7	1.4	3.1	1.1	.8	.5	1.1	.9	3.7	78.8	.7
Unemployed	100.0			8.3	8.3							8.3								16.7	66.7

1 Less than 0.05 percent.

TABLE D-22.—*Percentages of respondents who shifted or remained in same industry field, 1939, 1943, and 1946*—Continued

Industry field	All reports	Agriculture, forestry	Mining	Construction	Manufacturing											Transportation	Communication	Utilities	Service industries	Other industry fields	Unemployed
					Total	Food, textiles	Lumber, paper products	Printing and publishing	Chemicals and allied products	Petroleum and coal products	Rubber, stone, clay and glass products	Iron, steel, and nonferrous metals products	Machinery	Transportation equipment	Other manufacturing industries						
In 1939		*Industry field in 1946*																			
All reports	100 0	0.7	3.9	18.2	43.9	1.9	1.4	0.3	5.1	3.7	2.0	7.1	12.6	6.6	3.2	3.0	6.0	9.0	9.4	5.4	0.5
Agriculture, forestry	100.0	63.7	.8	13.3	13.3	2.2	------	.8	2.2	------	------	1.5	2.2	3.7	.7	------	1.5	2.2	3.0	2.2	------
Mining	100.0	.1	81.8	3.6	9.2	.6	.4	.1	1.4	.7	.6	2.0	1.3	1.7	.4	.4	.3	.7	1.0	2.0	.9
Construction	100.0	.3	.8	80.2	8.9	.4	.5	.1	1.3	.6	.3	1.6	1.7	1.7	.7	1.3	.4	2.1	3.0	2.5	.5
Manufacturing	100.0	.2	.2	1.3	91.4	4.0	3.0	.5	10.5	8.2	4.3	14.9	26.3	13.3	6.4	.4	.7	.6	2.8	2.1	.3
Food, textiles	100.0	.6	.6	2.6	89.2	68.8	.6	------	5.7	1.9	1.0	1.9	3.5	2.9	2.9	.3	1.0	1.0	2.5	2.2	------
Lumber, paper products	100.0	------	.4	1.8	92.0	1.3	76.2	.4	4.8	1.3	1.3	1.8	1.3	1.8	1.8	1.8	------	.5	1.8	1.3	.4
Printing and publishing	100.0	------	------	------	91.8	2.0	------	59.2	------	------	2.0	6.1	4.1	14.3	4.1	------	------	------	8.2	------	------
Chemicals and allied products	100.0	------	.1	1.0	93.9	2.2	1.0	.3	82.6	1.1	.4	2.2	2.6	.4	1.0	------	.6	1.6	1.8	1.6	.4
Petroleum and coal products	100.0	.4	.7	1.6	88.7	.9	.3	------	5.6	76.0	1.3	.6	2.0	1.6	.4	.3	.3	1.2	3.2	2.7	.9
Rubber, stone, clay, and glass products	100.0	.3	------	.9	95.8	1.9	.6	.3	2.5	1.6	79.8	2.5	2.2	1.9	2.5	.3	.3	.3	1.2	.6	.3
Iron, steel, nonferrous metals products	100.0	------	.3	2.2	91.1	.6	.6	.1	1.6	.4	.7	80.3	3.7	1.5	1.6	.4	.4	.3	3.3	1.7	.3
Machinery	100.0	.1	.1	.7	91.4	.6	.3	.1	.6	.3	.3	1.4	83.8	2.8	1.2	.3	1.1	.8	3.3	2.0	.2
Transportation equipment	100.0	.2	.1	1.8	90.6	.3	.5	.1	.4	.4	.5	1.1	4.7	80.2	2.4	.5	1.0	------	2.4	3.0	.4
Other manufacturing industries	100.0	------	------	.9	91.6	.9	.2	------	1.3	1.3	1.3	2.0	4.5	3.8	76.3	.2	.7	.5	2.7	3.2	.2
Transportation	100.0	------	.4	4.0	5.9	------	------	------	.7	.2	------	.4	1.8	2.4	------	85.6	.4	1.8	2.2	1.5	.2
Communication	100.0	------	------	.1	4.4	.1	------	------	.3	------	.1	.1	2.1	.6	1.1	.1	91.3	.3	1.6	2.1	.1
Utilities	100.0	.1	.1	3.9	11.0	5.	.3	------	1.4	.5	.5	1.5	4.0	1.2	1.1	.5	1.1	77.2	3.2	2.6	.3
Service industries	100.0	.1	.5	2.9	18.6	.4	.3	.2	1.8	.6	.8	2.7	6.1	3.7	2.0	.7	1.3	1.1	71.2	3.0	.6
Other industry fields	100.0	.1	.4	5.1	12.9	.6	.1	------	1.5	.7	1.1	2.1	3.3	3.0	.6	.7	1.4	1.4	3.7	73.5	.8
Unemployed	100.0	1.4	4.2	11.3	39.4	1.4	1.4	1.4	5.6	1.4	2.8	7.1	7.1	5.6	5.6	4.2	2.8	1.4	14.2	8.4	12.7

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——— *Handbook of Descriptions of Specialized Fields in Ceramic Technology and Engineering.* Superintendent of Documents, Washington 25, D. C., 1944. 9 pp. 5 cents.

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Occupational Outlook Publications of the Bureau of Labor Statistics

Studies of employment trends and opportunities in the various occupations and professions are made by the Occupational Outlook Service of the Bureau of Labor Statistics.

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Occupational Outlook Handbook—Employment Information on Major Occupations for Use in Guidance.

Bulletin 940 (1948). Price $1.75. Illus.

Occupational Outlook Bulletins

Employment Opportunities for Diesel-Engine Mechanics.

Bulletin 813 (1945). Price 5 cents.

Employment Opportunities in Aviation Occupations, Part I—Postwar Employment Outlook.

Bulletin 837–1 (1945). (Edition sold out; copies are on file in many libraries).

Employment Opportunities in Aviation Occupations, Part II—Duties, Qualifications, Earnings, and Working Conditions.

Bulletin 837–2 (1946). Price 25 cents. Illus.

Employment Outlook for Automobile Mechanics.
Bulletin 842 (1945). Price 10 cents.

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Bulletin 844 (1945). Price 10 cents.

Postwar Outlook for Physicians.
Bulletin 863 (1946). Price 10 cents.

Employment Outlook in Foundry Occupations.
Bulletin 880 (1946). Price 15 cents. Illus.

Employment Outlook for Business-Machine Servicemen.
Bulletin 892 (1947). Price 15 cents. Illus.

Employment Outlook in Machine-Shop Occupations.
Bulletin 895 (1947). Price 20 cents. Illus.

Employment Outlook in Printing Occupations.
Bulletin 902 (1947). Price 20 cents. Illus.

Employment Outlook in Hotel Occupations.
Bulletin 905 (1947). Price 10 cents. Illus.

Employment Outlook in the Plastics Products Industry.
Bulletin 929 (1948). Price 15 cents. Illus.

Employment Outlook in Electric Light and Power Occupations.
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Bulletin 961 (1949). Price 30 cents. Illus.

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Bulletin 972 (1949). Price 35 cents. Illus.

Employment Outlook in Petroleum Production and Refining.
In press.

Special Reports

Occupational Data for Counselors. A Handbook of Census Information Selected for Use in Guidance.

Bulletin 817 (1945). 15 cents (prepared jointly with the Occupational Information and Guidance Service, U. S. Office of Education).

Factors Affecting Earnings in Chemistry and Chemical Engineering.

Bulletin 881 (1946). 10 cents.

Economic Status of Ceramic Engineers, 1939 to 1947.

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U. S. GOVERNMENT PRINTING OFFICE: 1950

EFFECT OF DEFENSE PROGRAM ON

Employment Outlook in Engineering

August 1951

Supplement to Bulletin 968,
EMPLOYMENT OUTLOOK FOR ENGINEERS

UNITED STATES DEPARTMENT OF LABOR
Maurice J. Tobin - Secretary

BUREAU OF LABOR STATISTICS
Ewan Clague - Commissioner

Letter of Transmittal

United States Department of Labor,
Bureau of Labor Statistics,
Washington, D. C.,
August 15, 1951

The Secretary of Labor:

I have the honor to transmit herewith a report on the effect of the defense program on the employment outlook for engineers. This is one of a series of reports made available through the Bureau's Occupational Outlook Service for use in vocational counseling of young people in school, veterans, and others interested in the choice of an occupation. The report supplements and brings up to date the discussion of employment trends and outlook in Bureau of Labor Statistics Bulletin No. 968, Employment Outlook for Engineers, which was written in 1949.

The report was prepared by Helen Wood and Robert W. Cain of the Branch of Occupational Studies, Division of Manpower and Employment Statistics. The Bureau wishes to acknowledge the generous assistance received from members of the engineering profession, including officials of engineering societies and engineering colleges, and engineers in industry and government.

Ewan Clague, Commissioner.

Hon. Maurice J. Tobin,
Secretary of Labor.

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EFFECT OF DEFENSE PROGRAM ON EMPLOYMENT OUTLOOK IN ENGINEERING

The tremendous contribution engineers make to the national security and welfare has been underlined by the defense program. In this mobilization period, the country relies on its engineers to develop the new and improved equipment and products required for the national defense, as well as for further economic progress. Engineers are counted on also to devise the most efficient methods of manufacturing these products and to give technical leadership throughout the production process. Furthermore, large numbers of persons with engineering training are needed by the Armed Forces to handle the increasing amounts of highly complex equipment which are being put into use.

This report discusses the general effect of the defense program, as planned in the early summer of 1951, on the demand for engineering personnel. Another subject considered is: how many young engineers are likely to complete training in the near future and how will the expected supply of new graduates compare with the anticipated demand? In addition, some information is given on past trends and major characteristics of this profession which are important in interpreting the current and prospective employment situation. The report supplements and brings up to date the chapter on engineers in the Occupational Outlook Handbook, as well as the sections on employment trends and outlook in the Bureau's Bulletin No. 968, "Employment Outlook for Engineers". 1/

Highlights of the current employment situation and outlook in the profession are, briefly, as follows: A serious shortage of engineers has developed since mid-1950, owing primarily to the increased demand for personnel generated by the defense program. Opportunities both for new graduates and for experienced men will be excellent in the near future. Over the long run, the profession will probably continue to expand substantially, under conditions either of peacetime full employment or of continuing mobilization.

Boys with aptitude and interest in engineering should have good employment opportunities when they complete their training. Though there are now extremely few women engineers, opportunities for women in the profession are better than at any time since World War II and will probably continue to be so for a number of years.

1/ Bulletin No. 968, which was published in 1949, contains chapters on engineers' earnings and on occupational mobility in the profession, as well as a much more detailed discussion of the different fields of engineering and of employment trends and outlook than could be included in the present, brief supplement.

Growth of the Profession

Engineering, by far the largest technical profession, is one of the Nation's fastest-growing fields of work. It is estimated that over 400,000 engineers are now employed in the country. There has been a tenfold expansion in the profession over the last half century (see chart 1). During the past decade alone, the number of engineers employed is estimated to have increased by about two-thirds (from 245,000 in 1940).

Industry's need for technical personnel grew rapidly during World War II, as a result of the changeover to war production and the great increase in industrial activity. It rose also during the postwar period of reconversion and expansion in civilian-goods industries. Then, in late 1949 and early 1950, the demand for engineers slackened; a survey of leading employers in January 1950 showed that they expected to hire fewer engineers that year than in 1949. This slow-up of the profession's growth was of short duration, however. The hiring of engineers rose sharply immediately after the Korean crisis began and a new mobilization program was announced. The increase in demand was so great that, by the end of the year, many employers reported a need for additional personnel, though the engineering schools' 1950 graduating class was the largest in history.

All major branches of engineering have shared in the profession's growth but the expansion has been more rapid in some branches than others. Mechanical engineering is now the largest branch, with nearly 40 percent of the profession's members. Civil engineering, which was the largest branch prior to World War II, has dropped to second place, with about 25 percent of all engineers. The proportions employed in the other major branches of the profession are estimated to be as follows: electrical, 20 percent; chemical, 10 percent; and mining and metallurgical, about 5 percent.

Fields of Employment

Engineers are essential to the operation of all of the Nation's major industries, both defense and nondefense. Large numbers work in the general areas of design, development, and research. Many use their engineering knowledge in administration and management, particularly in industries in which engineering methods are important. A sizeable group supervise construction or the operation of plants or mines. Some, particularly younger engineers, do drafting or analysis and testing, much of which is routine work. Still others are employed as independent consultants, who advise their clients on engineering matters and prepare designs or plans. Many companies employ engineers in selling their products, particularly when the buyer is a business firm, and when the salesman must be able to discuss the product technically and advise engineers as to its installation and use. The teaching of engineering in colleges or technical schools is another activity in which significant numbers of engineers are employed.

Altogether, about three-quarters of all engineers (300,000) are now employed in private industry. Some 90,000 work for Government agencies,

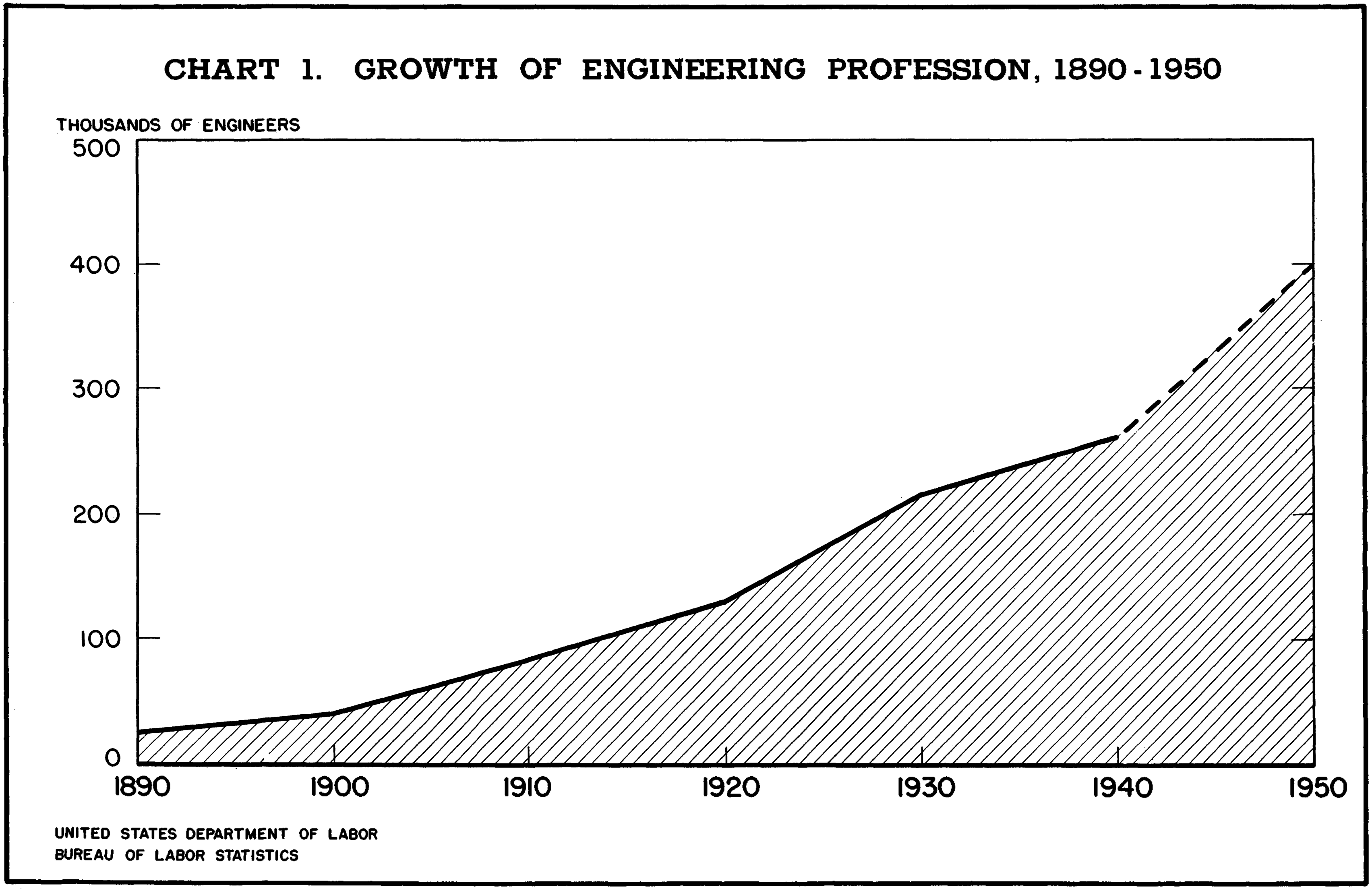
CHART 1. GROWTH OF ENGINEERING PROFESSION, 1890-1950
THOUSANDS OF ENGINEERS
500
400
300
200
100
0
1890
1900
1910
1920
1930
1940
1950
UNITED STATES DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS

Federal, State, and local. About 10,000 are in educational institutions.

The industries in which engineers are concentrated vary from one branch of the profession to another. Table 1 shows the industry distribution of personnel in the four largest branches of the profession.

Estimated Yearly Demand

How many new engineers will be needed yearly in the near future to meet the needs for personnel in all specialties and with all types of employers? Precise answers to this question are not available, but some information on the subject can be given.

Part of the demand for engineers arises from the need to replace those dying or retiring. It is estimated that approximately 7,500 young engineers will be required yearly in the near future to fill vacancies arising from deaths and retirements. Toward the end of the decade, these losses are likely to rise to about 9,000 annually. 2/

A number of men will also be required to replace those leaving the profession for other fields of work. A certain amount of occupational shifting always takes place. Even at times when industry's demand for engineers is intense, some men choose to leave the profession. A survey of the employment status of 1950 engineering graduates made in the spring of 1951 showed that about 10 percent of those with civilian jobs were employed in nonengineering work. 3/ Some experienced members of the profession also leave for other lines of work each year. On the other hand, a good many men, including some with backgrounds in other scientific fields such as chemistry or physics, obtain engineering jobs without having completed formal engineering school education. Not enough information on occupational shifting is available to make it possible to estimate the net annual gain or loss to the profession from this source.

Besides the engineers required as replacements, large numbers will be needed for growth of the profession. Continued expansion is likely in the types of industrial activity which make the most use of engineers' services manufacturing, mining, construction, transportation and public utilities. The increasing utilization of engineers for many different functions in industry will also be an important factor in the expansion of the profession. Engineers will be needed not only to staff newly created positions but to fill jobs previously held by men with other backgrounds, where professional engineering skill has come to be required.

During the past half century, employment of engineers has grown much more rapidly than total employment in the basic commodity-producing and

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2/ These estimates are derived from data on the age distribution of members of the profession, by the use of death and retirement rates for different age groups. See U. S. Department of Labor, Bureau of Labor Statistics, Bulletin No. 1001, Tables of Working Life, table 15, p. 48.

3/ American Society for Engineering Education and Engineers Joint Council, "Employment Status of 1950 Engineering Graduates." (Report presented at 59th Annual Meeting of American Society for Engineering Education, East Lansing, Michigan, June 28, 1951).

Table 1.--Percentage Distribution of Engineers in Selected Fields of Engineering, by Major Industry, 1946

Industry	Chemical engineers	Civil engineers	Electrical engineers	Mechanical engineers
Mining	1.4	a/	a/	a/
Construction	2.0	26.6	2.5	2.5
Manufacturing	82.6	8.1	36.7	67.6
Transportation	a/	5.8	1.5	1.7
Communication	a/	a/	19.7	1.5
Utilities	1.0	4.1	16.7	3.5
Government...........	5.7	50.8	14.3	10.5
Other industries.....	7.3	4.6	8.6	12.7
Total...........	100.0	100.0	100.0	100.0

a/ Included with "Other industries."

Source: U. S. Department of Labor, Bureau of Labor Statistics, Bulletin No. 968, pp. 13, 17, 23, and 28.

transporting industries just mentioned. In 1900, there were 393 engineers in the United States for every 100,000 workers in these industries; by 1950, the number had increased fourfold. Looking at the figures in another way, the ratio between the total number of workers and the number of engineers has, of course, dropped sharply -- from about 255 workers per engineer in 1900 to about a fourth as many in 1950 (see chart 2). This ratio has decreased more slowly in recent years than earlier in the century. Nevertheless, the trend toward greater utilization of engineers is expected to continue for some time.

A study of past trends and prospective industrial developments suggested that, under strictly peacetime conditions, the total annual demand for engineering graduates would probably have averaged around 20,000 during this decade. 4/ This demand figure allowed for a growth of about 100,000 in the profession over a 12-year period, as well as for estimated replacement needs.

Under present mobilization conditions, the number of new engineers needed will undoubtedly be much higher. The mobilization program has created a great, added need for engineering personnel in defense industries and those converting to defense production and in the development of new defense-related products. Though an exact estimate of the number of new graduates required to meet both defense and civilian needs cannot be made on the basis of the available information, the average annual demand during a prolonged partial mobilization would probably be at least 30,000. In addition to replacing men who die or retire, this number of graduates would provide 21,000 to 22,000 engineers annually to fill new jobs and make up for any transfers out of engineering not offset by transfers into it from other fields. It would make possible a fairly rapid growth in the profession, both in absolute numbers and relative to the total number of engineers now employed in the country (estimated at over 400,000).

Although 30,000 new engineers per year might be enough to meet the demand over a long period of partial mobilization, the number of new graduates needed is expected to be much greater still in the immediate future, while defense production and development work are still in the initial build-up stage. In June 1951, the Engineering Manpower Commission of the Engineers Joint Council made a survey to find out how many new graduates employers needed. Replies were received from companies and government agencies employing a total of 128,000 graduate engineers, or nearly a third of the engineers in the country. These employers alone reported a need for 22,000 new engineering graduates. This fact suggests a total Nation-wide need for many more than 30,000 graduates immediately, in the tooling-up and development stage of the defense program. The employers in the survey had obtained acceptances of job offers from only about 10,000 members of the 1951 graduating class.

4/ U. S. Department of Labor, Bureau of Labor Statistics, Bulletin No. 968, p. 3.

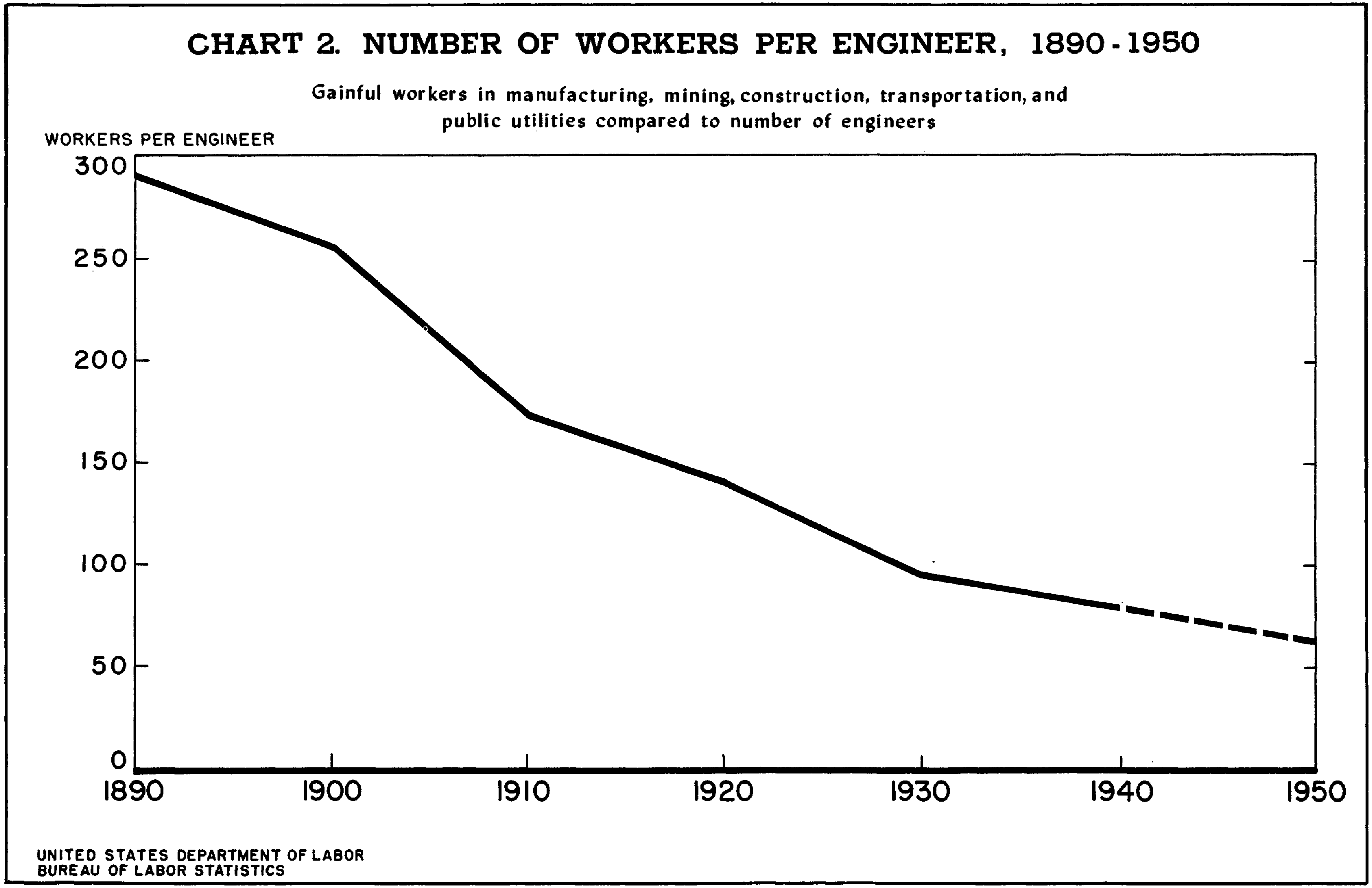
CHART 2. NUMBER OF WORKERS PER ENGINEER, 1890-1950
Gainful workers in manufacturing, mining, construction, transportation, and public utilities compared to number of engineers
WORKERS PER ENGINEER
300
250
200
150
100
50
0
1890
1900
1910
1920
1930
1940
1950
UNITED STATES DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS

These estimates all assume that the country will have only partial mobilization, at about the level planned in mid-1951. If the international situation should at any time make it necessary to have full mobilization, the demand for engineers would be greatly increased.

Estimated Supply

During the next few years the supply of new engineers is likely to be far less than the demand.

Engineering graduations will decline sharply from the peak figure of 52,000 reached in 1950, when the greatest number of veterans completed their training (see chart 3). Previous record classes of 21,000, 32,000 and 45,000 were graduated in 1947, 1948, and 1949, respectively--also reflecting the postwar influx of veterans in to the colleges. Freshman enrollments have dropped sharply since 1946 in engineering and other specialties which are predominantly men's fields, as the number of veterans entering college has declined. In the fall of 1950, the first-year engineering class was once more made up almost exclusively of non-veterans, and the engineering schools got about their prewar proportion of high school graduates.

On the basis of 1950 enrollments and assuming prewar drop-out rates (for example, 50 percent between entrance and graduation), the numbers of engineering graduates in 1951 and the following three years may be estimated as follows: 1951, 38,000; 1952, 26,000; 1953, 20,000; and 1954, 17,000. The figure of 17,000 graduates for 1954 is below even the average peacetime demand and is far below the number needed under mobilization conditions.

These estimates of graduations make no specific allowance for withdrawals of students for military service. However, in view of the recently announced policy with respect to college-student deferments, the proportion of present students leaving for all reasons may not greatly exceed the drop-out rate of previous years (which includes those leaving because of financial difficulties, ill health and the like, as well as poor scholarship).

Not all of the students graduating from engineering schools in the next few years will be available for civilian employment immediately. A number of them will be definitely committed to military service upon graduation; included are those in ROTC and similar programs who are called to duty, those in reserve status called to active duty, and those who voluntarily enter the Armed Forces. For some other students, liability for military service may not have been determined by the time of graduation; among the men in this situation are those in the draft-eligible age groups who have not been classified by their Selective Service Board, and those in the reserve who have not yet been called to active duty. However, a third group of students will be specifically exempted or deferred from

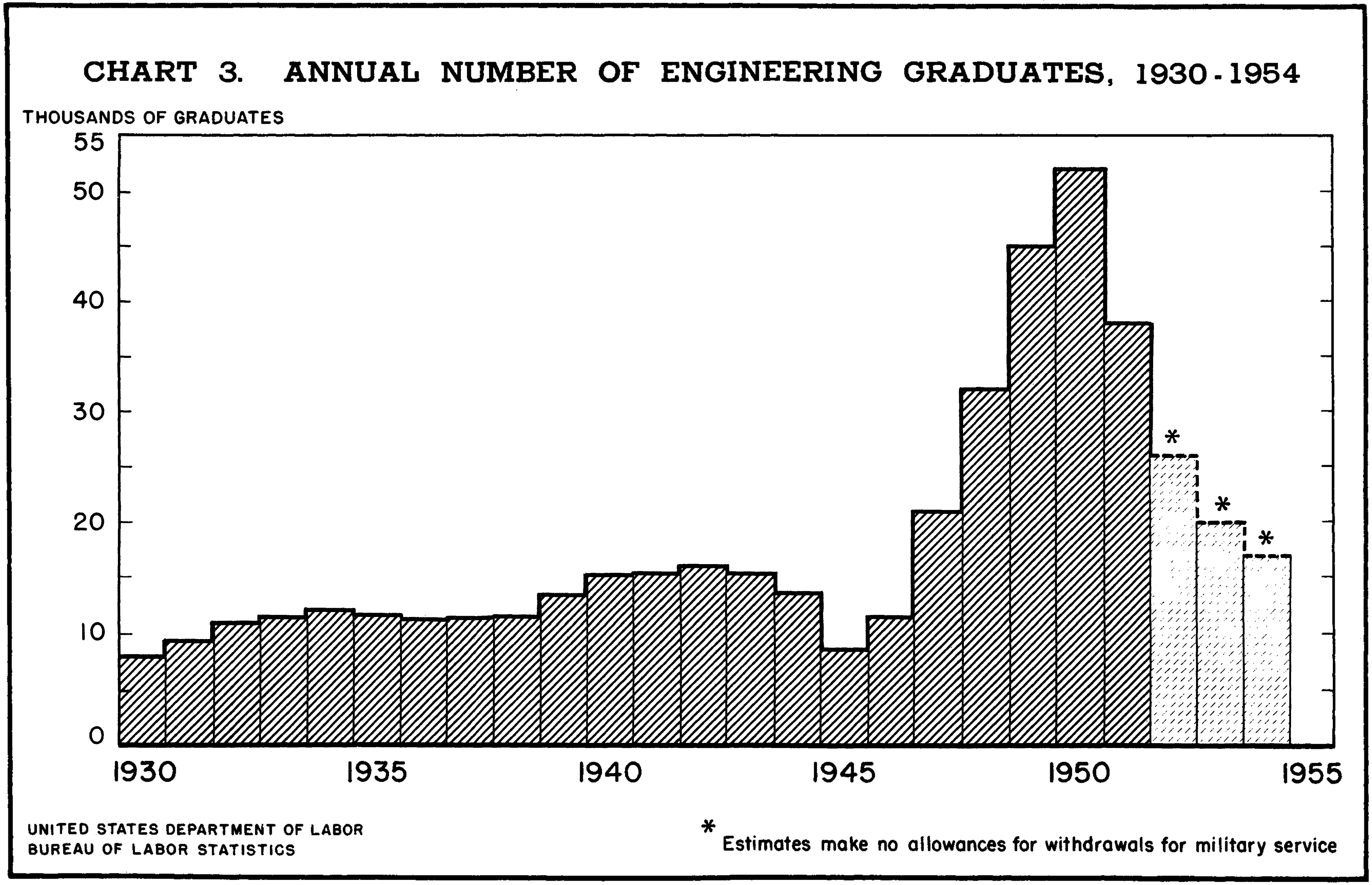

CHART 3. ANNUAL NUMBER OF ENGINEERING GRADUATES, 1930-1954
THOUSANDS OF GRADUATES
55
50
40
30
20
10
0
1930
1935
1940
1945
1950
1955
*
UNITED STATES DEPARTMENT OF LABOR
BUREAU OF LABOR STATISTICS
* Estimates make no allowances for withdrawals for military service

military service at time of graduation; included in this group are veterans with no reserve status, those classified as 4-F's, and several other specifically deferred classes. This last group is the only one which employers can rely on as being definitely available for employment upon graduation from engineering school.

In view of the large numbers of veterans in the 1951 graduating class, employers were probably able to obtain the services of at least half of this class. In 1952 and subsequent years, most graduates will be liable for military service. It is possible that the number of new graduates available for civilian employment will reach a postwar low in 1952. Thereafter, men returning after completion of a period of military service will probably augment the flow of new entrants into the profession.

The number of young men graduating from high school and potentially available for college entrance each year will soon begin to rise. After the middle of the decade, the increase in high school graduations is expected to be sharp. But during the next few years, the gain will be very slight and any effect it might have on college enrollments will, in all probability, be more than offset by the increasing proportions of college-age youth serving in the Armed Forces.

Obviously, there will not be enough engineering graduates to meet expected defense and civilian needs, at least until the mid-1950's and probably for some time thereafter. Both the mobilization program and the long-term growth of the profession point to a continuing high demand for engineers. This can be met only if the proportion of high school graduates who decide to prepare for the profession is much larger in the next few years than in 1950 and than before the war.

Boys interested in engineering, who have the aptitudes necessary for success in the field, should have favorable employment prospects when they graduate from engineering school. The number of women engineers is still very small in all branches of the profession, but the opportunities for girls to obtain college training in engineering are much better than during the late 1940's, when the colleges were crowded with veterans. Opportunities for their employment in the profession are also better than at any time since World War II and are expected to remain relatively favorable for a number of years.

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Occupational Outlook Handbook

Employment Information on Major Occupations for use in Guidance
Bulletin 998 (1951 Revised edition). $3.00. Illus.

Includes brief reports on more than 400 occupations of interest in vocational guidance, including professions; skilled trades; clerical, sales, and service occupations; and the major types of farming. Each report describes the employment trends and outlook, the training qualifications required, earnings, and working conditions. Introductory sections summarize the major trends in population and employment, and in the broad industrial and occupational groups, as background for an understanding of the individual occupations.

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Bulletin 968 (1949). 50 cents. Illus.

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Employment Outlook in Men's Tailored Clothing Industry
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Employment Outlook in Department Stores
Bulletin 1020 (1951). 20 cents. Illus.

Occupational Outlook Supplements

Effect of Defense Program on Employment Situation in Elementary and Secondary School Teaching (Supplement to Bulletin 972, Employment Outlook for Elementary and Secondary School Teaching)
(1951). (In press).

Special Reports

Occupational Data for Counselors. A Handbook of Census Information Selected for Use in Guidance
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Factors Affecting Earnings in Chemistry and Chemical Engineering
Bulletin 881 (1946). 10 cents.

Occupational Outlook Information Series (By States)
VA Pamphlet 7-2 (1947). 10 cents each. (When ordering, specify State or States desired).

Employment, Education, and Earnings of American Men of Science
(1951). (In press).

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