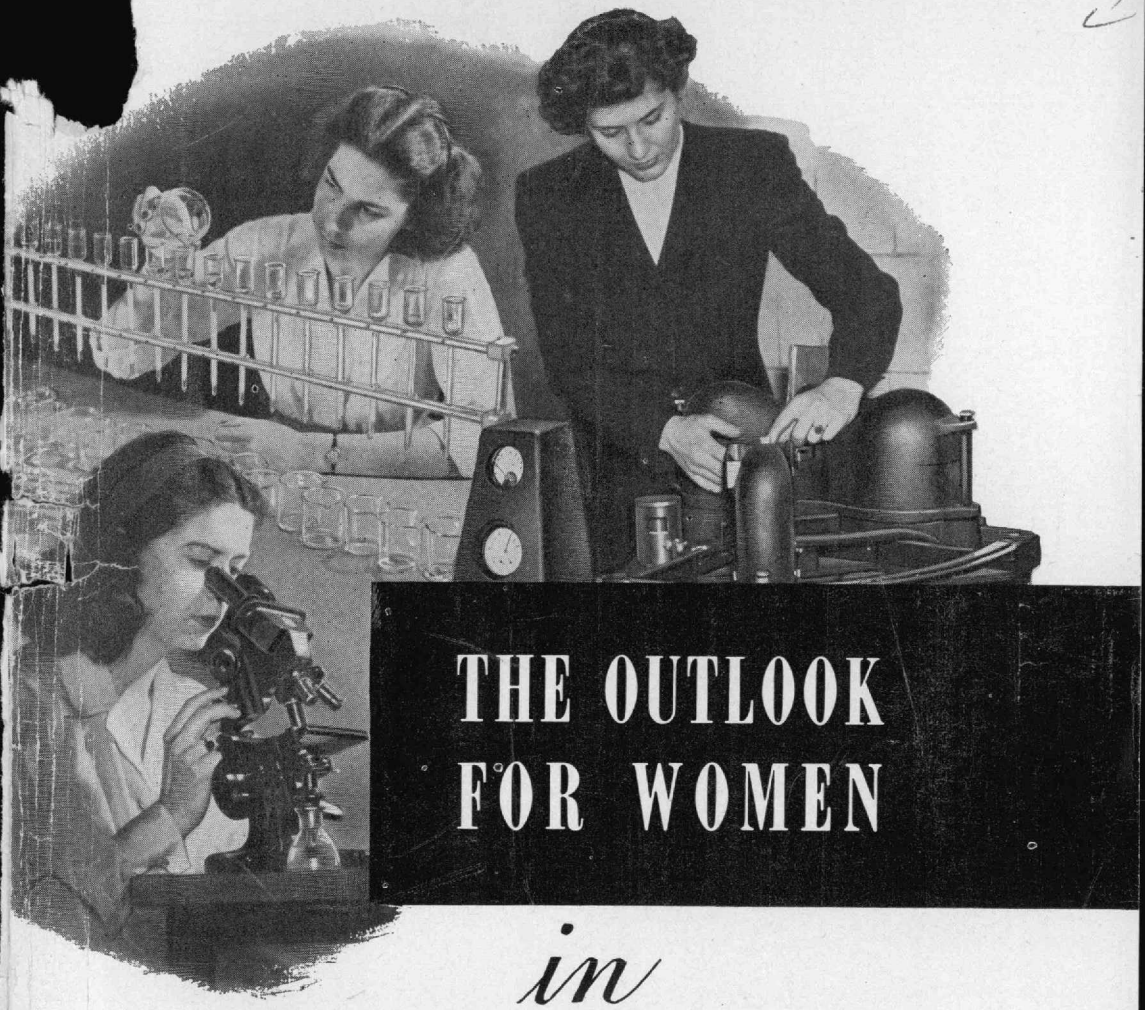

THE OUTLOOK FOR WOMEN *in* ARCHITECTURE AND ENGINEERING

Bulletin No. 223–5

U. S. DEPARTMENT OF LABOR

WOMEN'S BUREAU

UNITED STATES DEPARTMENT OF LABOR
L. B. SCHWELLENBACH, SECRETARY
WOMEN'S BUREAU
FRIEDA S. MILLER, DIRECTOR

The Outlook for Women in Architecture and Engineering

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No. 223–3 *The Outlook for Women in the Biological Sciences*

No. 223–4 *The Outlook for Women in Mathematics and Statistics*

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LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF LABOR,
WOMEN'S BUREAU,
Washington, December 22, 1947.

SIR: I have the honor of transmitting a description of the outlook for women in architecture and engineering which has been prepared as a part of a study on the outlook for women in science. The extraordinary demand for women with scientific training during World War II and the resulting questions which came to the Women's Bureau prompted us to undertake this study. The paucity of published information on women in science and the encouragement of the scientists and educators who were consulted in the course of this study confirmed the need for the information here assembled and synthesized. The study was planned and directed by Marguerite Wykoff Zapoleon and completed with the assistance of Elsie Katcher Goodman and Mary H. Brilla of the Employment Opportunities Section of the Bureau's Research Division. Other members of the Bureau staff who helped to broaden the coverage of this study through interviews in the field were regional representatives Margaret Kay Anderson, Martha J. Ziegler, Rebecca G. Smaltz, and another member of the research staff, Jennie Mohr. Corinne LaBarre, research assistant, of the Western Personnel Institute, Pasadena, Calif., furnished the information obtained from western colleges.

The part of the study here transmitted was written by Marguerite Wykoff Zapoleon.

Respectfully submitted.

FRIEDA S. MILLER, *Director.*

HON. L. B. SCHWELLENBACH,
Secretary of Labor.

FOREWORD

Much has been written about science and scientists, but little has been told about the work women trained in science have done and can do in the future.

Although these women are few in number when compared to men in science or to women in such occupations as teaching and nursing, their contribution to the national welfare, so strikingly demonstrated in World War II, goes forward daily in the laboratories, classrooms, offices, and plants in which they work.

The everyday story of where these women work, of what kind of work they are doing, and of what other young women who join their ranks in the future may do has been the subject of this report on the outlook for women in science. Unlike the usual monograph which describes an occupation in detail at a particular point in time, this study, like the Women's Bureau series on occupations in the medical and health services which preceded it, is concerned primarily with changes and trends.

Although more than 800 books, articles, or pamphlets were culled for background information, the principal raw material for the entire study of which this bulletin is a part came from such primary sources as scientific organizations, employers and trainers of women scientists, and men and women scientists themselves. Principal sources were as follows:

Scientific organizations: The National Research Council supplied useful directories of scientific laboratories and organizations. Helpful criticism and direction to other authorities were obtained from its Office of Scientific Personnel. Sixty separate organizations of scientists supplied information on their women members, by interview or correspondence.

Federal agencies: Unpublished information on personnel in scientific fields was supplied by:

The United States Bureau of Labor Statistics,
The National Roster of Scientific and Specialized Personnel,
The United States Office of Education,
The United States Civil Service Commission, and
The United States Public Health Service.

In addition, 52 separate bureaus, offices, or other operating units of the Federal Government known to employ scientists were solicited for information regarding the number of women employed on jobs requiring scientific training and the type of work they were doing. Detailed statistics over a period of years

were available from some agencies, while only fragmentary data were obtained from others. The women's military services likewise supplied information on the wartime use of women trained in science in the WAC, WAVES, and the Marine Corps.

Private industry: One hundred industrial firms were visited in 1945 and 1946 to obtain information, usually by interview with the director of research or the personnel director, on the women employed by any part of the organization in any capacity requiring scientific training of college level. Prewar, wartime, and postwar statistics were obtained where available, as well as suggestions and comments. In many instances, some of the women in scientific work were interviewed on the job. The firms visited included:

Seventy-eight firms listed in the National Research Council's 1946 directory of 2,443 firms having research laboratories. The firms visited are listed in the directory as employing 24,816 persons as scientific or technical personnel in their laboratories. This number represented 28 percent of the total personnel of this type estimated as employed in all the laboratories listed. In addition to this numerical coverage, an attempt was made to include among the 78 firms visited small as well as large firms, plants in all parts of the United States, and a variety of industries. However, the intricate industrial organization, inter-relationships, and variety of research revealed in the directory, added to the fact that some firms did not report personnel statistics and none reported women separately, made the selection of a true sample complicated beyond its value for this purpose. The firms visited were chosen rather as a clue to industrial firms most likely to be engaged in the type of work in which women trained in science are used. In all firms, information was requested for the entire organization rather than for the research laboratory only.

Eighteen commercial testing laboratories which offer testing services to industry and individuals and which employed women were also visited. Seven others contacted did not employ women. These 25 laboratories represented 10 percent of the 244 commercial testing laboratories listed in the National Bureau of Standard's 1942 Directory of Commercial Testing and College Research Laboratories. Since personnel is not reported in the directory, there is no clue to the coverage of workers.

Three large additional industrial firms which employed women in laboratory work but were not listed as having research laboratories were visited, as was one biological supply house.

Research institutions: Eight research institutions or centers, some of them identified with a particular college or university, also supplied information on women members of the scientific staff.

Colleges and universities: Statistical information on the number of women graduated with degrees in science, mathematics, and engineering over a period of years from 1939–40 to 1946 was obtained from 30 colleges and universities and from 9 engineering schools. Again an attempt was made to obtain wide geographical coverage and to cover different types of institutions, such as women's colleges, State universities, and small liberal arts colleges. The information available from these sources, too, varied. Placement bureaus and heads of science departments as well as deans of women at these institutions and at 6 other colleges contributed reports on the demand for women trained in the sciences. The Western Personnel Institute made possible the inclusion of data which it collected for the Bureau from its affiliated colleges and universities in the far West.

Since no recent data were available on the number of women teaching science in the colleges, a count was made in 1947 of the women identifiable by name who were listed on science faculties in the catalogs of 330 institutions of higher learning which were then available in the United States Office of Education Library. These institutions were selected because they are believed by the United States Office of Education to be representative in their enrollments of the 1,749 institutions of higher education in the United States and, therefore, are likely to have faculties equally representative.

Other sources: In addition, 97 individuals not included in the afore-mentioned sources, most of them women scientists, contributed information, suggestions, or helpful criticisms of the preliminary manuscripts circulated before revision for publication.

While every effort has been made to obtain wide coverage, there remain some dark corners still unexplored because of the range and variety of these fields and the difficulty of obtaining information from widely scattered sources. Perhaps this beginning will result in further additions to our so-little knowledge.

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Courtesy University of Cincinnati

Figure 1.—Architectural students on cooperative jobs prepare a use map in a Municipal Planning Commission.

Architect and Landscape Architect as Defined in the Dictionary of Occupational Titles (*54*)

"Architect (professional and kindred) 0–03.10. Plans, designs, and oversees construction of buildings, such as private residences, office buildings, theaters, municipal buildings, factories, and similar structures: Consults with clients to determine needs and preferences as to style and plan, furnishes professional advice on such matters as cost, design, materials, equipment, and estimated building time. Plans lay-out of structure, coordinating its structural and ornamental elements into a unified design. Prepares sketches of proposed building to enable client to visualize appearance of completed structure. Writes specifications, and prepares scale drawings and full sized detail drawings for use of building contractors and craftsmen. Oversees operations at building site to insure compliance with plans and specifications. May plan and oversee remodeling or repair of buildings. Ordinarily, required to meet State licensing laws with respect to professional training and experience. Workers concerned chiefly with ornamental development of building sites or other areas of land should be classified as landscape architects."

"Architect, landscape (professional and kindred) 0–03.20 landscape designer. Plans and prepares drawings for ornamental development of an area of land: Studies condition of site, such as drainage, topsoil, trees, rock formations and buildings. Prepares sketches and scale drawings for development, locating roads, footpaths, buildings, bridges, fences, and sewers. Recommends types and location of trees, shrubs, and flowers, harmonizing improvements with existing land features and architectural structures. Prepares specifications and cost estimates. Supervises execution of plan details, including purchase of nursery stock, statuary, and other items. Sometimes specializes in a particular phase of landscape architecture and is designated according to the field of specialization, such as golf-course architect, park architect, city planning architect, or highway architect."

THE OUTLOOK FOR WOMEN IN ARCHITECTURE AND LANDSCAPE ARCHITECTURE

Unlike engineers, half of all architects are engaged in independent practice, and most of them are registered in one or more of the States (*46*). All but six States have licensing laws for architects, since structures designed by them can endanger the public if they are not properly planned (*3*). Unless an individual does architectural work for someone else who assumes the responsibility for public safety, he must be registered. These licensing laws also usually prevent those without proper training from calling themselves architects. In New York State, for example, only those who are registered may call themselves "architects." On the other hand, this State, like most of the others, does not have a licensing law for landscape architecture since here safety is not involved.

Architecture is considered by some educators as a better field for women than engineering, which has similar basic qualifications. They say that in architecture, women who marry may practice independently and take on as much or as little work as they wish. In fact, a number of women architects are engaged in practice with their architect husbands (*67*). It is also claimed that women can make a special contribution in the field of home and apartment-house design. However, most women who are registered architects challenge this view. They assert that part-time work or occasional work is possible in architectural drafting, but the successful practice of architecture requires full-time devotion for success. They also point out that they must be qualified to design all types of structures and that "there are no specialists in architecture." Specialization is not of their choosing, although the public may have preconceived notions which may affect or limit the range of their work.

Landscape architecture, too, has been mentioned often as an appropriate field for women. Landscape architects usually take a distinct course in landscape architecture which may be offered in a school of architecture or fine arts or a school of agriculture. Only a few women have degrees in both architecture and landscape architecture.

Prewar Distribution

In 1940, there were more than 20,000 architects (including landscape architects) employed in the United States, of whom 477 or 2.3 percent were women (*43*). The largest number of women registered

architects, before the war, were in New York where there were 20 in 1939, and in California where there were 15. Michigan had 6, and Illinois and Pennsylvania each had 5 (*23*).

Most of the prominent women architects were engaged in independent practice, or were partners in architectural firms (*23*). There were also some in teaching. A few women trained in landscape architecture were serving as consultants to local or State playground authorities. Some were in private practice and some were teaching. A number of women had written books and articles and had edited publications in architecture and in landscape design.

At the Massachusetts Institute of Technology, which has admitted women since its opening, more women had been graduated before the war in architecture than in any other technical field. Sixty-four women had received the bachelor's degree, and 7 had received the master's degree in architecture from that institution. Most of them have married and raised families. Three retired after a lifetime of practice in architecture. In 1940, 16 were engaged in active practice; 1 of them specialized in colonial reproductions, another in restaurant design, and 3 were practicing jointly with their husbands. Three were teaching art or architecture, 1 in the landscape field. Three were architectural draftsmen, 1 with her husband's firm. Two were project planners, 1 with a housing authority, the other with a real-estate firm. Two became dress designers, and 2 were writers; 1 became an interior decorator, another, an archaeologist. One was a statistician and another a clerk in an insurance company's actuarial department. Four women had also taken the relatively new major in city planning, and all 4 were married and working, too.

The type of work done by 19 women who were graduated with degrees in architecture or in landscape architecture from Ohio State University from 1912 to the outbreak of World War II also indicates the range of prewar outlets for women architects. Of 3 who received degrees in landscape architecture, 1 was engaged in research with an Ohio firm of landscape architects, 1 was in private practice as a landscape architect and also served part time on a city-planning board, and the other became a technical librarian. On 5 of the others, all of whom had bachelor of science degrees in architecture, there was no report of occupation, although all were known to be married and were probably engaged full time in homemaking. One was a practicing architect, and 4 others had practiced before their marriage and 1 before her death. Two were employed by architectural firms, 1 of them as a draftsman. One worked for a public utility. Two were in Federal Government service. One of those became a buyer for the United States Treasury Department after working as a set designer

and architect in Hollywood; the other worked as a draftsman with the United States Engineer Corps in the War Department.

Before the war, however, only a few women applied for the occasionally announced Federal civil service examinations for architects. In the fiscal year of 1940, for example, only 2 women passed examinations (as assistant architects) that year, and none was among the 16 persons appointed to probational or permanent positions as architects that year (*42*).

Annual Addition to the Supply

The profession of architecture grows by the addition of new graduates from architectural schools and of those who qualify by practical experience obtained in an architect's office. The number of these newcomers usually exceeds the annual loss from the profession due to death, retirement, or other causes. Over the years, an increasingly large proportion of the additions has come directly from member schools of the Association of Collegiate Schools of Architecture. However, in 1940, the number of graduates was declining in spite of an increase in the number of schools. Only 378 men and women were graduated in 1939 as compared with 472 in 1936 (*39*). This may have been due to the fact that over 7 percent of the architects were unemployed in 1940, a rate slightly higher than that for all professional and semiprofessional workers.

On the other hand, the interest of women students in architecture appeared to be increasing before the war. About 21 percent of all resident undergraduate students in architecture in all institutions of higher education in 1939–40, according to the United States Office of Education, were women (*62*). They numbered 914, almost twice as many as all the women architects employed in 1940. Eighteen women were also enrolled as graduate students in architecture, forming 15 percent of the total graduate group in architecture. Relatively few architects, however, as compared with those in other scientific fields, have higher degrees, since work experience rather than continued academic training has been emphasized in this field.

No separate information on those training in the smaller field of landscape architecture was available.

Wartime Changes

During the war, both enrollments and degrees granted in architecture declined for women as well as for men. Only 223 first degrees in architecture were awarded in 1943–44, according to the United States Office of Education, and only 764 women were enrolled as

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undergraduates in 1943–44 as compared with the more than 900 in 1940. The drastic reduction from 3,550 to 652 in the number of men students which took place during this period was to be expected. But the drop in the number of women students in architecture, in spite of the general increase in the number of women college students, was probably due to the fact that architecture was not publicized as a field of key importance in the war effort, as were engineering and chemistry, for example. However, many architects and landscape architects did serve in architectural and in engineering jobs in both military and civilian service.

One young woman who was graduated with a degree in landscape architecture by Cornell University started as a draftsman at a radio manufacturing plant shortly after Pearl Harbor. In 1946, holding the title of engineer, she was in charge of properties, being responsible for space mapping and lay-out for the entire company, the moving of office fixtures, etc., and had several men working under her supervision.

Because private building was virtually stalled during the war, many architects, both men and women, gave up their private practice and did drafting or other production work or entered military or Federal service, resuming their practice after the war. One, for example, joined the Women's Marine Corps Reserve. A few women architects were employed in aircraft companies covered in the course of this study. One, for example, after orientation training, was engaged on tool design; another with long experience taught drafting to women newly recruited during the war. A number were employed on production illustration, preparing pictorial illustrations to supplement the usual mechanical drawings. A container manufacturing company used women architects on design and estimating work. One graduate in city planning who married an Englishman was put in charge of wartime evacuation plans for English children. During the war, there was very little demand in the Federal service for architects except in the National Housing Agency and its affiliates, in the Office of Price Administration, and in the War Production Board, where a few men were hired for allocation work. However, 5 women architects were employed by the Engineer Corps on temporary war work; and a half dozen, on war housing in Washington, D. C., alone. Only a few women were teaching architecture during the war, according to a survey made at the end of 1942 by the National Roster of Scientific and Specialized Personnel which reported 10 women among a total of 336 college teachers of architecture (*57*).

Earnings, Hours, and Advancement

As in all fields where independent practice is prevalent, earnings vary from a net loss to substantial incomes, according to the employ-

ment or practice of the individual. Most architects in private practice customarily charge a fee based on a percentage of cost varying with the type of construction. A New York architect, for example, reports the following: residential work, 10 percent or more; large-scale developments, relatively less; interior design, 15 percent or more. Earnings for those in independent practice and their employees, therefore, tend to rise quickly in times of building activity and fall sharply when the volume of construction is low. In 1936-37, the annual income of men architects who had been graduated from the College of Architecture of the University of Southern California during the preceding 8 years, most of which were years of depression, ranged from $200 to $6,500. The lowest median, $1,250, was found in the depression class of 1931; the highest, $2,800, in the class of 1928 (*66*). Late in 1945, entrance salaries for architectural graduates employed by architectural firms, however, usually approached the top limit of the prewar salaries of $25 to $40 weekly ($1,300 to $2,080 a year) according to the Bureau of Labor Statistics (*46*) and in some cases exceeded it. The rate of pay for architects at the beginning Federal civil service professional level was $2,644 in 1947.

A landscape architect may charge a percentage-cost or a flat fee, depending upon the nature of the project.

Hours in any architect's office are apt to be long, with periods of high tension. Clients often want last-minute alterations, and time schedules with both client and contractors must be maintained.

Advancement for women architects, as for men, lies chiefly in building up an active independent practice by acquiring a reputation for outstanding work in a local community. The quality of their work and their ability to consider the functions to be performed in the structure as well as pleasing facades are important especially in dwelling design. A few women have gained distinction in architecture through writing and other nonpracticing channels.

Organizations

The American Institute of Architects, founded in 1857, is the principal organization of professional architects (*3*). In 1947, it was estimated by the Department of Education and Research of the Institute that there were about 15,000 registered architects in the United States, of whom about 6,500 belonged to the Institute. Fifty-six women were listed as members in the 1945–46 Annuary of the Institute. For full or "corporate" membership, the endorsement of 2 corporate members and assurance by the local chapter of the Institute that the candidate possesses the qualifications required and an honorable standing in the profession and in his community are required. If he is a registered

architect who has passed an examination satisfactory to the Institute, or has the approval of the chapter executive committee, submission of exhibits is waived. Associate membership, usually for a limited 3-year period, is available to architects, skilled architectural draftsmen, and other technical employees in an architect's office, and to professors in recognized schools of architecture. A junior associateship is available to draftsmen or other technical employees in architects' offices who cannot qualify because of inexperience or financial limitations for the associateship. There is also provision for student membership.

The American Society of Landscape Architects in 1947 had 381 full members of whom 54, or 14 percent, were women. Members must be landscape architects at least 21 years of age in good professional standing and of sound technical training including sufficient knowledge of and practical experience in landscape architectural design and construction and in the preparation and execution of plans involving the materials used in landscape architecture. Membership is by election of the board of trustees following recommendation by 3 members of the society and review by the total membership and a special examining board. "Junior Associates," who in 1947 numbered 107 of whom 17 were women, are affiliates who have a degree in landscape architecture approved by the society or other acceptable evidence of qualifications and are recommended by 2 members, 1 of whom must have supervised the candidate's work or study.

The Outlook

The increase in building needed to make up the lag in housing, commercial, and institutional construction which characterized the war period and the depression which preceded it will result in a continuing demand for architects, according to the American Institute of Architects and the United States Bureau of Labor Statistics (*46*) (*3*). Since the number of persons training for this field during the war decreased even more markedly than enrollments in other fields, the outlook for those entering during the next few years is declared to be good. Unfortunately, few women took training in this field during the war.

Women architects take the same basic training as men architects and are fully qualified to design office buildings, stores of all types, and large as well as small developments. An idea of the variety of possibilities may be gained from a selected list of books on architecture prepared by the Committee on Education of the American Institute of Architects (*4*). However, in the design and remodeling of homes, institutional residences, hotels, and of dress shops and tearooms, schools, and community buildings, women can fill a peculiar need.

Courtesy University of Cincinnati

Figure 2.—Students in architecture at work in an architectural drawing class.

Residential construction is assumed by the public to be an appropriate field for women, and probably more women architects have devoted themselves to this branch of work than to any other. In public housing, women have shown special interest and facility, according to the executive director of one large planning commission (*27*). Being more familiar with home functions, women usually excel in the lay-out of kitchens, storage, and other rooms. City and community planning, too, is a growing field; one woman trained in this work was employed at Tennessee Valley Authority in 1947. The course in this field at Massachusetts Institute of Technology is one of the few at that school to which men and women trained in social science without the usual mathematics and science required for technical degrees are admitted at the graduate level. In 1946, only a few women architects were employed in the Federal Government: one by the National Advisory Committee on Aeronautics, one by the Tennessee Valley Authority, one by the United States Department of Agriculture, and two by the Federal Public Housing Authority.

There will continue to be occasional openings for women in teaching. In 1947, 3 women were listed as members of architecture faculties and 3 others as members of landscape architecture faculties in the 113 universities or professional schools selected by the United States Office of Education as representative in their enrollments of the 418 institutions of this type in the United States. Two had reached professorial rank. If these institutions are representative of all similar institutions in faculty as well as in enrollment, there were 10 women

on architectural faculties and 10 women on landscape design faculties in 1946–47.

A list of the 42 schools of architecture that were members of the Association of Collegiate Schools of Architecture in 1947 as well as a list of other schools and departments offering instruction in architecture are available from the American Institute of Architects. Thirty-four schools were on the 1947–48 list of schools accredited by the National Architectural Accrediting Board. In 1947, women were enrolled in all but a few of the approved schools. Degrees in landscape architecture are offered at some of these schools. Some collegiate schools of design and schools of agriculture also offer degree courses in landscape design or architecture.

For landscape architecture, a knowledge of horticulture as well as of certain phases of civil engineering is needed. In architecture, mathematics and physics are important background subjects as well as history, art, and drafting. The study of social housing has become increasingly useful. The engineer's ability to visualize a structure and his knowledge of structural materials, the artist's feeling for balance and harmony of color and design, and the entrepreneur's business sense are necessary for success in architecture. One woman architect says "Only the gifted, thoroughly trained, and vigorous woman will want to take on a career so demanding. But to her, the profession will be satisfying."

Engineer as Defined in the Dictionary of Occupational Titles (*54*)

"Engineer (professional and kindred). A general term used to designate persons who meet the educational, experience, or legal qualifications established by engineering schools or licensing authorities for the fields of professional engineering. Classifications are made according to field of engineering specialization, as chemical engineer; civil engineer; electrical engineer; industrial engineer; mechanical engineer."

"Chemical engineer (professional and kindred) 0–15.01. A classification title for engineers who apply chemistry and the various branches of the engineering sciences to the design, construction, operation, and improvement of equipment for carrying out chemical processes on a commercial scale. Conducts research to develop new and improved chemical-manufacturing processes. Designs, plans layout, and supervises workers operating equipment, such as condensers, absorption and evaporation towers, columns, and stills for producing synthetic rubber, soap, aluminum, high-octane gasolines, and other products. May specialize in engineering fields, such as consulting, technical sales and service, testing, purchasing, and teaching at the university level."

"Civil engineer (professional and kindred) 0–16.01. A classification title for engineers who plan, design, and supervise construction and maintenance of a large variety of structures and facilities, such as roads, railroads, airports, bridges, harbors, channels, dams, irrigation projects, pipe lines, power plants, water and sewage systems, and waste disposal units."

"Electrical engineer (professional and kindred) 0–17.01. A classification title for engineers who plan and supervise construction and operation of electric-power generating plants, transmission lines, and distribution systems; plan and supervise construction and installation of illumination, wire communication, and electric transportation systems; design and develop radio, television, electronic, and allied equipment and supervise technical operation of broadcasting stations; design and supervise manufacture of various types of electrical machinery and apparatus, such as motors and generators, convertors and regulators, switchgear, and welding equipment. May also specialize in research, consulting, inspection, testing, teaching at the university level, specification and other technical writing, and sales and service of complex electrical equipment."

"Industrial engineer (professional and kindred) 0–18.01 management engineer. A classification title for engineers who supervise production departments of manufacturing plants, lay out machinery and apparatus, and determine flow of work for most efficient production, conduct and interpret time-and-motion studies, devise means and set up programs to curb industrial accidents and fires, set up personnel policies and procedures and evaluate jobs, and devise and install accounting and inventory-control systems. May specialize in such fields as setting up production cost records and control systems, developing jigs and fixtures, training production personnel, and wage administration."

"Mechanical engineer (professional and kindred) 0–19.01. A classification title for engineers who specialize in design of tools, engines, machines, or industrial equipment; installation and maintenance of industrial equipment; supervision of mechanical industrial processes; or planning and operation of central distribution systems for heat, gas, water, or steam. May also specialize in research, consulting, inspecting, testing, teaching at the university level, technical writing and editing, or technical sales and service."

"Metallurgical engineer. A general term applied to a worker who performs professional duties in the fields of processing or physical metallurgy. Workers are classified according to specialization, as metallurgist, extractive, or metallurgist, physical."

"Mining engineer; mine analyst; mine expert (anthracite coal mining; bituminous coal mining; metal mining) 0–20.01. Makes preliminary surveys of coal deposits or undeveloped mines and plans their development; examines deposits or mines to determine whether they can be worked at a profit, making geological and topographical surveys to determine location, size, and slope of deposits and character of surrounding strata; lays out plans for development of property, such as shaft, drift, or slope (mine entrance) location, breaker, or tipple location, water supply, and power requirements; evolves method of mining best suited to character, type, and size of deposits, including type of machinery and equipment to be used; makes safety and efficiency surveys of mine work to develop safer working conditions and to coordinate work of men and methods so as to secure maximum production; conducts mine surveys [surveyor, mine]; supervises all mining operations."

Courtesy Purdue News Service

Figure 3.—A civil engineer from Greece engaged in graduate work in her profession at an American university under a grant by the American Association of University Women.

THE OUTLOOK FOR WOMEN IN ENGINEERING

Of all the principal professional occupations, that of engineering is lowest in the proportion of its members who are women. In 1940, less than 0.3 percent of the approximately quarter of a million professional engineers in the United States were women, according to the United States Census. Only 730 women engineers were then employed (*43*). Although women pioneered in engineering as early as the 1890's, and although many women were trained for work in engineering departments of war production firms during World War II, the number of women who qualified as engineers in 1947 was still less than 1 percent of the national total in this profession.

Engineering shares with medicine and architecture the distinction of being one of the few scientific fields in which provision for legal registration is general in the United States. All States, as well as Hawaii, Puerto Rico, and Alaska, have engineering registration laws, most of which require a license to practice "professional engineering," where public safety and health are involved. (For usual requirements for registration see p. 5–75.) Unlike physicians, however, many engineers are not licensed because their employment does not require registration. Most engineers who engage in consulting work or who are responsible for construction, sanitation, or similar projects find registration desirable. In 1946, about 93,000 engineers had applied for and secured licenses to practice professional engineering in the United States, approximately one-third of the number of engineers in 1940. In the 1943 directory of registered professional engineers, only 15 women were distinguishable by their names, although there may be others among the lists from States reporting given names by initial only (*65*).

To understand the outlook for women in engineering in the future, it is necessary to review their place in engineering in the years before the war as well as during the abnormal war period. This chronological view is followed, in this report, by additional information on women in the principal branches of engineering. In the order of the number of women employed in them at the time of the 1940 census, these branches are as follows: civil, mechanical, electrical, industrial, mining and metallurgical, and chemical (*43*). The many finer specializations in engineering have been described in detail by the National Roster of Scientific and Specialized Personnel.

Transfers from one branch of engineering to another sometimes take place especially at the beginning level, before specialized experi-

ence has been obtained, or at the top among those who have gained experience in two or more branches and have broadened the range of their knowledge. One woman, for example, registered as a construction engineer, has done consulting work in the fields of chemical, mechanical, and sanitary engineering. However, specialization usually starts in the second year of the engineering college course, earlier than in any other scientific field, and engineers tend to remain in the branch for which they train (*45*).

Prewar Distribution

The extent to which women and men were employed in the principal branches of engineering in 1940 is shown in table 1. Women, like men, were more numerous in civil, mechanical, and electrical engineering than they were in the chemical, industrial, and mining and metallurgical branches. But, civil engineering outranked mechanical engineering in its employment of women, while the reverse was true for the men. Although each of these two fields employed roughly one-third of all male engineers, each included only one-fourth of all women engineers. The proportion women comprised of all engineers in the other branches was consequently higher, especially in industrial and in mining and metallurgical engineering.

Table 1. ***Distribution by Branch of Engineering of Men and Women Employed as Professional Engineers, 1940***

Branch of engineering	Total	Number		Percent		Percent women are of total
		Men	Women	Men	Women	
All employed professional engineers	245, 288	244, 558	730	100. 0	100. 0	0. 3
Civil engineers	80, 362	80, 171	191	32. 8	26. 2	. 2
Mechanical engineers	82, 443	82, 255	188	33. 6	25. 8	. 2
Electrical engineers	53, 267	53, 103	164	21. 7	22. 5	. 3
Industrial engineers	9, 283	9, 209	74	3. 8	10. 1	. 8
Mining and metallurgical engineers	8, 813	8, 739	74	3. 6	10. 1	. 8
Chemical engineers	11, 120	11, 081	39	4. 5	5. 3	. 4

Source: U. S. Census (43).

The places in which engineers worked varied widely in the different branches. In 1934, for example, the Bureau of Labor Statistics reported that chemical, mechanical, and industrial engineers were employed primarily in manufacturing industries (*45*). Public utilities among electrical engineers and extractive industries among mining and metallurgical engineers combined with manufacturing industries in each case to account for the principal employment in those branches. In civil engineering, Government employment predominated; in the

private employment of civil engineers, the construction industry outranked all other sources.

In 1938, there were no women among the almost 20,000 engineers employed in the Federal classified civil service, where the War, Navy, Interior, and Agriculture Departments and the Federal Works Agency were the largest employers of engineers (*59*) (*37*). Furthermore, no women were among the approximately 1,500 persons appointed to probationary or permanent positions in engineering in the year ending June 30, 1940, and only 8 women passed examinations for such positions that year (*42*). Some women were employed before the war, however, by State and local governments.

Most engineers were engaged in engineering operation work in connection with current production and other processes, or in design and research, or, in the case of civil engineers, in engineering construction activity. Comparatively few, only 5 percent in 1934, were engaged in teaching (*45*). This percentage is lower than that for most of the other scientific groups. A few women were probably among those teaching before the war, although the first figures available are for 1942 when 50 women were among the 5,394 teachers of engineering reported by the National Roster of Scientific and Specialized Personnel (*57*).

Annual Addition to the Supply

Although about one-third of those entering the engineering profession each year in the twenties came from the ranks of experienced workers without benefit of college graduation, the proportion of college graduates among the beginners in the profession rose steadily during the thirties to three-fourths of the total (*45*). The number of students enrolled in undergraduate engineering courses in 1940–41 (either in 4-year programs leading to the bachelor's degree in engineering or in 5-year programs leading to an engineer's degree) was almost double the number enrolled 20 years before (*31*). In 1940–41, 17,684 students were in the final year of their undergraduate engineering program (*16*). Taken all together, they equalled about 7 percent of the number of engineers employed in 1940. The corresponding percentages for each of the principal branches of engineering in which these students had specialized differed widely. (See table 2.)

Table 2. *Distribution by Major Field of Students Enrolled in Final Year of Undergraduate Engineering Program 1940–41 in 155 Schools Compared With That of All Employed Engineers in 1940*

Major field	Number		Percent		Percent students in final year engineering program in 1940–41 were of employed engineers in 1940
	Employed engineers 1940	Students in final year engineering program 1940–41	Employed engineers 1940	Students in final year engineering program 1940–41	
Total	245,288	17,684	100.0	100.0	7.2
Mechanical engineering (including aeronautical and agricultural engineering)	82,443	5,608	33.6	31.7	6.8
Civil engineering (including architectural engineering)	80,362	2,599	32.8	14.7	3.2
Electrical engineering	53,267	3,074	21.7	17.4	5.8
Chemical engineering	11,120	3,006	4.5	17.0	27.0
Industrial engineering	9,283	652	3.8	3.7	7.0
Mining and metallurgical engineering (including ceramic engineering)	8,813	1,229	3.6	6.9	13.9
Unclassified or all other engineering		1,516		8.6	

Sources: Statistics on students, Journal of Engineering Education (*16*). Statistics on employed engineers, U. S. Census (*43*).

Chemical engineers, in a field where the new entrants from schools equalled more than one-fourth the employed group, were multiplying most rapidly, assuming that withdrawals for death, retirement, and other causes were similar for all branches. The number of mining and metallurgical engineers was also increasing at a rapid rate. Civil engineers, on the other hand, were lagging behind in the rate at which new graduates were being added to their number. Perhaps students were influenced in their choice of specialization by 1929–34 trends which showed a 35 percent increase in chemical engineering employment as compared with a 1 percent increase in civil engineering. (A decline of 31 percent in private civil engineering employment was offset by increased Government employment.) However, employment in all branches was then failing to keep pace with the growing number of engineers. Although even in 1929, 6 percent of all professional engineers were in nonengineering employment, by 1934 during the depression period the proportion had increased to 14 percent, and unemployment had grown from 0.7 percent to 8.5 percent (*45*). In 1940, according to the United States Census, unemployed engineers found in a sample count numbered 16,000 or 5.9 percent of the total number of experienced engineers reported in the labor force. This was only slightly less than the 6.2 percent rate of unemployment for all professional and semiprofessional workers in 1940 (*44*).

Wartime Changes

The war, affecting both the demand for and the supply of engineers, altered the 1940 picture rapidly and drastically. The need for engineers skyrocketed especially in manufacturing industry and in the Federal service, both military and civilian. Because of the vital importance of engineering services in the war effort, a special analysis of the personnel situation in engineering was made by the National Roster of Scientific and Specialized Personnel in 1943 (*58*). The resulting estimates of the number of engineers in both military and civilian service are shown in table 3. According to these estimates, admittedly subject to such errors as emergency haste and the use of miscellaneous sources are likely to produce, the number of employed engineers in 1943 had increased 14 percent over the 1940 number, but their distribution among the branches of engineering was roughly the same as in 1940. Although, for most branches, estimates of the additional numbers needed for the next 6 months approximated one-tenth of the employed group, in aeronautical engineering the estimate was two-thirds and in industrial engineering one-third. In civil engineering a decrease in need of some 8 percent was expected.

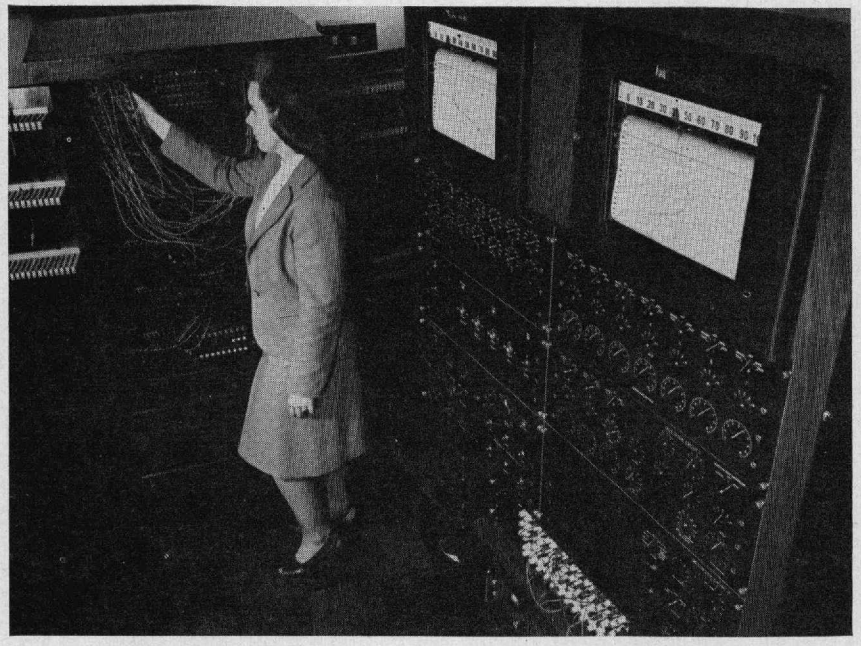
Table 3. *Distribution of Employed Engineers by Branch of Engineering, 1943*

Branch of engineering	Number	Percent
Total	280,000	100
Civil engineers	87,600	31
Mechanical engineers [1]	85,000	31
Electrical engineers	59,400	21
Chemical engineers	16,700	6
Mining and metallurgical engineers	11,700	4
Industrial engineers	10,600	4
Aeronautical engineers [1]	9,000	3

[1] On all other tables in this bulletin, aeronautical engineers are included under mechanical engineers.

Source: National Roster of Scientific and Specialized Personnel (*58*).

These estimates reflected the marked increase in demand for engineers in manufacturing, especially in the aircraft industry, only one year after the war began. At that time more than one-third of all engineers were already in manufacturing employment, and almost a third were in Government employment. (See table 4.) The shortage of engineers in manufacturing continued. More than 90 percent of the 105 industrial companies, large and small, canvassed in 1945 by the dean of engineering at Purdue University as a sample of the 400 with whom it placed its engineering graduates, reported a need for additional engineers; the average shortage was 47 per company (*33*). The Federal Government announced one civil service examination after another for engineers. Even the Navy Department,



Courtesy Carter Oil Company

Figure 4.—A junior engineer setting an assumed future rate of production for which a pressure prediction is needed.

largely staffed with men, ultimately sent out a plea for women in electrical, mechanical, or chemical engineering (*12*).

This demand affected all phases of engineering activity. Unfilled teaching vacancies in engineering ranked next to those in medicine, as engineers left teaching for war production or military service and as wartime engineering instruction was begun (*60*). A few women became instructors in engineering schools, in some of which women had not previously been found even among the students.

Table 4. *Estimated Distribution of Active Engineers by Place of Employment, January 1, 1943*

Place of employment	Number	Percent
Total	280,000	100.0
Manufacturing	105,000	37.5
Government	88,000	31.4
Federal, including military and civilian service	67,000	23.9
State and local governments	21,000	7.5
Transportation, communications, and public utilities	40,000	14.3
Construction	20,000	7.1
Mining	12,000	4.3
Private consultants and their staffs	10,000	3.6
Teaching	5,000	1.8

Source: National Roster of Scientific and Specialized Personnel (*58*).

Meanwhile the war was also affecting the source of supply of young engineers. At first, enrollments were maintained in engineering schools by groups of servicemen trained under the Navy V–12 and the Army Specialized Training Programs. An enrollment peak was reached in 1942–43 when 115,000 men were enrolled. By 1944, however, the full effect of the draft was felt, and enrollments fell below 50,000. Although women were welcomed in many engineering schools and such institutions as Columbia University, the Drexel Institute of Technology, and Rensselaer Polytechnical Institute, and the Case School of Applied Science opened their undergraduate curricula in engineering to women for the first time, the numbers of women students increased by hundreds only and so remained a small fraction of the total. The 1,800 women undergraduate students in engineering in 1944–45 comprised less than 3 percent of the total (*19*).

That year, the 56 women graduating with first degrees in engineering were only slightly more than 1 percent of the total of 4,724. This total was only slightly more than one-fourth of the prewar 1940–41 number.

Most engineering schools also accelerated their curricula so it was possible to complete the degree course faster, in some cases in less than 3 years. A few set up special certificate courses of 2 or 3 years to train women for war jobs as assistants to engineers. Cooper Union in New York provided for three certificate courses, which when combined were equivalent to a degree course (*29*). A 2-year certificate program at the University of Cincinnati included algebra, trigonometry, analytic geometry, calculus, general inorganic chemistry, industrial chemistry or qualitative analysis, general and experimental physics, statistics, dynamics, engineering drawing, and composition and literature. Half-time cooperative work experience, alternated with school and discussed in special classes in coordination, was a part of this program. Other training programs for engineering aids are described on pages 5–53 to 5–58.

As early as 1940, the Congress, recognizing that engineering skills were basic to an expanding military force, appropriated funds for a training program in engineering which later expanded into the Engineering, Science, and Management War Training Program. At first, few women applied for these courses offered in more than 200 colleges. But, as the war progressed, women were actively recruited. Many were paid by war production firms or Federal agencies while they took these courses in engineering, drafting, fundamentals of engineering, and such specialized subjects as aeronautical structure, to prepare themselves for the work for which they had been hired (*29*) (*10*). Subsequent training took place on the job. Requirements

for entrance varied with each of the more than 31,000 courses in engineering subjects offered during the course of the program (*61*). For certain ones, only engineers with long experience were eligible. Others required a college degree with specified credits in mathematics or science; some were available to high school graduates. In 1943, more than 56,000 women were enrolled in engineering subjects under this program, and 62 percent completed the courses in which they had enrolled (*10*). For the most part, these women were trained to become aids, technicians, or engineering draftsmen rather than engineers. (See p. 5–58.) Only a few had sufficient background in science and mathematics or obtained enough subsequent training and experience to qualify as graduate engineers.

A 1946 survey of the engineering profession conducted by the Engineers Joint Council showed that, at the end of the war, electrical, civil, and mechanical-industrial engineers continued to be the largest groups among professional engineers (*18*) (see table 5). It is interesting to note that these percentages, although not exactly comparable to those reported in the 1940 census (see table 1), show a higher proportion of the total in chemical and mining and metallurgical engineering, although in both reports they are the smallest groups. Correspondingly lower proportions are evident in civil and mechanical engineering. The Engineers Joint Council Report showed little change in distribution in 1939, 1943, and 1946 of some 30,000 engineers who in 1946 reported their general field of employment in those years.

For 86 of the 94 women included in the 1946 survey, the major field of employment reported showed a distribution not unlike that of the 730 women covered in the United States Census (see tables 5 and 1). The proportion in chemical engineering was larger in the Council group; that in mining and metallurgical engineering was about the same as in the Census. The apparent differences in the larger civil, mechanical, and electrical groups are probably attributable to the "other engineering" and "nonengineering" classifications included in the later report.

Among the "other engineering," for example, might be some of the 17 women found listed on college engineering faculties in 1947 in a Women's Bureau review of the catalogs of 330 institutions of higher learning included in a United States Office of Education enrollment sample. Only 2 of these women held professorial rank; most of them were laboratory, research, or graduate assistants. However, their presence indicated that there were probably as many as 33 women on engineering faculties in the United States 2 years after the close of the war.

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Table 5. *Percent Distribution of Men and Women Engineers by Branch of Engineering, 1946*

Branch of engineering	Percent	
	Men	Women
Total	100.0	100.0
Mechanical-industrial engineering	23.7	26.7
Civil engineering	23.6	20.9
Electrical engineering	25.2	18.6
Mining-metallurgical engineering	7.6	10.5
Chemical engineering	9.8	9.3
Other engineering	6.5	7.0
Nonengineering	3.6	7.0

Source: Based on survey of the Engineers Joint Council, 1946; reports of 37,671 men and 86 women members of professional engineering societies included (*18*).

Earnings, Hours, and Advancement

The increasing demand for the services of engineers resulted in increased salaries as well as in earnings which were augmented by overtime work.

In 1946, according to a Nation-wide survey of the Engineers Joint Council, the median base monthly salary rate for professional engineers ranged from $231 a month ($2,772 a year) for men with less than 1 year's experience to $554 a month ($6,648 a year) for those who had been in the profession 35 to 39 years (*18*). The spread in earnings in each experience group was substantial, especially among the advanced group.

In 1946, the American Society for Engineering Education reported current beginning annual salaries for inexperienced men engineers at $2,520 ($210 a month) for those with the bachelor's degree, $2,880 ($240 a month) for those with the master's degree, and $3,600 ($300 a month) for those with a doctorate. The 1946 salary for those with the bachelor's degree was 45 percent above the 1939 salaries offered (*31*). The beginning basic salary in Federal Government service during the same period rose from $2,000 to $2,644 ($167 to $220 a month), a 32 percent increase. (For requirements for such positions, see p. 5–76.)

The median basic salary rates were lowest in civil engineering according to the 1946 Engineers Joint Council survey. Minimum annual salaries recommended in 1946 by the American Society of Civil Engineers ranged from $2,700 to $3,400 ($225 to $283 a month) for those without experience to more than $12,000 ($1,000 a month) in the top grades (*6*). Such salaries would raise the average annual salary of civil engineers to one considerably higher than the $3,970 ($330 a month) average reported in 1938 for members of the American Society of Civil Engineers (*5*).

According to a Nation-wide 1943 study by the Bureau of Labor Statistics which covered the actual earnings of chemical engineers, their median annual income, including salaries, fees, and bonuses, was only $2 short of $4,000 ($333 a month) and some $700 a year higher than that of chemists. The beginning salary of chemical engineers, higher than that of chemists by some $300, was usually $2,452 ($204 a month). The Engineers Joint Council survey also showed that chemical engineers in 1946 had the highest basic salary rates among engineers; mining and metallurgical engineers ranked next.

Since there are so few women among the engineers covered in such studies as these, their salaries or earnings are seldom reported separately or in detail. However, the median salary for the 94 women included in the Engineers Joint Council survey was $298 a month ($3,576 a year), and the median of their years of professional engineering experience was 8.6 (*18*). The median salary rate for men with 7 to 8 years' experience was $360 a month ($4,320 a year). During the war, according to one prominent woman engineer, women engineers were usually started at a minimum salary of $1,800 a year ($150 a month) (*12*). With overtime, according to reports from scattered colleges, recent graduates working in war plants sometimes earned $2,400 to $3,000 a year ($200 to $250 a month). Experienced women engineers, of course, earned more, up to $5,000 ($417 a month) and occasionally more.

Hours of salaried engineers depend upon the nature of the work. Those of operating engineers, especially, are related more directly to the hours the plant works than are those of most professional workers. Development and research engineers, too, are more likely to make observations and studies in the plant than are, for example, research bacteriologists or chemists. This may mean shift work. During the war, this was especially true, and overtime was frequent. Normally, the engineer's work is regular and does not involve more than the normal 35 to 44 scheduled hours of professional staffs.

Advancement for women in engineering is conceded to be difficult. They seldom follow the usual line from junior engineer to senior engineer to project engineer, nor are they often transferred to nonengineering work in sales, purchasing, or administration. Usually limited by custom to office work, as compared with field or plant work, women engineers rarely find opportunities to obtain the rounded experience necessary for normal progression. The fact that many of the positions representing advancement often require field work or travel to remote locations further reduces their chances. However, a few women have broken through these bounds.

One, for example, in 1947 was serving in a responsible capacity in the Philippines as a radio engineer in charge of an ionospheric research station of the United States Bureau of Standards. Others have stayed with an organization for years, developing a specialty through which advancement came. Several have become well-enough established to operate independently as consultants.

Organizations

National associations of engineers are as varied in scope as engineering specializations. There are organizations of sanitary engineers, safety engineers, agricultural engineers, and automotive engineers, to name only a few. The 5 organizations representing the principal branches of engineering include most of those belonging to more specialized groups. With 3 other organizations, the American Society for Engineering Education (which had 3,922 individual and 162 institutional members in 1946), the Engineering Institute of Canada, and the National Council of State Boards of Engineering Examiners, these organizations cooperate in raising the status of the engineer through the Engineers' Council for Professional Development. The principal requirements for membership in each of the 5 are given on page 5–75. They are listed below in order of the size of their membership at the end of 1946, and for each the number of women members at that time is given:

Organization	Total membership	Number of women members
American Institute of Electrical Engineers	24,526	14
American Society of Civil Engineers	21,100	23
American Society of Mechanical Engineers	20,060	33
American Institute of Mining and Metallurgical Engineers	12,600	26
American Institute of Chemical Engineers	5,788	5

The National Society of Professional Engineers includes members from all branches of engineering who are registered under an appropriate State law. (See p. 5–75 for usual requirements.) In 1947, there were less than 20 women among its 16,500 members.

The American Chemical Society also includes in its membership a large number of chemical engineers. More than 5,000 members of that organization reported themselves in a 1943 survey of membership as having their principal educational background in the field of chemical engineering (*2*).

Women belong in small numbers to many other engineering associations organized within a specialized field or on a geographical basis. For example, the American Society of Safety Engineers in 1946 esti-

mated its female membership at 20 or less. The Western Society of Safety Engineers had 2 women members. No women are known to have held office in any national engineering organization.

During the war, some engineers joined subprofessional and technical workers in such unions as the A. F. of L.'s International Federation of Technical Engineers', Architects', and Draftsmen's Union and the C. I. O.'s Federation of Architects, Engineers, Chemists, and Technicians. Statistics on the number of engineers (men or women) in such organizations were not available in 1946, but the number is believed to be small in relation to those belonging to professional engineering organizations, some of which in 1944 were studying the problem of collective bargaining (*14*) (*15*).

The Engineering Societies Personnel Service, Inc., has been operated for many years by the principal engineering organizations as a nonprofit placement and vocational guidance service to members.

The National Bureau of Engineering Registration, operated by the National Council of State Boards of Engineering Examiners with an advisory board of representatives from engineering societies, verifies and certifies the experience and educational record of professional engineers and serves as a clearinghouse for State registration authorities.

The Outlook

The overwhelming postwar interest in engineering education, which in the fall of 1946 had more than doubled enrollments in engineering schools over their 1940 number, introduced an important, unpredictable factor into the future outlook for young engineers. No one appeared to question that the long-time trend in the demand for engineers was definitely upward. An estimate of a probable demand for 337,000 engineers in 1950, 29 percent more than the comparable 1940 number, was believed to be a "reasonable guide with respect to the future needs of engineers" and "conservative" by a committee of the Society for the Promotion of Engineering Education which reported on the outlook in demand for and supply of engineering graduates in 1946 (*31*).

Allowing for loss by death or retirement from the practice of engineering and the addition of those receiving degrees in engineering from 1941 to 1946, the committee estimated that 90,000 additional engineers would be needed during the years 1947 to 1950, or an average of 23,000 engineers per year. Thereafter, an annual addition of 18,000 was estimated as sufficient to maintain equilibrium between supply and demand. Actually, according to latest estimates, it appeared that 106,000 persons would be graduated by accredited engineering schools in the following years, 1947, 1948, and 1949, more than 35,000 a year

(*7*). Considering these additions and allowing for those without degrees in engineering who were added to the engineering profession during the war through training or experience in military or civilian service, the U. S. Bureau of Labor Statistics estimated that there would probably be more than 400,000 engineers available for work in 1950, more than the number needed under assumed conditions of full employment. The Bureau in unpublished studies has predicted excess of supply over demand in engineering after 1950, if the number graduated in engineering continues at current high levels.

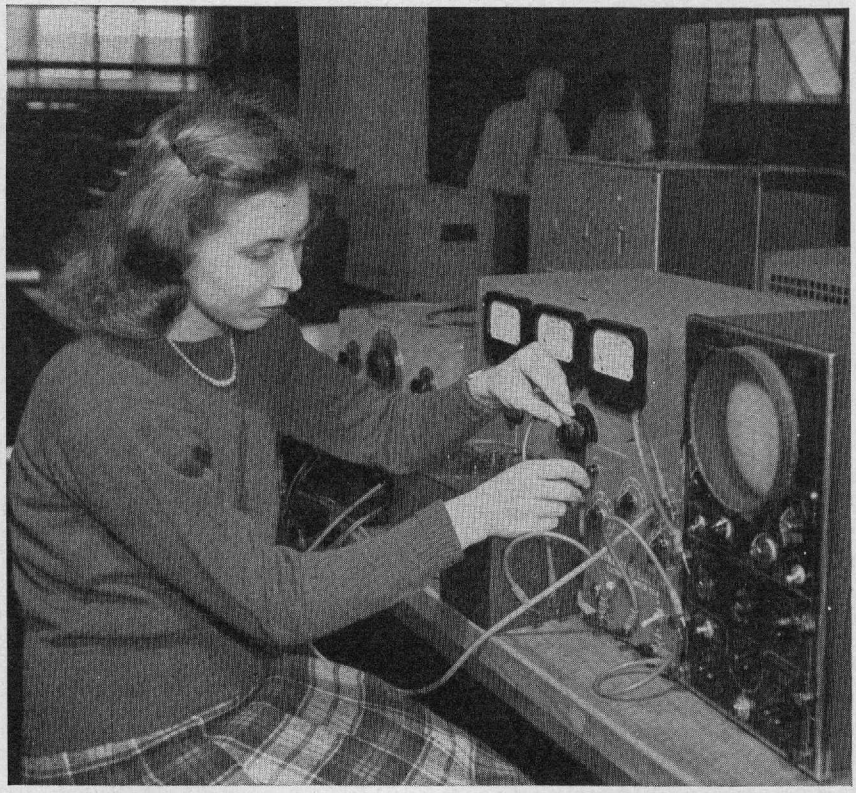
In March of 1946, the number of professional engineers had already reached an estimated 317,467, almost 63,000 or 25 percent more than the 254,522 reported as employed or seeking work in 1940 (*18*). Unless enrollments in engineering schools should decline from 1946–1947 levels, there might be serious overcrowding of the engineering profession in spite of the continued trend in the increase of demand for engineers.

Under conditions of this sort, women are likely to find it more difficult than ever to obtain admittance to engineering schools, on the one hand, or to obtain engineering employment, on the other. However, in 1947, the demand for women engineering graduates was reported to be "still good" by 4 of the 11 engineering schools reporting placement prospects to the Northwestern National Life Insurance Co. (*28*). The remaining 7 noticed a slackening in demand, but most of them added that there was still no difficulty in placing those available. One western university described the situation to the Women's Bureau as follows: "We can place the few women who graduate normally but anticipate difficulty if the number is increased too much." In June 1946, 86 women were graduated from 130 of the 155 accredited engineering schools. Their distribution by field of engineering and their relation to the total is shown in table 6. Even at this time, when the effect of the war on the number of men graduates was marked, the women numbered only a little more than 1 percent of the graduates. Only in chemical engineering did they rise above 2 percent (*20*).

In spite of the extraordinary pressure from returning servicemen and young men graduating from high school for entrance to accredited engineering colleges, in the fall of 1946, women numbered 1,269, as compared with a total of nearly 200,000 undergraduate students in 130 of the 155 accredited engineering schools reporting to the Society for Engineering Education (*20*). A list of accredited undergraduate engineering curricula and the criteria for accrediting are published by the Engineers' Council for Professional Development (*17*). Of these women students, 285 were just beginning their courses as freshmen. Their distribution according to the branch of engineering they

were studying, compared to that of all undergraduate engineering students, is shown in table 7. In all, women comprised only 0.6 percent of the undergraduate students in engineering.

All but 31 of the 130 schools reporting had 1 or more women enrolled, although an additional 24 had no women enrolled in the freshman class. However, the fact that more than half of all the schools reporting did admit women to the beginning class in 1946 and that in 8 schools the number of women freshmen was 10 or more is encouraging, in view of the extraordinary competition for admission (*20*) (*38*). The picture in the fall of 1947 will be even more significant, since many engineering colleges in the spring of 1947 were no longer accepting applications for entrance to the freshman class of 1948; others reported twice as many applicants as they could accept. Some, however, still had places available. It appears, however, that women have gained enough recognition in engineering to open the doors of training



Courtesy Purdue News Service

Figure 5.—A senior student in electrical engineering whose wartime engineering aid work made her decide to obtain an engineering degree.

and employment in this field to the relatively few well-qualified young women who seek entrance to it. Some notion of the work women have done and are doing in the major branches of engineering is presented in the following pages.

Table 6. *Distribution of Women and of All Students Receiving First Degrees in Engineering From 130 of the 155 Accredited Enginering Schools, by Major Field, 1945–46*

Major field	Number		Percent		Percent women are of total
	Total	Women	Total	Women	
Total	7,381	86	100.0	100.0	1.2
Chemical engineering	1,283	29	17.3	33.7	2.3
Mechanical engineering (including aeronautical, marine, and agricultural engineering)	2,835	24	38.4	27.9	.8
Civil engineering (including architectural and sanitary engineering)	1,200	17	16.3	19.8	1.4
Electrical engineering	1,358	12	18.4	13.9	.9
Industrial engineering	147	1	2.0	1.2	.7
Mining and metallurgical engineering (including petroleum and ceramic engineering)	270	1	3.7	1.2	.4
Other (general and unclassified)	288	2	3.9	2.3	.7

Source: American Society for Engineering Education (*20*).

Table 7. *Distribution of Women and of All Undergraduate Students in Engineering in 130 of the 155 Accredited Engineering Schools, by Major Field of Study, November 5, 1946*

Major field	Number		Percent		Percent women are of total
	Total	Women	Total	Women	
Total	197,797	1,269	100.0	100.0	0.6
Mechanical engineering (including aeronautical, marine, and agricultural engineering)	51,598	257	26.1	20.3	.5
Civil engineering (including architectural and sanitary engineering)	32,597	205	16.5	16.2	.6
Chemical engineering	20,445	205	10.3	16.2	1.0
Electrical engineering	36,129	143	18.3	11.2	.4
Mining and metallurgical engineering (including petroleum and ceramic engineering)	8,428	36	4.3	2.8	.4
Industrial engineering	5,404	28	2.7	2.2	.5
Other (general and unclassified)	43,196	395	21.8	31.1	.9

Source: American Society for Engineering Education (*20*).

WOMEN IN CIVIL ENGINEERING

Before the war the largest group of women engineers were in civil engineering. Numbering 191, they comprised, however, only 0.2 percent of the 80,362 civil engineers employed in 1940. (See table 1, p. 5–13.) At first thought this branch, so closely associated with the construction industry, might be considered unsuitable for women. However, as "office-engineers" employed in this field on designing or specification work women have been successful, especially in municipal

and highway planning and in sanitary engineering, where they appear to have had greater opportunity for employment. Among the outstanding women in civil engineering are three who are among the dozen women listed in the 1941 edition of Who's Who in Engineering (*11*).

One in 1947 was manager of the business news department and in charge of market surveys and construction reporting for the Engineering News Record, where she had worked for 20 years. During World War I, she spent her summer vacations from college drafting and computing for a mining company, a railroad, and the United States Bureau of Public Roads. After receiving her bachelor of science in civil engineering degree from the University of Colorado in 1920, she taught engineering mathematics at her Alma Mater and later worked as a draftsman for the State Highway Department. This work was followed by 4 years of employment as an office engineer for a consulting engineering and contracting firm. In this job, she prepared specifications, contracts, financial statements, and cost records; calculated and plotted influence lines for continuous girders; checked bar lists; and made graphs, obtaining experience which led to her employment in technical publication (*11*).

Another of the three was teaching mathematics in a Washington, D. C., high school at the outbreak of World War I. Following courses in surveying and experience as a wartime teacher of mathematics and surveying, she obtained her civil engineering degree from Cornell in 1920. Starting as a draftsman with a railroad, she was soon appointed engineer of service, a unique job in which she applied her engineering training and her feminine understanding of the traveler's need for comfort and relaxation to the improvement of design. Among her many achievements is the invention of the Dennis ventilator for use in railroad passenger cars. Her experience was to some extent paralleled in another utility, a telephone company, where a woman civil engineer, after some experience during the last war in surveying and estimating, specialized in cost studies. In 1946, she was assistant to the plant extension engineer (*22*).

The third woman civil engineer listed in Who's Who in Engineering received her degree in civil engineering from Cornell in 1924 and became specification engineer with the Philadelphia City Transit Department. Following her marriage, she continued to work as an office engineer on construction projects, being registered as an engineer in Pennsylvania (*11*).

As noted earlier, few women engineers are registered. But, among the 15 or so women identified as registered professional engineers in 1943, there were at least 8 civil engineers. Registered in such widely separated States as Indiana, Arizona, Pennsylvania, Ohio, New York,

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Michigan, and West Virginia, 4 were employed by State governments, including 1 junior engineer with the bridge department of a State Road Commission and a sanitary engineer in charge of a State laboratory. One was a structural engineer with a steel company; another was assistant office engineer for a major construction project (*65*). Another civil engineer, in business with her father, a road builder, illustrates why many practicing engineers, even in civil engineering, find registration unnecessary for employment.

In her book "Women Can Be Engineers," Alice Goff, herself a registered structural engineer employed by a steel company to design and estimate reinforced concrete buildings, describes the work of women in various branches of engineering (*22*). In her news letters to women engineers and architects she has described some of the pioneer women in the field. Among those receiving their degrees in civil engineering at State universities in the nineties, was one who designed the structural framework of the old Waldorf Astoria; another who served as an assistant professor for 10 years and then worked with a firm of structural engineers for many years; and several others who through experience or further training went into architecture or architectural engineering.

Only two women have ever graduated in civil engineering from the Massachusetts Institute of Technology; one has prepared engineering reports on hydrological surveys for the Government and one checked drawings and served as editorial assistant for the Civil Engineering Journal.

Women in civil engineering, as indicated by these examples, although few in number, were employed before the war by Government, public utilities, educational institutions, and private contractors, as well as by publishers of technical journals.

A 1938 study of the members of the American Society of Civil Engineers showed that 55 percent of all its members were employed principally by State, Federal, or local governments. Twelve percent were self-employed; 8 percent were employed by contractors; 7 percent by public utilities including railroads; and 4 percent by colleges (*5*).

During the war, after the first wave of construction for the Army and for war production plants was over, the civil engineers were the only engineering group which had a personnel surplus. With all nonessential construction postponed, 7,000 of the 87,600 civil engineers estimated by the War Manpower Commission as employed at the beginning of 1943 were declared to be among those not needed in that field during the next 6 months (*58*). It was suggested that displaced civil engineers transfer to teaching basic engineering subjects, to local public engineering departments, to naval architecture, aeronautical engineering or radar work, after brief training. Some women

civil engineers during the war did work with marine engineers or naval architects, doing mold loft work in shipyards, laying out the lines and making full-scale patterns or molds for various parts of the ship. Until then, women had been unheard of in this field of naval architecture and marine engineering. (See mechanical engineering, p. 5–31.)

Other new trails were blazed. In the WAVES, an ensign with a degree in civil engineering from Purdue became the first woman member of the Navy's Civil Engineer Corps in 1943, after serving for some months without full Corps status. The United States Bureau of Reclamation, considered to be decidely a "man's agency" because of the predominance of field work in connection with such projects as irrigation, flood control, etc., employed women engineers for the first time, mostly in field offices and on desk jobs.

In 1943, a woman civil engineer was employed for the first time with the United States Coast and Geodetic Survey as assistant magnetic and seismological observer at the Tucson Magnetic Observatory, where she made observations with delicate scientific instruments for the determination of basic data in the study of geomagnetism and seismology. Two women cartographic engineers were also employed by this agency. In the Tennessee Valley Authority, five women were employed as engineers: one civil, two hydraulic, one materials, and one plant records. The United States Civil Service Commission also employed a woman civil engineer during the war, who later transferred to the United States Public Health Service as a sanitary engineer. Meanwhile, the young women graduating with degrees in engineering were easily placed. Work with a State Highway Commission, the teaching of college mathematics, employment in the engineering department of an aircraft company, a position as a junior engineer with an oil company, and another in sanitary engineering with the State Board of Health were reported as the wartime jobs of 5 recent women graduates of two midwest engineering schools.

In 1947, at least 6 women were employed as assistants on civil engineering faculties in universities. If the 142 universities included in the sample used (a United States Office of Education sample based on enrollments) are representative, there were approximately 18 or 19 women assisting in university instruction in civil engineering in 1947.

More than a year following VJ-day, at the end of 1946, at least 34 women were still employed in the Federal Government as engineers whose work was in civil engineering or whose degrees had been received in that field. The highest positions were held by 2 women in the third professional grade (or associate engineer category) in the Engineer Corps of the War Department and in the United States Public Health Service. Three assistant engineers at the second pro-

fessional level and 11 junior engineers at the first or beginning level were also employed in the Engineer Corps.

The Tennessee Valley Authority employed two women as civil engineers and two as hydraulic engineers. Another woman hydraulic engineer was with the United States Geological Survey, which also had 2 women on the staff as photogrammetric engineers and one as a geodetic engineer who had college background and had worked up from a wartime position as a photogrammetric engineering aid. The Department of Agriculture and the Coast and Geodetic Survey each employed two women as cartographic engineers. (For detailed description of cartographic and photogrammetric work, see Bull. 223–7, section on geography.)

Only one woman engineer was employed after the war by the Bureau of Reclamation. She was assigned to office work in connection with irrigation projects. The National Advisory Committee on Aeronautics also had one woman structural engineer in its Langley Field Laboratory. In the United States Public Health Service, at least one sanitary engineer was a woman. In the United States Civil Service Commission, a woman civil engineer was serving as administrative assistant to the head of a division, and in the United States Patent Office, another was working as a patent examiner.

Although no women are known to be in erosion engineering, this field, important in State and Federal conservation, may well attract women who wish to combine an interest in botany with civil engineering (*35*). The resumption of road and other public construction, postponed during the war, would indicate that women's chances for employment with State agencies were better in 1947 than before the war and better than they will be later when more male graduates are available.

Government employment is expected to become increasingly important in civil engineering in which, in 1946, it accounted for roughly half of those employed (*18*) (*36*). In such fields as sanitary engineering, the future is described by a professor of sanitary engineering as presenting "both an unlimited task and an engrossing opportunity" (*69*). In this field, so vital in public health, surely, there is room for women to make their contribution to the solution of problems of water supply and sewage, insect and rodent control, housing, and air control. In architectural engineering, too, women can make a special contribution. In 1945–46, 9 women were among the 78 who received first degrees in this field, and 92 women were among the 4,146 undergraduates enrolled in the fall of 1946 in 130 of the 155 engineering schools (*20*).

Because of the widespread destruction in war-devastated countries and the postponement of construction during the war, according to

the Bureau of Labor Statistics, the demand for civil engineers is expected to increase more than that for other types of engineers and will be "exceptionally high" during the next 5 years (*48*). Not all of the 205 women undergraduate students preparing to be civil engineers in 1946–47 will complete their courses, the drop-out rate being high for both men and women. But those who do graduate should be able to find employment as interesting as that of the women who have preceded them in this field.

WOMEN IN MECHANICAL ENGINEERING

Mechanical engineers, totaling 82,443, were the largest single group of employed engineers in 1940, slightly outnumbering civil engineers. However, only 188 women were employed as mechanical engineers as compared with 191 women who were then civil engineers (*43*).

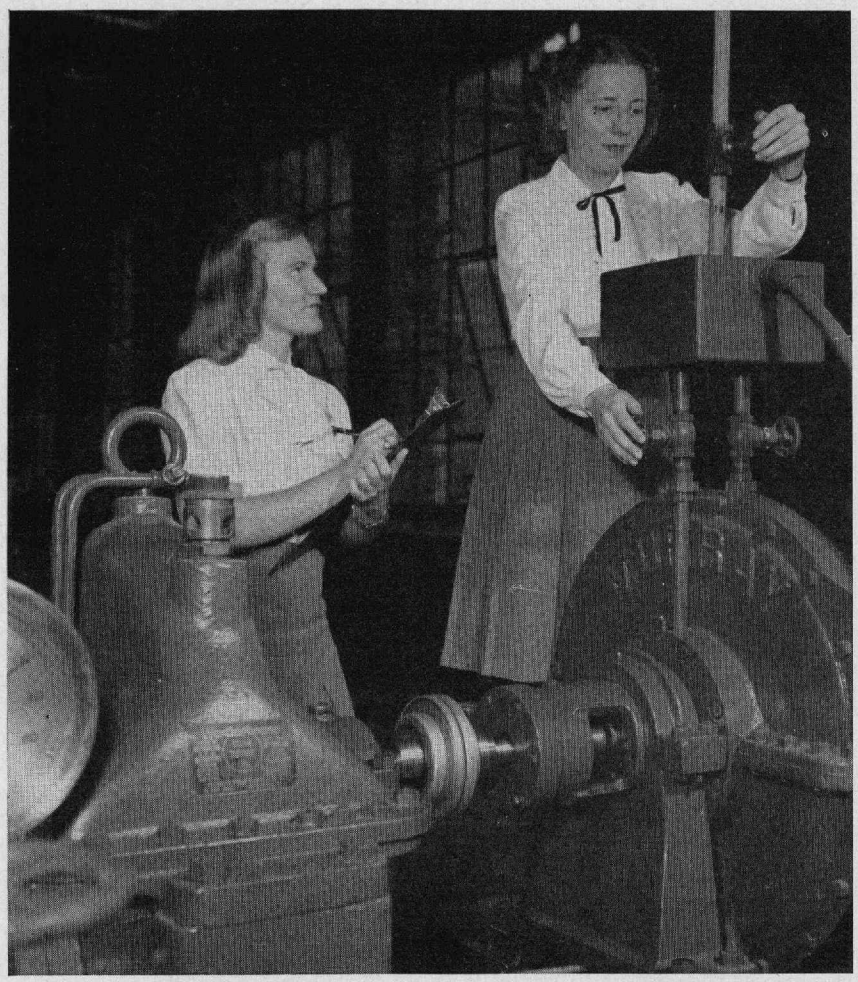
Although aeronautical engineering was not emphasized until World War II, one of the early pioneers in this field, listed in the 1941 Who's Who in Engineering, was a woman who inspected airplane engines during World War I and then became assistant to the engineer in charge of the Specification and Material Section of the Navy Bureau of Aircraft Production (*11*). Later she worked as a mechanical engineer with several industrial firms and in 1947 was a registered professional engineer in New Jersey.

Another woman mechanical engineer listed in Who's Who in Engineering was graduated from the University of Kentucky in 1916. After various research jobs in airconditioning engineering, in 1941 she became engineering editor for a large corporation (*26*).

An outstanding woman consultant in the field of refrigeration received her basic training as a bacteriological chemist. Her work in private industry and in the Federal Government led to her specialization in the problems of preserving perishable foods in transit, and she became an expert in refrigeration engineering (*22*).

Only three women had been graduated in mechanical engineering by the Massachusetts Institute of Technology before the war. Of these, two specialized in textile technology before they married and withdrew from practice. The other in 1940 was engaged in engineering design with an eastern firm. A young woman graduated by the University of Wisconsin just before the war, after specialization in automotive engineering, was employed by a Rochester firm.

Women who were graduated in mechanical engineering during World War II were quickly placed. The demand for personnel skyrocketed especially in aeronautical engineering. Engineering departments in aircraft companies expanded enormously; the percentage of women



Courtesy Purdue News Service

Figure 6.—Senior students in mechanical engineering at Purdue University preparing to test a steam turbine.

among the engineering department personnel in aircraft companies grew from zero or a negligible fraction to more than one-third. Few of these women, of course, were engineers. Most of them did simple tracing and checking, drafting, or engineering aid work. (See p. 5–52.) Some girls with mathematics and science background worked up to the grade of junior engineer; a few started off with degrees in engineering. Two Massachusetts Institute of Technology women graduates in aeronautical engineering, for example, were employed as flight-test analysts by aircraft firms, one on the west coast, and one in the East. The number of women engineers employed in any one plant seldom exceeded

2 or 3, although there were exceptions. One plant employed as many as 12 women design engineers.

In addition to aircraft companies, 7 of the 81 industrial firms visited by a representative of the Women's Bureau in connection with this study employed women as mechanical engineers during the war. One, an instrument manufacturing plant, employed 2 women in the lower classifications of engineering on development work on processes, but both left to marry and were not replaced by women. The other firms continued in 1946 to employ the women mechanical engineers they had on their staffs during the war. In one, a woman mechanical engineer was employed on difficult computations; 1 was assigned to the machine shop in another. A radio manufacturing company employed 2 in its development section; 1 was designing small parts, and the other worked with electrical engineers. Another radio company employed several in design and research. Some 10 or 15 women mechanical engineers were employed in the design engineering division of a large electrical machinery corporation, which also employed a few in its general engineering consulting laboratory. Some of these women had worked into their jobs, starting with a degree in science. One woman working on tool design had had her original training in architecture rather than in engineering.

The wartime emphasis on shipbuilding encouraged women to transfer to naval architecture and marine architecture, which women have seldom entered directly. One of the few women prewar graduates in this field was working in 1940 with her husband on the preparation of small engineering laboratories for industrial firms. In 1946, a woman was elected for the first time as a junior member of the Society of Naval Architects and Marine Engineers. Graduating from Stanford in 1943, she has been employed with a firm of naval architects ever since, working on the interior design and decoration of passenger ships. Only 1 woman was reported enrolled as a student in this field in the fall of 1946 (*20*). At least 1 other young woman during the war period became unusual even among women engineers by obtaining a degree in the relatively small field of agricultural engineering. However, at least 1 woman in the United States in 1947 was serving as an assistant professor of agricultural engineering. In the fall of 1946, 5 women were among the 1,908 enrolled in agricultural engineering courses, 2 of them freshmen (*20*). Steam turbine and electrical machinery design have been the assignments of 2 young women recently graduated in mechanical engineering who were placed in private employment.

In Government, too, a larger use was made of women engineers during the war, and this carried over to some extent into the postwar period. Two of the women engineers employed during the war by the

National Advisory Committee for Aeronautics at Moffett Field, Calif., were still there in 1946. Three women similarly continued with the Civil Aeronautics Administration as aeronautical engineers, having worked up from prewar positions as draftsmen. Their duties included work on the application of regulations to existing design and construction and the examination of blueprints submitted by aircraft manufacturers. A woman aeronautical engineer, hired by the Civil Service Commission to handle wartime recruitments for the Bureau of Aeronautics in the Navy, was ultimately employed in that Bureau as an aeronautical engineer. She and another woman were the only two women with professional status as aeronautical engineers in the Navy Department at the end of 1946. The career of the second one illustrates the type of adjustment women engineers make to changes in demand. As a mathematics major, she inspected gages for airplanes and airplane engines in World War I. Following some evening courses in engineering she worked as an assistant test engineer at an aircraft plant. In 1927, she became associate editor of the Engineering Index of the American Society of Mechanical Engineers, becoming contributing editor of Aero Digest in 1930. In 1936, she became a technical editor at the Wright Field Laboratory of the Army Air Forces, where she worked until her transfer to the Navy Department. Meanwhile in 1932 she had obtained a degree in aeronautical engineering (*22*).

The Navy also used women in related jobs in the WAVES during the war. For example, 146 college women became officers assigned to air navigation. Since engineers were not available, women with science and mathematics backgrounds, preferably with aviation or teaching experience, were trained for this work. One high school teacher of mathematics and science became a multi-engine instructor. Most of the celestial link-trainer instruction was given by women, and a number of authorities reported that women proved superior to men in this field.

The War Department also utilized the skills of women in mechanical engineering. In 1947, five women were employed there as ordnance engineers. Women with science or mathematics background were trained for other mechanical engineering jobs. One woman with a master of architecture degree, for example, ultimately became an associate mechanical engineer, working on the designing of railway hospital cars, writing specifications, making drawings and compiling information on spare parts for locomotives, and preparing patent drawings. In the Army Air Forces just after VJ-day, three women were employed as mechanical engineers in addition to four as safety engineers and four as production engineers. One of the women patent examiners working on mechanical devices in the United States Patent

Office in 1946 had a degree in engineering, and one of the technical librarians there was a woman who had had some work in engineering. One mechanical engineer and one aeronautical engineer were among the women employed in the National Bureau of Standards.

In spite of this evidence of the continued use of women as mechanical engineers in private industry and in Government, the future outlook for women in mechanical and especially in aeronautical engineering is not very favorable. More than one-third of the employment of such engineers, according to the Bureau of Labor Statistics, is in plants manufacturing machinery, iron and steel products, aircraft, and automobiles (*50*). Except in wartime, few women are employed by firms of this type. Moreover, the interest of returning veterans in mechanical and aeronautical engineering has been tremendous. An ex-Army pilot or mechanic who completes an aeronautical engineering course would prove stiff competition for anyone, particularly for a woman, unless she develops a specialty. With this in mind, one woman, who graduated in 1946 in aeronautical engineering, was training to become an attorney, with the idea of doing patent work, especially on aircraft instruments.

Industrial needs for mechanical engineers were expected to be above normal, because of the engineers required to produce an expanding volume and variety of consumer goods and the increasing use of engineers in research. But the supply of mechanical engineers was expected to grow more rapidly than the demand. As early as the fall of 1946 many of the larger companies already had more applications from mechanical engineers than they could accept. Some were beginning to recall the thirties when mechanical engineers, feeling the tremendous slump in production, were less well off than civil engineers, who benefited from public work programs, and chemical engineers, who were developing new products for the chemical industry which declined less than the industries that employ most of the mechanical engineers. The Bureau of Labor Statistics in 1946 predicted that: "Because of the wartime expansion, mechanical engineers will be confronted with keener competition than other major engineering groups" (*50*). In aeronautical engineering, particularly, difficulty was anticipated, while heating, ventilating, refrigeration, and air conditioning were thought to offer greater promise. In power, industrial machinery, and automotive engineering, where women have been almost unknown, competition is also likely to be keen. Although no women are known to be practicing in textile engineering, this field offers promise to women who combine a flair for design with excellence in mathematics, physics, and chemistry. Alabama Polytechnic Institute (Auburn, Ala.), the Lowell (Massachusetts) Textile Institute, Texas Technological College (Lubbock, Tex.), the Rhode Island School of

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Design (Providence), and North Carolina State College (Raleigh) admit women to their special courses in this field (*41*).

Some of the more than 257 women undergraduate students in mechanical engineering in the fall of 1946 (see table 7, p. 5–26) who survive the course will undoubtedly find work of their choice. But, it is possible that some, at least, barring unforeseen developments, will probably have to seek jobs in engineering writing, editing, library, or secretarial work rather than in plant engineering.

WOMEN IN ELECTRICAL ENGINEERING

Of the 53,267 electrical engineers reported as employed in the United States in 1940, only 164 or 0.3 percent were women. More than half of them were employed in the Northeastern States (*43*).

Ninety percent of all electrical engineers are employed in private industry, according to the United States Bureau of Labor Statistics (*49*), and most of the remaining are in Government service. Some, of course, are in teaching. The number of self-employed is negligible. Principal private employers are utilities, such as electric power companies and electric railways. These employ more than one-fourth of all the electrical engineers. Manufacturers of electrical machinery and equipment, as well as of electrical supplies of all kinds, commercial and household, employ about one-fifth; radio and other communication systems employ over one-sixth.

Of the dozen women listed in the 1941 Who's Who in Engineering, only one was an electrical engineer (*11*). After college graduation, she taught mathematics, then worked for 6 years on computations for a communications company, being placed in charge of calculations for the transmission and protection department. At the end of World War I, she entered the Massachusetts Institute of Technology where she secured her master's degree in electrical engineering. After further computing experience and 2 years as a professor of physics at Istanbul Women's College in Turkey, she has since been employed as an electrical engineer by a large electrical machinery manufacturing company working on special problems in power transmission. She has invented a calculator and is responsible for another patent in electrical power transmission.

Only three other women had received degrees in electrical engineering from Massachusetts Institute of Technology before World War II. One became an electrical engineer with a radio manufacturer; another was a college professor of physics and mathematics; another worked as a technical librarian.

One woman electrical engineer who graduated before the war from Ohio State University was employed with a radio manufac-

Courtesy Radio Corporation of America

Figure 7.—A radio tube engineer.

turer; another from the University of Missouri was reported on drafting work in the East.

A 1925 Stanford graduate in electrical engineering worked as a consulting engineer with her husband, also an electrical engineer, then became plant electrical engineer with an aircraft company in 1938; at the outbreak of World War II she was supervising more than 20 research engineers on production work (*22*). Another woman, formerly employed as an electrical engineer by a western power company, during the war became the first woman faculty member of Cooper Union School of Engineering. A woman who was graduated in engineering by a Midwest school in 1929 was employed by Army

Ordnance during the war, after experience as an engineer with a lighting company, as a sales engineer, and as a draftsman on a municipal job. Several women wartime graduates of Massachusetts Institute of Technology were employed by electrical manufacturing companies, and one became an illuminating engineer with an electrical utility. A number of Chinese women trained in the United States have returned to China to contribute to their country's progress in electrification.

Although very few women have received degrees in electrical engineering, a number have entered the field through experience, usually coupled with college training in mathematics and physics. A Hunter College graduate in statistics, with a minor in physics, in 1946 was preparing pamphlets explaining the use of radar equipment, as a technical assistant in an engineering laboratory. Another 1941 graduate with a major in chemistry and a minor in physics took a job as laboratory assistant in an instrument manufacturing company upon graduation. Four years later she became the first woman to hold the title of engineer in that company, because of her design work in optics which increased the accuracy of a gunsight used during the war (*1*).

In the WAVES, 121 women officers with a background in science or mathematics were trained for work in radio, radar, or electronics, although none of them had engineering degrees. However, most of them were trained only as aids to engineers, examining and testing vacuum tubes. (See p. 5–52.)

In 1946, the Navy employed 13 women as engineers in its Bureau of Ships, a reduction from the 31 employed just before VJ-day. Most of them were radio or electrical engineers. Some of these had received degrees in engineering, like the men used on this work before the war; others with science degrees were trained on the job. Four women radio engineers were also employed in December 1946 in the Naval Research Laboratory, 1 at the third professional level. One was also employed at the Boston field station of the Laboratory. Two women radio engineers were working for the Bureau of Standards in 1947.

Although during the war period, electronics engineering (the science of the vacuum tube), in which some 10,000 engineers were then estimated to be employed, was described as a field in which women should be equally as successful as men (*24*), the tremendous interest of returning servicemen in this specialty and the large number of technicians developed in the armed forces will make the competition unusually keen for future openings, although this field is expanding. However, the first woman to receive an electrical engineering degree from Carnegie Institute of Technology in 1947 is a specialist in this field.

The first woman engineer graduated by the University of Delaware, with a bachelor's degree in electrical engineering in 1946, was placed in the aircraft industry, in which competition with men is also likely to

be keen in the future, judging from student enrollments in 1946. In illuminating engineering, electronics, and the design of household appliances, women have more natural advantages, however, than in power and utility engineering, including rural electrification, in which field-work and travel are more likely. The smaller utilities especially want their engineers to be available for rough outside work as well as for desk or laboratory work. Except for computers, therefore, there is relatively little opportunity for women in this field. Only 3 of the 81 industrial companies visited by a representative of the Women's Bureau in the course of this study employed women electrical engineers. Two were radio manufacturing companies which employed 5 or 6 in design or research; the other was an electrical manufacturing firm which also employed them in design engineering and in research.

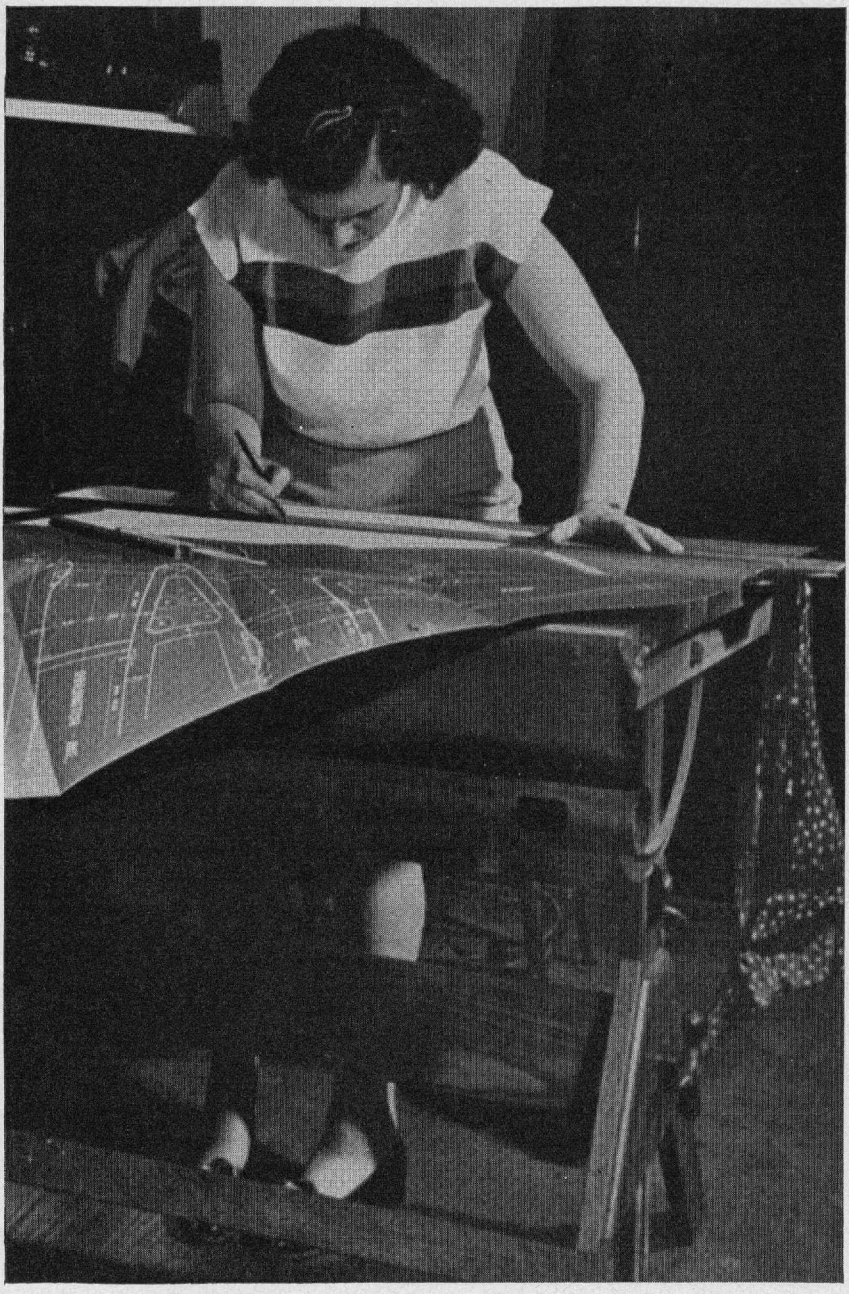
On the whole, electrical engineering is expected to offer "good prospects for experienced engineers and for well-trained new entrants during the next 4 or 5 years," according to a 1946 statement by the Bureau of Labor Statistics (*49*). Those among the less-than-150 women enrolled in undergraduate courses in electrical engineering in the fall of 1946 (see table 7, p. 5–26) who complete their course should also find opportunities for their contributions to this growing field.

WOMEN IN INDUSTRIAL ENGINEERING

Industrial engineers are usually classified as mechanical engineers, although they are reported separately in the Census. Since they are concerned both with mechanical operations in industry and with the personnel engaged in these and other work tasks, they may enter the field with an engineering background (often obtained in a course that may be called industrial, management, commercial, production, or mechanical engineering) or with a background in economics or business administration (including training in the personnel field). Some industrial engineers specialize in safety engineering.

In 1940, there were 9,283 industrial engineers in the United States, including 74 women, 0.8 percent of the total (*43*). Two of the women listed in the 1941 Who's Who in Engineering have specialized in this field. One, beginning as a psychologist, became a consulting engineer with her husband, pioneering in time-and-motion studies. Licensed to practice engineering in the State of Indiana and qualified in mechanical and industrial engineering, she has contributed much to the literature as well as to the performance in her field. At present, she is professor of management at Purdue University in addition to her consulting work (*11*).

The other, an associate professor of economics at a woman's college, has specialized in the management field and has contributed to the



Courtesy National Safety Council

Figure 8.—A safety engineer specializing in traffic problems charting collision sites.

literature on the relationships between machines and those who operate them (*11*).

During the war, the limitations on the supply of production workers in relation to the overwhelming demand for them in industrial production made vital the most effective use of the personnel available. Industrial engineers were employed in the Federal Government and in war production plants to study the work processes, to eliminate unnecessary tasks and motions, and to suggest changes in procedures, work places, and equipment that would obtain the highest output with the least expenditure of effort. Women with experience in this field were especially welcome, since among the pressing problems were the adaptation of machines and equipment to the smaller average size of women operators, the solution of problems arising out of the employment of large numbers of inexperienced women and young people under wartime pressures, and the shortage of expert supervisors.

Very few women with specialized training were available. One, graduated by Ohio State University in 1945, was immediately hired by a Pennsylvania company manufacturing air-conditioning equipment.

Young women college graduates with mathematics, physics, and chemistry, and some knowledge of production methods acquired by work experience or special training, were pressed into service. Typical of these were the five women employed as junior time-study engineers in a radio plant. They did time-studies on repetitive parts or products, established output rates for various classes of work under a senior time-study engineer, and suggested corrections to reduce costs or improve working conditions.

Although only one woman was graduated with a bachelor's degree in industrial engineering in 1946, according to reports from most of the engineering schools (see table 6, p. 5–26), this branch may hold more promise for women than some others. Those trained in it can make a special contribution in industries and occupations in which large numbers of women are employed. The most effective use of human energy in such professions as nursing and teaching, for example, is a problem to which industrial engineers can contribute as much in the future as they have in the past in manufacturing industry.

There ought to be room in this little-explored territory in the coming 5 years for a larger number of women than the 100 or so women in it and the 28 women enrolled in industrial engineering courses in the fall of 1946. (See table 7, p. 5–26.) Industrial engineering offers unusual opportunity for the woman who combines scientific interest and competence with interest in the maximum development and effectiveness of the individual in his job. But, she will also need patience, a considerable amount of work experience, and the persuasive qualities needed to obtain the chance to prove the economic as well as the social value of her skill.

WOMEN IN MINING AND METALLURGICAL ENGINEERING

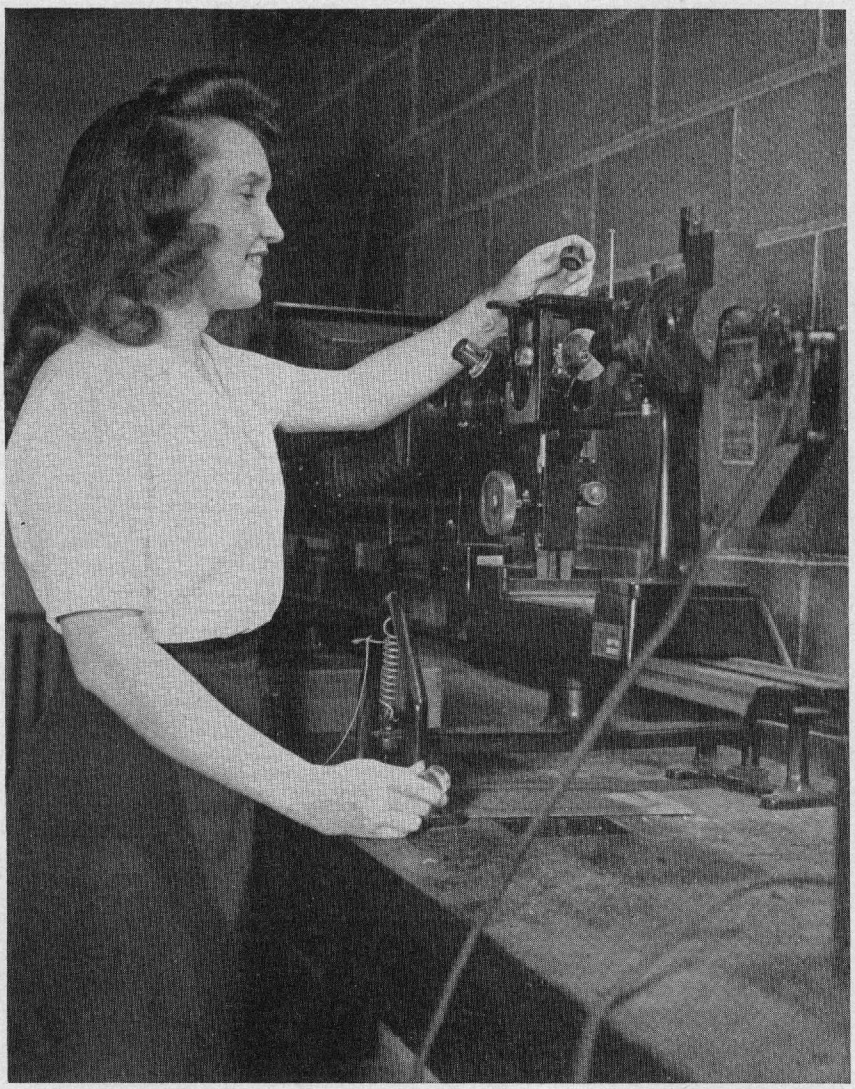
Although mining and the conversion of metals into useful products are economic activities with which women are seldom associated, the proportion of women among mining and metallurgical engineers in 1940 was greater than in any other of the branches except industrial engineering. Although they then numbered only 74, women composed 0.8 percent of the 8,813 mining and metallurgical engineers reported employed in the 1940 Census (*43*). The variety of specializations in this field and its relationship to others has been described by the National Roster of Scientific and Specialized Personnel (*56*) and in pamphlets on careers in the mineral industries such as those published by Pennsylvania State College (*32*) and the American Institute of Mining and Metallurgical Engineers (*34*).

Among the dozen women listed in the 1941 Who's Who in Engineering are two women classified in this field. Both married mining engineers with whom they have at various times worked in consultation. One, who took her bachelor's degree in metallurgical engineering at Massachusetts Institute of Technology, became development engineer with an Ohio company where in 1946 she was head of the refractory and ceramic department and in charge of research and development on beryllium oxide. She has worked with her husband in South America, Central Asia, and Canada as well as in the United States (*11*) (*22*). The other, beginning as a secretary to a supervising engineer in an oil refining company, learned petroleum engineering by experience. Registered as a mining engineer, she is listed with her husband as co-inventor of a patent for process and apparatus for secondary recovery from oil wells and of a patent for recovering sulphur and iron from ores (*11*).

Another outstanding married woman in this field, also a Massachusetts Institute of Technology graduate, has her own laboratory on the development of products out of waste materials, in addition to a job as metallurgist with a communications company. She also taught part time in an engineering school during the war.

Even in the steel industry there have been a few women engineers, including a Stanford graduate in mining engineering employed with a New York company. During the war, a woman with a degree in mining engineering was used to survey the possibilities of using women for surface work in a molybdenum mine. She later supervised the women hired.

A few women have become ceramic engineers, who are sometimes grouped with mining and metallurgical engineers because they are concerned with the engineering of glass, pottery, tile, and other prod-



Courtesy Purdue News Servic

Figure 9.—A junior student in metallurgical engineering testing a metal sample.

ucts made from clay, silica, and similar nonmetallic minerals (*56*). Two have graduated with degrees in ceramic engineering from Ohio State University since it originated the first ceramic engineering course in 1894 (*30*). Both were employed by tile or pottery companies in the Midwest. During the war, one woman ceramic engineer was employed in the Federal Government with the War Labor Board. Another was employed at the National Bureau of Standards

in 1947. There were no women among those graduated in ceramic engineering in 1945–46 according to reports from most of the schools, and only 17 women were then enrolled as undergraduate students (*20*).

Some women, after training in mining engineering, have specialized in work in other sciences. The first woman to receive a degree in mining engineering from the Colorado School of Mines became an assistant physicist in the National Bureau of Standards in 1940. The 22 women who were members of the American Institute of Mining Engineers in 1942 came into the field from various routes including degrees in engineering, geology, and chemistry. One started out as a nurse with a mining company (*70*). A few have become interested in mining through family connections. One woman whose family is engaged in the oil industry, for example, did her major graduate work in the specialized study of oil muds. Although women in this branch of engineering have been employed in a variety of industries, the jewelry industry has attracted at least two outstanding women metallurgical engineers.

Although mining and metallurgical engineering are expanding fields, the Bureau of Labor Statistics has called attention to the fact that in total they employ only a small proportion of engineers as compared with mechanical, civil, and electrical engineering (*51*) (*52*). In 1946, prospects were described as good for the next 4 or 5 years, but they may become less so depending on the size of the graduating classes in this branch. However, so far, the number of students enrolled appears to be more in keeping with the demand than enrollments in mechanical engineering. Only one woman was graduated with a degree in this field in 1946 according to reports from a majority of the engineering schools (table 6), and only 36 women were enrolled in undergraduate courses in this branch, 0.4 percent of the total majoring in mining and metallurgical engineering (table 7). These small numbers of women should be easy to absorb, particularly if they develop unique specialties. A flair for design would be particularly helpful in ceramics and jewelry work. Research in metallurgical engineering and small, or family, mining ventures, according to one authority, offer better opportunities for women than most operating jobs where they are definitely handicapped by their sex.

WOMEN IN CHEMICAL ENGINEERING

Chemical engineering is related on the one hand to chemistry and, on the other, to engineering. Although training for chemical engineering is usually obtained in a school of engineering, some chemists whose training has been taken in a school of arts and sciences become chemical engineers through work experience, by working on problems

Courtesy Purdue News Service

Figure 10.—Junior students learning practical applications of chemical engineering principles.

related more to the process of manufacturing a product than to the composition or nature of the product itself. Two of the women listed in the 1941 Who's Who in Engineering started as chemists, the one becoming an engineering consultant in the recovery of precious metals from waste and the other a consultant on water conditioning and corrosion control, having had previous experience in power plant design.

Very few women, however, have become chemical engineers either through training or through experience. In 1940, the Census reported only 39 women employed as chemical engineers in the entire country, 0.4 percent of the total of 11,120 (*43*). However, this branch of engineering was at that time one of the fastest-growing groups; the number of available beginners in that year outnumbered one-fourth of those already employed. (See table 2, p. 5–15.)

The growth of chemical engineering began in 1935, being related to industrial expansion especially in the chemical industries and in petroleum refining. The latter industry in 1940 was reported to be absorbing one-eighth of the annual supply of graduates in chemical engineering (*13*).

Women graduating in chemical engineering before the war, with some outstanding exceptions, more often practiced as chemists than as engineers. A 1923 graduate from Ohio State University, for example, worked as an assistant chemist in a State laboratory until she married in 1925. A 1929 graduate, also married, was working as a chemist in the United States Department of Agriculture in 1946; another Ohio State graduate was employed in the chemical division of a glass manufacturing company. Three of the 4 women chemical engineers who graduated from the University of Cincinnati before the war were employed in research in 1945—one in medical research, one with a distillery, and one at a State agricultural station. All three had had other jobs in industry varying from work with a fur company to work as a bacteriologist with a pharmaceutical firm; two married but have continued to work most of the time. The fourth took a law degree following graduation and was practicing law in 1945. Two of the four women who have received degrees in chemical engineering from the Massachusetts Institute of Technology were employed in industry in 1946; one on flavoring research with a foods company, the other on a laboratory job with a large chemical corporation where her husband was also employed. A third was taking graduate work. The fourth, after obtaining her master's degree in chemical engineering some years ago, taught on the faculty of a State university. Later, she obtained her doctorate at that university, where she now holds the rank of assistant professor of chemical engineering and research and serves as research chemist and consultant at its petroleum refining laboratory (*22*).

Only 4 of the 81 industrial establishments visited in the course of the Women's Bureau survey in 1946 employed women who had degrees in chemical engineering. One foods company employed 1 as a control chemist and another as a junior technologist in bio-assay work. The latter was an older woman with a bachelor's degree in chemical engineering supplemented by 10 years of teaching experience and in-

dustrial experience with a chemical company. She was declared to have by far the best technical background of any of the junior technologists in that company, employed as persons who perform all types of food laboratory work with a minimum amount of supervision. Two chemical companies were among the 4 employing women with chemical engineering training. One in 1946 employed 2 women with bachelor of science degrees in chemical engineering, 1 as an engineer in research and development and 1 as a chemist. Another chemical company, having employed a woman with a degree in chemical engineering on patent work involving drafting during the war, was so well satisfied with her work that when she left in 1946 a special and successful effort was made to replace her with a woman of equivalent training. During the war, 4 or 5 women with degrees in chemical engineering were employed in analytical work in the research laboratory of this firm, but most of these left to be married. The fourth firm was an electrical machinery company which employed a few women chemical engineers in its design engineering division.

Among women, as among men, there are a few whose degrees were in chemistry rather than in engineering but who became engineers by virtue of their jobs. At one research institution visited by a Women's Bureau representative in 1946, seven women who had bachelor's degrees in chemistry were working as research engineers.

At that time women chemical engineers were scarce also in Federal agencies. One was employed at the Aircraft Engine Research Laboratory of the Civil Aeronautics Administration, and 1 was employed at the Tennessee Valley Authority, where, in addition, 11 women with less training were classified as chemical engineering aids. In the Chemical Corps of the War Department, where 2 women had been employed as engineers during the war and 2 as engineering aids, only 1 woman engineering aid remained at the end of 1946.

Government, as a rule, is a relatively insignificant employer of chemical engineers, more than 90 percent of whom in 1946 were employed in private firms, mostly manufacturing industries (*18*). Only 7 percent were in Government work, mostly Federal. Less than 2 percent were working in educational institutions in 1943 (*53*). Undoubtedly, expanding enrollments will increase faculty openings. But in 1947, only 2 women were listed among faculty members in chemical engineering in the catalogs of 42 universities included in a United States Office of Education enrollment sample of 131 institutions of higher education of this type. One was a laboratory assistant and 1 an investigator. The sample would indicate that there are not more than 6 women on chemical engineering faculties throughout the country. In any case, the demand for chemical engineers will rise or fall with industrial needs, especially in

chemical manufacturing and petroleum refining which engaged more than half of all chemical engineers (*55*). The small proportion of chemical engineers in technical writing and editing suggests the possibility for further development in this type of work for a woman who may choose a desk job following her training.

In most chemical engineering work, whether it be research and development, production, administration, or control work, a considerable amount of work in the plant is involved. One authority included chemical engineering in the classification of "overalls" work, frequently requiring strong arms and mechanical work. This characteristic must be added to the fact that field assignments, shift work, and construction jobs that are often involved tend to limit a woman's usefulness in the eyes of an employer. However, one employer suggests that chemical engineering is valuable background for girls who want to become technical secretaries or assistants to executives, especially in such industries as drugs, foods, textiles, and cosmetics. One head of an engineering school doubts that women will ever be hired as chemical engineers in industry except perhaps in foods and canning. The history of the women trained as chemical engineers bears out these predictions—only a few are working as engineers, and most of these are doing laboratory work. The number who have gone into medical research or organic chemistry indicates the trend for women to specialize in biochemistry and organic chemistry rather than in inorganic and physical chemistry.

In spite of the lack of demand for women as chemical engineers, more women received first degrees in chemical engineering in 1945–46 than in any other branch. (See table 6, p. 5–26.) More than 200 women were also enrolled in undergraduate courses in chemical engineering. After the next few years, during which the prospects for employment are good, the absorption of women will be further complicated by a possible oversupply of men if male enrollments in chemical engineering continue at a high level. In November 1946, they amounted to almost twice the number of engineers employed in 1940. (See tables 7 and 1.) If enrollments continue at a high level, the Bureau of Labor Statistics predicts keen competition for jobs in this field within a few years (*47*). However, one woman chemical engineer in 1947 offered a silver lining to the black picture, "Chemical engineering offers the best training for any work in chemistry or allied fields. I feel very strongly that the point of view of the engineer is one of the best things I received as a result of that training. I have found myself automatically doing things and thinking in a practical way where others stumbled around quite a bit." Most women engineers in other branches, too, seem to share this opinion of their training.

SUGGESTIONS TO WOMEN CONSIDERING ENGINEERING AS AN OCCUPATION

Because women are so small a minority in the field of engineering, where there is also a prevailing preference for men, the young woman who plans to apply for entrance to an engineering school must have superior qualifications. In 1946, a summary of research findings on the qualifications needed for success in engineering training was made by the Veterans Administration for use in its advisement and guidance program (*63*). Superior aptitude for college work and demonstrated proficiency in mathematics and science are the best indications of success in the study of engineering. Average mechanical aptitude and spatial visualization (the ability to picture in one's mind the space relationships between objects) are also important factors.

The coordinator at one accredited engineering school, who reported to the Women's Bureau that "The girls are as good as the boys, some poor, some excellent," explained the equal success of the girls on the basis of high admission requirements. They must be in the upper fifth of their high school class and have 3 years of mathematics plus physics and chemistry. Another school, enthusiastic about its women students, reported that 2 girls led its 1943–44 freshman class of 200.

Not all comments from engineering schools were favorable. One dean of an engineering school complained that most of the women students it had admitted since 1939 had not done very well. Those who entered during the war were affected by glamorous publicity. However, he went on to say that the few women who are really interested will continue to find places in engineering, but in research departments rather than in competitive engineering work. A number of employers also mentioned that tradition makes it difficult to use women in engineering work where they must go into the plant to set up the job. Another dean of an outstanding engineering school which has long admitted women says that those who are really interested and have the ability are very successful. The problem is how to encourage them and at the same time discourage the girls whose interest in engineering is a passing fancy.

During the war, the problem of obtaining well-qualified women for engineering training was analyzed by representatives of an engineering school which previously had not admitted women to its undergraduate courses. Entrance tests given to both men and women indicated that while some women scored as high as men, the women were usually low in both technical knowledge (especially of physics) and space sense. Although women excelled in reasoning, computing, and report writing, only one or two out of 10 women who met the entrance requirements were found to possess suitable aptitudes and interest

for engineering training as compared with about five out of 10 of the men applicants (*8*). Possibly if more women studied science and mathematics in high school, their ratio might be higher. Even so, it indicates that there are a number of potential engineers among women although they are fewer than among men.

In addition to assurance that she has a fundamental interest in and superior qualifications for engineering, a young woman should be aware of the handicaps she is likely to face and must be ready to overcome or circumvent, if she is to be successful in engineering. A prominent woman industrial engineer, Lillian M. Gilbreth, outlined them in an article on mechanical engineering as follows:

1. Attitudes of family, friends, and schools toward more women going into engineering.
2. Inadequate selection. Wrong women sometimes get in; right ones sometimes stay out. Even the preparatory schools often discourage promising candidates for engineering.
3. Inadequate training in the preparatory schools, in colleges, etc. Even those who admit and give equal opportunities may not have adequate courses. This is especially true in the field of management, as yet the neglected area in the engineering field.
4. Prejudices of employers, technical societies, public.
5. Inadequate "in-service" training.
6. Inadequate promotion.
7. Difficulty of combining marriage with career. This, while less in engineering than in many areas, still exists.
8. A feeling that man should have first call on all jobs.
9. A feeling that man should have first call on engineering jobs.
10. Unemployment and all hazards that men face (*21*).

Beth Schmid Kerrmann, from her engineering experience, adds to these another which was more noticeable in the thirties when young graduates from engineering were plentiful. At that time young engineers often had to work up from a subprofessional or a skilled job to engineering. This created an additional handicap for women, since many of these entering jobs involved heavier physical labor than most women could safely perform.

Another outstanding woman engineer, Olive Dennis, says, "The field of engineering is still a pioneer one for women." Women who enter it, therefore, need not only talent but the vitality and personality that characterize a pioneer. They will do best if they develop unique specializations in which they have a natural advantage: Engineering related to the styling of consumer products, to household appliances and equipment, and to such products as textiles, clothing, and foods.

The possibility of applying engineering techniques in fields in which women are especially interested has never been fully explored. The woman who received her Ph. D. in 1945–46 from Purdue, specializing in general engineering and home economics, suggests the possibilities

that lie in this direction. A new course at Massachusetts Institute of Technology in biological engineering, developing processes and equipment for medical and biological fields, attracted eight women students in 1946, one of whom planned to enter medical school. A food technology program is also offered. The sound field, including the reduction of vibrations and the absorption of sound to add to efficiency and comfort, is almost wide open according to one woman engineer and offers no particular barriers to women.

Perhaps because so many of the men in engineering have not developed facility in writing, opportunities for women engineers will continue in the writing and editing of reports, in the preparation of operating and training manuals used in engineering departments, and in work for trade journals. Some women trained in engineering may also use their background in such nonengineering jobs as budgeting, cost work, and statistical control. One or two, in the past, have become purchasing agents.

A machine-tool firm recently asked an engineering college to recommend a woman graduate for a position as sales engineer. They wished to try her out on selling their products to purchasing agents, many of whom have little or no mechanical training.

Although women who become engineers may have to adapt themselves to unusual competition from men in the next decade, their status is likely to differ very little from that of the women engineers who have worked in this field in the last 50 years.

It is unlikely that, in the immediate future, many women will make engineering their lifework. For those who do, however, there will be opportunity for the interest, vitality, and talent they must possess to join the successful women pioneers in this profession.

THE OUTLOOK FOR WOMEN AS ENGINEERING AIDS

Although few women are employed as engineers, an additional number are engaged in assisting engineers with those duties that can be turned over to one with only partial training or experience in engineering. Before the war, computers and engineering draftsmen were the most usual type of assistants in engineering departments or on engineering projects large enough to employ specialized staff. Many of these and other assisting jobs in the larger firms have been customarily filled by young engineers who stayed in them only temporarily as part of their in-service training for more responsible work. However, some have been regularly filled by persons who specialized in this work, called engineering aids or engineering assistants.

Prewar Distribution

The term "engineering aid" was used by the United States Civil Service Commission before the war for certain subprofessional workers who assisted engineers, especially in field work. Few women applied for positions of this sort. In the year ended June 30, 1940, only 12 women were among the approximately 12,000 who passed Federal civil service engineering aid examinations (*42*). In that year 1 woman was among the 758 appointed to such positions.

Only a few large industrial firms, almost exclusively those in the electrical and communications industries, employed women in this capacity before the war. One large company, in addition to computers, had about 50 women engineering assistants on its prewar staff. Most of them were women with college degrees in physics, mathematics, or chemistry who were given special training by the company after they were employed.

Wartime Changes

During World War II, the attempt to conserve the skill and knowledge of engineers included supplying them with more assistance than they were accustomed to having. There was the additional problem of replacing the usual supply of young engineers, virtually cut off by the draft.

Early in 1942, the Federal Government began to recruit "student aids" to be trained for work in engineering, at a salary of $1,440. Later, women were actively sought as "engineering aids" for all fields

Courtesy Radio Corporation of America

Figure 11.—Engineer explains design of special purpose acorn tube to engineering aid.

of engineering for jobs varying in pay from a basic salary of $1,440 to $2,600.

In the War Department, where the demand was greatest, the Engineer Corps, Ordnance, and the Signal Corps were the principal branches needing engineering aids. On February 1, 1943, the Office of the Chief of Ordnance announced a 3-month intensive training program (8 hours a day for 6 days a week) to train women to become junior engineering aids in ordnance. High school graduation, including courses in algebra, plane geometry and trigonometry or mechanical drawing, was required to enter the course set up at the University of Michigan. Although the course was established primarily to train civil service appointees, ordnance manufacturers working on Government contracts were also invited to send employees for training. The basic course included: Drafting, mathematics, machine shop practice or plane surveying, metallurgy or iron and steel or engineering calculations, and shop visits to study production methods. Similar programs were later given at Drexel Institute, Temple University, and the University of Pennsylvania to train personnel for the Frankford Arsenal. A group of college graduates and, later, high school graduates were trained at Rutgers University for engineering aid work at Picatinny Arsenal. No record of the total number of women em-

ployed during the war as engineering aids in the various arsenals is available. But at the Frankford Arsenal, for example, a maximum of 18 women engineering aids and 3 women junior engineering aids were employed during the war.

The Signal Corps, beginning early in 1942, trained about 400 women as engineering aids. Women were placed at the Aircraft Radio Laboratory at Wright Field in Dayton after a 24-week course for engineering aid trainees (aircraft radio) offered at a number of Midwest universities covering mathematics, radio circuit theory, radio laboratory, practical radio communications, d. c. and a. c. (direct current and alternating current) theory, transmission lines, electrical measurements, radio laboratory and selected readings and supervision. For this course, college graduates or students with at least 6 hours of college mathematics and physics were preferred. An intelligence test was one of the factors used in selection. After assignment, these women worked in the Development Division on every phase of aircraft radio equipment. Some tested apparatus, assembled components, or worked on modifications designed to improve the most intricate communications devices (*64*). Others were assigned to clerical work for which a technical understanding was necessary. Many of the girls, expecting to do technical work, did not like the clerical assignments, and turn-over was high. Out of a class of 31 women selected for training at one college, for example, 19 completed the course and were placed at Wright Field Signal Corps Laboratories. In 1945, only 5 or 6 were still employed there. Some WACs were also trained for work as engineering aids with the Signal Corps.

At the October 1944 peak of its wartime employment, the Army Air Forces employed 474 women as engineering aids. However, many of these women, like those in the Signal Corps, were assigned to clerical jobs. The Air Forces also recruited women with electrical engineering or technical radio experience for positions as instructors in radio (*29*).

In 1943 the Engineers Corps employed 151 women as engineering aids, ranging from the lowest level of "under engineering aid" to the highest grade of "principal engineering aid." Other branches of the War Department employed an occasional woman as engineering aid. The Chemical Corps, for example, had 2 and the Quartermaster Corps, 5.

Industry, too, finding few women with engineering training immediately available, made a special attempt to recruit college women with mathematics and science backgrounds who could be trained as engineering aids. The dearth of young assistants to engineers, in the face of overwhelming expansion, was especially critical for the aircraft industry. One company, in spite of vigorous recruiting in the

summer of 1942 to obtain women for vibration analysis work (to analyze ocillograph records of tests made on airplane propellers for stress factors), was able to hire only 5 women with sufficient college training in mathematics; during subsequent war years, 10 more were hired. A number of aircraft companies, therefore, in cooperation with selected universities set up special training programs for which young women were recruited as "engineering cadettes"; the full cost was borne by the companies which in turn were covered in such expenditures by the "cost-plus" contracts under which they were manufacturing planes for the armed forces. The estimated cost per girl trained ranged from $1,500 to $2,500, since the students were paid while learning. Almost all of the larger aircraft companies inaugurated such programs, although they varied somewhat in detail. Complete information was obtained by the Women's Bureau on 5 of these programs operated by the larger firms in this field.

Altogether 1,670 women completed engineering aid training courses conducted by these 5 companies on a number of college campuses; the first course started early in 1943. One company recruited only college graduates, but the usual requirement was 2 years of college, preferably with mathematics and science background. Actually, selection became

Courtesy University of Cincinnati

Figure 12.—Students being trained during World War II as engineering aids for work in an aircraft company.

highly individual, and students ranged from outstanding high school graduates with a background in mathematics and science to women with master's degrees. Intelligence and aptitude tests, school records, recommendations from colleges, and physical examinations were used in the process, but final selection was based on an interview with 1 or more company representatives.

The courses of study varied in length from 6 months to 1 year. All of them included: Mathematics (ranging from a course in "aircraft mathematics" to a review of algebra, trigonometry, analytic geometry, introduction to calculus, and computational and graphic procedures); engineering drawing; aircraft materials and processes; aircraft terminology; mechanics; aerodynamics; and shop practice. One company operating a 12-month program provided for specialization during the final 6 months in drafting and design; aerodynamics; chemistry and metallurgy; or engineering laboratory work.

Those who completed the training were assigned to jobs in one of the company's plants at basic salaries ranging from $130 to $150 a month. The first assignment was usually to the drafting board, although there were variations depending upon the needs of the company and the background of the new employee. In one company, the title "technical aid" was used to classify these women during the first year of their employment. They were then given regular assignments throughout all sections. About 40 percent of those in one plant remained in drafting and design, while the others were assigned to other sections such as aerodynamics and structures; experimental section; blade design section; material laboratory; research analysis; color design; administrative section. Next to drafting, the most common assignment was that of computing. In some plants, the title "engineering computer" was created for these women, since such work before the war was done by young junior engineers as part of their induction training following graduation from an engineering college. Others were called engineering aids, technical assistants, or laboratory assistants, according to their assignments. A few women with the best backgrounds after 1 or 2 years of employment were assigned to such jobs as junior aerodynamics engineer, junior structural engineer, junior stress analyst, junior weight engineer, and test engineer in the lower classifications. These jobs involved more complicated calculations than those usually done by computers and were performed with less direct supervision. Junior weight engineers, for example, assisted weight engineers in making estimates or calculations necessary to insure that the weight of aircraft and aircraft parts was kept to specifications and that proper loading and balance was secured. Junior stress analysts and junior aerodynamicists assisted engineers with mathematical work and records pertaining to wind-tunnel, vibrations,

and other tests to check on the performance and stability of aircraft. Few reached this level however. One aircraft company in 1944, for example, employed 9 women in such capacities as compared with 26 computers, 200 draftsmen, and 28 illustrators.

A follow-up report on one group of young women trained for the propeller division of an aircraft company illustrates both the successes and the failures of these programs. One hundred girls were selected for a 10-month course given at Rensselaer Polytechnic Institute in 1943, and 83 of them completed the course. The school drop-out rate for this group was 17 percent—slightly above the 15 percent average for all groups. The 83 who completed the course were assigned to jobs in one of the plants on January 1, 1944. About 25 percent of the girls left during the first 6 months, usually because they didn't like the living conditions (the plant was located in an isolated spot for security reasons) ; others were homesick or found they lacked interest in the work. Early in 1945, at the end of their first year of employment, 48 were still working at the plant. Of these, 15 were in the drafting section; 6 in propeller design; 4 in aerodynamics; 4 in vibrations department; 2 on testing at the airport; 3 in the propeller test unit; 1 in the structures department; 4 in the experimental laboratory; 4 in the materials laboratory; and 1 in the chemistry laboratory. Another was in the engineering library, another on research analysis, 1 on service liaison, and the other in the mathematics department of another plant. That many of those still employed looked upon the work as a temporary war job was shown by the fact that of those still employed at the company in 1945, 5 already had plans to leave for further study, 3 of them planning to enroll with their husbands. Eight others were married or engaged. In the fall of 1945, 6 or 8 left to return to school. In March 1946, only 20 of the group were still employed. Those remaining were assigned as follows: 9 engineering computers (3 on aerodynamics analysis; 3 on vibrations analysis; 1 each on stress analysis, test equipment analysis, and color design) ; 5 laboratory assistants (2 in experimental laboratory; 1 each in chemical laboratory, physical testing laboratory, flight testing) ; 5 detailers; 1 technical librarian.

Several electrical and radio manufacturing companies followed the aircraft industry in inaugurating special resident college courses to train women assistants. The arrangements and pay were similar to those offered by the aircraft manufacturing companies, but the course emphasized subjects in electrical rather than aeronautical engineering. One large electronics company operated a "Cadette Program" for example. Using tests, rating scales, and interviews, it selected young women between 18 and 22 years of age, with 1 or more years of college and an interest in mathematics, from among hundreds of applicants for a special 10-month course at Purdue University. Eighty-six were

enrolled, 49 of them coming directly from colleges. Twenty-three of the remaining group were girls already employed by the corporation. Seventy-three girls completed the course which covered, besides mathematics, engineering drawing, and shop practice, alternating and direct current, electrical measurement, radio theory and laboratory electronics, and statistics of quality control. They were assigned to jobs in 6 different plants. Fifty-five of them worked in engineering departments assisting in the designing and development of plans used later in the factory. Eighteen had engineering assignments in the factory in quality control engineering, process analysis, or instruction book writing. Most of them carried the title of engineering aid, a new title in this firm created to describe the jobs which fell midway in difficulty of performance between that of the laboratory assistant and that of the class C engineer (the usual title for engineers just graduated from college). In 1946, 2 years after their initial employment 14 of the 20 girls assigned to one of the plants of this company and 13 of the 22 assigned to another were still employed there.

Similarly, a large electrical manufacturing company trained 33 women in a 36-week course which covered applied mathematics, engineering drawing and design, properties and strength of materials, fundamentals of electrical engineering, electrical circuits, electrical apparatus, engineering problems, manufacturing process, and mechanical design. In the last 12 weeks, when specialization was optional, the 3 possible choices were electronics and radio, mechanical engineering design, or electrical machines and control. Work assignments of these assistants included drafting and design of electrical and steam equipment, calculation of engineering data, electrical and mechanical testing and analysis of test results, the writing of specifications for materials and equipment, and the preparation of engineering reports.

During the war, a number of smaller companies recruited and trained within their organizations one or more women to assist engineers, especially in laboratory work. Sometimes, they were called engineering aids, sometimes scientific aids. They were usually college graduates; some were teachers. Many other firms used Engineering, Science, and Management War Training courses to supply the initial preparation required by women who had had no engineering training but who were needed to assist engineers. A 10-week full-time program and a 27-week evening program in engineering fundamentals were offered at Fenn College in Cleveland to train college women for work in the engineering departments of local firms. At Illinois Institute of Technology an Engineering, Science, and Management War Training program set up to train girls for civil service engineering aid work trained 60 women, but they were all hired away by industry before they completed the course.

Earnings and Advancement

Women who took jobs as engineering aids in industry during the war usually began at a salary of from $130 to $150 a month ($1,560 to $1,800 a year). The Federal basic salary scale for engineering aids ranged from $1,440 to $2,600. But, with overtime pay, earnings in both industry and the Federal Government were higher than the basic rates. Postwar salaries ranged from $1,600 to $2,600.

The few women who have advanced from aid or assistant jobs to those of junior engineers have usually had a college degree with considerable mathematics or science or have shown an unusual flair for engineering work. The large number of girls who have returned to college after employment as engineering aids reflects their conviction that they need more training. For a recent opening in a radio plant for which engineering aids on the staff were considered, only 1 out of 20 had the college background required for the job, and she was leaving to get a master's degree. To advance beyond the junior engineering level is virtually impossible for the girl without the equivalent of a full degree in engineering.

The Outlook

Only a few of the estimated 2,000 women who took engineering aid training during the war lost their jobs at war's end because of plant shutdowns, mainly in the aircraft industry, and they easily found positions elsewhere. Not all of them remained in engineering aid work, however. One, for example, transferred to an actuarial firm. Actually, many had already left voluntarily for marriage or further study. In fact, one company reported that young, marriageable girls had been purposely selected so that there would not be too large a residue to absorb into their regular staff following the end of the war.

Whether by accident or policy, the residue in 1946 proved to be small, probably one-fourth of those trained. Those remaining were assured of their jobs as long as they wished to hold them, but most of the companies planned to replace them with young graduate engineers as they left. Only two of the seven companies on whose special training programs of this type complete information was obtained expressed the intention of continuing to hire women for certain of these jobs. One, an aircraft company, actually hired a few women in 1946 for analytical or experimental work in the research department. Girls with at least 2 years of college including 1 year of physics were being trained by the company to do calculations, usually on the slide rule, and to make charts and plots required by office engineers analyzing particular problems. Others worked with experienced engineers as part of a team of two to eight people, reading instruments, recording

information, and assisting with simple adjustments of equipment, especially in wind-tunnel and airflow work (*25*).

Some firms in the electrical industry, as indicated earlier, had long employed women as engineering assistants or computers and planned to continue to do so. One, in 1946, had almost 400 women engineering assistants and reported difficulty in finding replacements for those who left from time to time and additional personnel for new positions of this type in design engineering. For the most part, these women in the past came from liberal arts colleges, with mathematics or mathematics and physics majors, rather than from engineering schools.

Another large electrical manufacturing company employed 45 engineering assistants in the summer of 1946, who assisted engineers or supervisors, performing technical tasks associated with the preparation for manufacture of a product in any of its phases. Twenty-two women also were employed as piece rate analysts, and two as piece rate setters, engaged in phases of timestudy engineering. Two women were inspection engineers assigned to quality-control work, devising and improving methods and facilities for testing quality of product.

At the end of 1946, partial information from the War, Navy, and other Government departments indicated that a considerable number of the women employed during wartime as engineering aids remained in the Federal service but that there was no additional demand. (For minimum requirements for a civil service position as engineering aid, see p. 5–76.)

Army Ordnance in 1947 had at least 23 women engineering aids, 20 of whom were reported by 4 different arsenals or other field installations, while 3 were in the headquarters office. Some were known to be employed by the Engineers Corps and the Signal Corps. There were 4 in the Quartermaster Corps and 1 in the Chemical Corps. In the Navy, 30 women were employed in 1947 as engineering aids in the Naval Research Laboratory, the Bureau of Ordnance, and the Bureau of Ships.

Less than a half-dozen engineering aids were employed in 1947 at the Federal Communications Commission where they worked on charts and assisted engineers in the preparation for hearings of cases in which engineering exhibits or information are presented. Eleven chemical engineering aids were employed at the Tennessee Valley Authority, and a large number of cartographic engineering aids were assigned to drafting work. The Bureau of Reclamation, with the largest number of women they have ever employed, reported 45 working as engineering aids and engineering draftsmen on plans for canals and irrigation projects. Seven women were engineering aids or in training for such positions in the United States Department of

Agriculture. Fifty-three women were employed as engineering aids and 2 as naval architecture aids by the National Advisory Committee for Aeronautics at Langley Field; one engineering aid was employed at the Committee's Cleveland Research Laboratory.

All the employers of women engineering aids, in industry and in Government, were quick to distinguish between the engineering aid and the engineer. The woman with an engineering degree has in most cases proved more satisfactory and has been absorbed more quickly and less conspicuously into the staff than has the engineering aid. All the industrial firms said they would consider an application from a woman engineer at any time, but only two firms intended to continue to hire women as engineering aids in the future.

Those who conducted the special training programs during the war were satisfied that an emergency need had been satisfactorily met but considered the cost of such training prohibitive in peace-time. Two employers felt that the publicity and attention which tended to isolate the cadettes and establish them as a special and separate group made their absorption into the staff difficult. Others said that the girls tended to ask for transfers, to express dissatisfaction with the work assigned, and to expect special treatment.

On the other hand, one or two reports from colleges indicate that some of the girls felt that they were assigned to jobs below the level of their training and left as soon as they could to return to school or to work at other jobs where they felt they could use their training more effectively. Monotony was given as the chief source of irritation on the job by engineering aids of one company after they had been on the job for 2 months. Thirteen percent of the girls, on anonymous questionnaires, checked that item. However, 93 percent said they liked their jobs most of the time. The majority of girls who commented to their colleges said they liked their work, felt well-paid, and considered their experience an unusually valuable one. Employers, too, were satisfied that the girls had done a good job.

Colleges which trained them generally praised their performance, saying they were on the dean's scholarship list more often than the average student and took more interest in their work. One college, which had never enrolled women in engineering before, reported that the women as a group did not do as well as men did, but a few excelled the average man.

Both supervisors and men engineers have been skeptical about employing women as engineering aids. The general skepticism with regard to the aid apparently remains, although a few of the outstanding girls have modified the attitude of many. An estimated 10 percent were in this unusual group which helped to break down the

prejudice against women in a number of plants where there was no previous experience in the technical employment of women in engineering departments. However, the high turn-over, the youthfulness of the engineering aid group, the additional supervision they needed at a time when experienced supervisors were scarce, and their lack of mechanical "know-how" were the principal disadvantages mentioned in connection with their employment. On the other hand, the advantages of the experiment in its effect on the attitude of engineering personnel toward women workers and in its effect on education have been pointed out by one of the personnel women who supervised a group of cadettes (*40*). There will continue to be a few openings for women as engineering aids in companies in which they have always been used or in which the war experience indicated their value on certain types of work. But, it is unlikely that many women will be employed as engineering aids in the future, especially as young graduate engineers become available. And those who are, will have little opportunity to advance unless they complete their training and become full-fledged engineers.

Draftsman as Defined in the Dictionary of Occupational Titles (*54*)

"Draftsman (professional and kindred). Prepares clear, complete and accurate working plans and detail drawings, from rough or detailed sketches or notes for engineering or manufacturing purposes, according to the specified dimensions: Makes final sketch of the proposed drawing, checking dimension of parts, materials to be used, the relation of one part to another, and the relation of the various parts to the whole structure. Makes any adjustments or changes necessary or desired. Inks in all lines and letters on pencil drawings as required. Exercises manual skill in the manipulation of triangle, T-square, and other drafting tools. Lays tracing paper on drawing and traces drawing in ink. Makes charts for representation of statistical data. Makes finished designs from sketches. Utilizes knowledge of various machines, engineering practices, mathematics, building materials, and other physical sciences to complete the drawings. Classifications are made according to type of drafting, such as draftsman, architectural; draftsman, electrical."

5–63

THE OUTLOOK FOR WOMEN AS DRAFTSMEN

Draftsmen, who do subprofessional work for engineers and designers preparing the detailed drawings from which the final product is built to exact scale, are grouped according to various gradations in the difficulty of their work. Where there is much drafting work, there is also a job below the level of the draftsman, that of the tracer who makes only simple sketches and copies final drawings on tracing cloth or paper from lay-outs and detail drawings already checked, making minor changes according to specific instructions.

Courtesy Standard Oil Co. (N. J.)

Figure 13.—A draftsman at work on some maps in the production department of an oil company.

An engineering draftsman in the lowest grade usually does detail drafting to complete engineering drawings for manufacturing or construction purposes, such as copying drawings with minor revisions, dimensioning, scaling, line locationing, preparing sectional views from lay-out drawings from given data and according to standard practices and requirements, and correcting and revising drawings by incorporating specific drawing changes, engineering change orders, shop orders, checkers' notations, and related information. A senior mechanical draftsman detailer makes complex detail drawings from sketches, lay-outs, and assemblies prepared by designers and makes important alterations to drawings as instructed. Women have been employed at all types of drafting but seldom as designer-draftsmen who create designs and supervise the making of the drawings which translate the design into a working drawing from which machinists, mechanics, carpenters, and other artisans can construct or manufacture a pattern and later the finished product accurately and without waste, whether it be a bridge, an electric iron or radio tube, a house, or part of a wheel.

Prewar Distribution

Like women engineers, a few women draftsmen before World War II were found in all the principal specializations. In 1940, according to the United States Census, they totaled 1,414, or less than 2 percent of all draftsmen (*43*). Judging from the limited data available, there were probably more women draftsmen in the architectural and civil fields than in the mechanical and electrical fields.

Only 5 of the 81 industrial firms and the 18 commercial laboratories visited in connection with this study employed women draftsmen before the war. In all, they employed less than 100 women draftsmen. However, architectural and construction firms were not represented in the sample, and the majority of women draftsmen in private industry were believed to be employed with firms of that type before the war.

In 1938, the estimated number of draftsmen in the Federal civil service was only 5.200, of whom 160, or 3.1 percent, were women. In 1940, 6 women were appointed to probational or permanent jobs under the civil service (*42*). The United States Coast and Geodetic Survey, the United States Geological Survey, the United States Department of Agriculture, the Tennessee Valley Authority, and the War and Navy Departments were among the agencies employing at least 1 woman in such work before the war. Unlike women engineers, women draftsmen were employed in almost every agency in which drafting work was important, although they were few in number in any one agency. On the other hand, a few agencies like the Bureau of Rec-

lamation in the United States Department of Interior did not employ women draftsmen until World War II.

Wartime Changes

During the defense period which preceded the war, the United States Civil Service Commission began to recruit engineering draftsmen for many types of drafting including aeronautical, architectural, civil, electrical, heating and ventilating, lithographic, mechanical (machine design), ordnance, plumbing, radio, structural, topographic, and statistical. Industry, too, sought additional draftsmen as the production of new war materials increased the need for draftsmen beyond the approximately 80,000 employed in 1940 (*43*). Even high school girls who had had mathematics and a little mechanical drawing were hired by some plants, according to school placement bureaus. The need for draftsmen became so great during the war, that special courses to train draftsmen were set up in colleges and technical institutes under the Engineering, Science, and Management War Training Program. The largest number of persons enrolled in any individual course under that program was in engineering drawing and descriptive geometry. In all, 169,313 were enrolled, many of them women (*61*). A number of special courses were set up to train women draftsmen for particular industries.

A course at Johns Hopkins University, for example, trained high school graduates with at least 2 years of mathematics or its equivalent for engineering drafting in the aircraft industry. The 8-week full-time course covered shop mathematics (arithmetic, algebra, trigonometric functions, and the solution of the right triangle and shop problems); aircraft nomenclature and Army, Navy, and industrial standards and specifications for airplane construction; and engineering drawing and blueprint analysis (including use of drawing instruments, sketching, standard projection, cross sections, and the development of patterns). A California aircraft company arranged for the training of 313 high school graduates (with 2 years of mathematics) in nearby colleges in 12 groups in a 12-week program covering algebra, plane geometry, trigonometry, descriptive geometry, aircraft drafting, and aircraft materials and process. Two-thirds of those trained were women, who were assigned, like the others, to work as draftsmen in the beginning grade. At first the turn-over was very high, but better selection was done with the later groups, and turn-over was reduced among them. Another aircraft company trained more than 200 women in 4-month full-time courses at a technical school. A radio manufacturing company in a 5-month course trained more than 70 women high school graduates as detailers, preferring those with mathematics background and some physics and art work.

Many women also took Engineering, Science, and Management War Training courses in cartographic or topographic drafting or photogrammetry (the making of maps from aerial photographs) in order to qualify for civil service positions. In the United States Coast and Geodetic Survey and the United States Geological Survey, more than 350 women were employed in such work during the war; and in the Army Map Service, there were many more.

The duties of women employed in such positions varied with their training and experience. For example, at the United States Coast and Geodetic Survey, there were more than 50 women with some training in drafting employed under the title "engineering draftsman" who did fine line drafting of charts on acetate, a transparent plastic that is later photographed for reproduction. This work included the drafting of contours, streams, roads, and other topographic features, each drawn to specified width and in accurate placement. Women with additional training were given more responsible positions. One woman, for example, made the final criticism of large scale topographic maps to determine if each map met the specifications adopted as standard for the national mapping program. She was a former artist who took a college course in photogrammetry and mathematics at the outbreak of the war.

Women who entered as trainees with no prior experience in drafting were given instruction in the training school maintained at the Survey for new draftsmen. There, two women, serving as assistant instructors, taught the fundamentals of cartographic drafting and the specialized methods used in the Survey. One woman who completed the course ultimately worked on the compilation of instrument approach and landing charts from field surveys and aerial photographs, to be used by aircraft in approaching and landing at airfields in the United States.

Women were engaged in drafting work in other agencies such as the Tennessee Valley Authority, the Department of Agriculture, and the Civil Aeronautics Administration. The Engineers Corps, the Signal Corps, and Army Ordnance in the War Department also trained women as draftsmen.

As in industry, Engineering, Science, and Management War Training programs were used to supply initial training which was often supplemented by on-the-job training. Rock Island Arsenal, for example, gave 2 hours of classroom training weekly for 6 months to its draftsmen. The course covered blueprint reading (angles, measurements, dimensions, title and notes) and drawing (titles, lettering, use of T square and angles, straight lines, compass exercises, tangent arcs, dotted lines, section lines, sketching in orthographic projection, reading by modeling, auxiliary projection). On the other hand, a few

women with prior experience or training were placed immediately on the job and trained by supervising draftsmen. A young woman with a degree in household administration but with an additional 30 semester hours in landscape architecture, for example, was hired early in the war to do drafting on building revisions for Army cantonments. She also had the responsibility for checking purchase orders against lists of required equipment for each building or base in a certain district.

Some of the women who entered military service were also trained for and assigned to drafting work. Next to that of medical technician, the principal technical assignment of WAC's was with the Engineer Corps and Ordnance, where they worked as mechanical draftsmen, lithographic draftsmen, and tracers. In 1944, draftsman (mechanical, structural, electrical, topographic) was listed among the classifications in which additional WAC's were needed. In the Marine Corps Reserve, 12 women were assigned as draftsmen. In the WAVES, enlisted women seamen prepared and corrected maps and charts. For example, as draftsmen in the Navy's Hydrographic Office they compiled and revised hydrographic charts and assisted in the selection of source material for the preparation of such charts.

A number of civilian women were trained in drafting courses offered by the public vocational schools. In the all-day trade courses in drafting, between 200 and 300 women were enrolled in each of the war years as compared with 3 women in 1939–40 and 8 in 1940–41. Although many of these were trained as tracers or detailers rather than as full-fledged draftsmen, such beginning positions put them in line for drafting jobs if they took further training or showed unusual aptitude. As noted earlier many engineering aids were assigned to the more difficult drafting work.

Earnings and Advancement

The war needs increased the salary scale of draftsmen in Government and in industry. Scattered information indicates that women in industrial drafting jobs averaged about $2,500 a year in 1947; the range was from $1,500 to $3,600. Chief draftsmen or designer-draftsmen in large firms earned as much as $4,000 to $5,500, but women almost never reach such positions.

In the Federal Government, beginning salaries for draftsmen of differing levels of training or experience varied from $1,440 to $2,600 before the war. During the war, with overtime pay, earnings on these salaries ranged from $1,752 to $3,163. In 1947, the basic entering salaries for the same jobs ranged from $1,954 to $3,397.

Advancement from the subprofessional level of draftsman to professional status as an engineer, architect, or cartographer is rare,

except for those who already have or acquire later the academic training usually required for professional status. But women of unusual ability in subprofessional positions in the Federal Government have sometimes been promoted to supervisory positions which do not require professional status.

The Outlook

The large number of persons who trained for drafting work during the war, in and outside of the armed forces, in relation to the reduced postwar need for draftsmen (as compared with that created by war production) suggests that the supply of draftsmen will for some time be greater than the demand, although there may be shortages in certain specialized types of drafting. The exceptionally large number of women enrolled in engineering schools also indicates that many of them, if they do not complete their engineering courses or if there is an oversupply of engineers, are potential draftsmen.

This darkens the outlook for women in drafting work. The situation has already been reflected in more reports of open hostility to women on the part of men in this field than in others in which women are an even smaller minority. One outstanding girl working in a machine-tool plant was urged by the chief engineer to stay on, but the men draftsmen, older men for the most part, literally drove her away by accusing her of "taking a man's job away." She left to train for teaching. A university placement officer reported that girls leave drafting because the men "make life miserable for them." The turnover of women in drafting during the war appeared to be unusually high, perhaps for this reason.

However, some women have so excelled in the neatness and appearance of their drawings and have proved so painstaking on the simpler phases of the work that many employers say they will always employ women. A Pittsburgh firm after releasing women draftsmen at the end of the war has called some of them back. However, the volume of returning servicemen seems to be unusually high in drafting work, and some firms were not able to keep any women draftsmen even though they wished to, because of their obligations to former employees returning from military service. In the 81 large industrial firms and 18 commercial laboratories visited in connection with this study, 20 employed one or more women in 1946, the approximate total approaching 300. Although the number was considerably under the estimated 1,000 to 1,500 employed by these same firms during the war, it was considerably more than the prewar number. Actually 15 of the 20 had never employed women as draftsmen until World War II. Four of the twenty intended to replace women

Courtesy University of Cincinnati

Figure 14.—Mechanical drafting in a machine tool company.

with men as soon as the women left voluntarily. Although women draftsmen were usually a small minority of the drafting group, in one company the only draftsman employed was a woman who did all the drafting for the laboratory and was outstanding.

Early in 1947, the Federal Government employed at least 380 women draftsmen in 12 different agencies reporting statistics to the Women's Bureau. (For minimum requirements for beginning civil service position as engineering draftsman, see p. 5–77.) The largest numbers were in the United States Geological Survey, the United States Coast and Geodetic Survey, and the United States Department of Agriculture. The Map Division of the State Department and the Bureau of Reclamation in the United States Department of Interior employed another 231 women who were draftsmen, engineering aids, or cartographers.

The full extent of the drop from the war peak of employment in this field cannot be measured because statistics are lacking. But an idea can be gained from the following facts:

The Army Air Forces, which employed 570 women draftsmen in October 1944, employed none in 1947.

The Tennessee Valley Authority reported 253 women engineering aids and draftsmen in 1943 as compared with 186 in 1947.

The Army Engineer Corps employed 444 women draftsmen in 1943 and a negligible number in 1947.

The United States Coast and Geodetic Survey, which employed 158 women as engineering draftsmen during the war, had less than half that number in 1947.

Among the agencies which employed women draftsmen during the war but had none employed in 1947 are the Moffett Field Station of the National Advisory Committee for Aeronautics and the United States Maritime Commission. The only report which indicated an increase rather than a decrease was that from the Quartermaster Corps, where 10 women draftsmen were employed in 1947 compared with 2 during the war peak.

In the future as in the past, there will be some women employed as draftsmen in industry and in Government, and a few more companies and a few more agencies than before the war are likely to employ them. In 1945–46, more than 330 women were enrolled in drafting courses in all-day trade courses in public vocational schools, where a demand for their services was still reported. However, competition for jobs is likely to become keen by 1950, perhaps a little less so in civil and architectural drafting where the demand is greatest and the war-created supply less. In 1947, a public vocational-technical school in a large eastern city reported a good demand for young women who completed their 2-year post-high-school course in architectural drafting. Even so, it was reported that the young women had to be considerably better qualified than the young men graduates to be sure of placement. Women have a special contribution to make in home planning and design. City planning work, where mapping, charting, and freehand drawing are involved, has also been suggested as a suitable field for women, although this relatively new field is largely dominated by men (*9*). A few women who became cartographic draftsmen during the war have secured positions in private map publishing houses, which produce school maps, road maps, or commercial maps of various types. The interest of the lay public in globes, atlases, and maps has increased map production, providing more opportunities for women in drafting work. The possibility of transfer from one type of drafting to another, and even from applied art work to drafting, is relatively easy at the beginning levels, since a few months of specialized training or experience can supply the additional knowledge needed.

The extensive use of women artists as draftsmen during the war suggests that girls who major in art take drafting work too. The increasing use of diagrams and perspective illustrations to supplement engineering drawings makes this combination market-

able. Statistics, home economics, and interior decorating are other fields with which drafting training might well be combined, according to one educator (*68*). Too long has drafting been considered almost exclusively a man's field. There is nothing in the nature of the work that is prohibitive to women, but because of the prevailing reluctance to accept women in this work the woman who wants to become a draftsman will do well to develop a specialty which will give her an advantage in obtaining employment in this field.

Surveyor as Defined in the Dictionary of Occupational Titles (*54*)

"Surveyor; chief of party; party chief (professional and kindred) 0–64.10. Supervises, directs, and is responsible for the accuracy of the work of an engineering survey party engaged in determining the exact location and measurements of points, elevations, lines, areas, and contours on the earth's surface for purposes of securing data for construction, map making, land valuation, mining, or other purposes; calculates information needed to conduct survey from notes, maps, deeds, or other records; keeps accurate notes, records, and sketches of work performed or data secured; verifies by calculations the accuracy of survey data secured; adjusts surveying instruments to keep them accurate, or oversees the adjustments by Instrument Man as a regular part of his duties. Different branches and types of surveying require special techniques gained through experience or training, and Surveyors are specifically designated by title according to the type of surveying work performed, as surveyor, land; surveyor, marine; surveyor, mine; surveyor, railroad; surveyor, topographical."

THE OUTLOOK FOR WOMEN AS SURVEYORS

Many civil engineers enter their profession by serving a sort of apprenticeship as a surveyor or member of a survey party, and all civil engineers receive training in surveying as part of their engineering course. However, many surveyors are high-school graduates (geometry and trigonometry are essential) who have been trained on the job, either as an axman who clears the way in rough territory, or as a rodman or chainman who handles the pole for sighting or the measuring tape and learns gradually to use surveying instruments to measure and record data on boundary lines and elevations and to prepare contour maps.

Of the 13,344 surveyors employed in the United States in 1940 according to the United States Census, only 101, or 0.8 percent, were women (*43*).

Most States (32 in 1942) provide for the licensing of surveyors. An examination or graduation from an approved school or college of surveying supplemented by a specified period of surveying practice, varying from 1 to 6 years, are the usual minimum requirements (*47*). Those engaged in independent practice or as chief surveyors usually obtain such licenses; employees working under a licensed surveyor whose stamp of approval can be placed on their work do not find it necessary to have one.

During the war, the curtailment of building reduced the demand for surveyors except for military and certain other essential wartime construction. Servicemen, for the most part, were used for Army surveying work. Almost no women, either in military or civilian service, were used as surveyors, although the United States Coast and Geodetic Survey reported that a few women were employed on some of their surveying parties as recorders. They were usually residents of the areas in which they were employed or relatives of male members of the party. Except in cases of this sort, there is almost no opportunity for women in this field.

APPENDIX

Minimum Requirements for Membership in the Principal Engineering Organizations

American Institute of Chemical Engineers	American Society of Civil Engineers	American Institute of Electrical Engineers	American Society of Mechanical Engineers	American Institute of Mining and Metallurgical Engineers	National Society of Professional Engineers
Regular member Age: 30 years or over. Experience: 5 to 10 years in practice or teaching of chemical technology depending upon education with specifications as to number of years of responsible directing work. *Associate member* Age: 21 to 30 years. Experience or education: Bachelor's degree in chemical engineering or any other bachelor's degree plus 1 year experience in chemical technology or 5 years experience in chemical technology.	*Regular member* Age: 35 years or over. Experience: 12 years experience in engineering or architecture for 5 years of which he must have been in responsible charge of important work proving ability to conceive and design engineering works as well as to direct them. *Associate member* Age: 27 years or more. Experience or education: 8 years in engineering or architecture proving ability to direct engineering works. *Junior member* Age: 20–33 years. Experience or education: 4 years or recognized degree in engineering qualifying for subprofessional work.	*Regular member* Age: 27 years or over. Experience: 5 years in practice of electrical engineering or the teaching of electrical engineering or electrical science or as a qualified executive or scientific contributor in electrical or closely allied work. *Associate member* Age: 21 years or more. Experience or education: Currently employed as an electrical engineer or teacher of electrical subjects or doing responsible work with an electrical enterprise.	*Regular member* Age: 30 years or over. Experience: 9 years in engineering or teaching of which 3 must have been in responsible charge of work showing ability to design as well as direct important work. *Associate member* Experience or education: Graduation from a recognized school of engineering or the equivalent.	*Regular member* Age: 27 years or over. Experience: 6 years in practice of engineering, mining, geology, metallurgy, or chemistry, 3 years of which must have been in responsible charge of work. *Associate member* Age: Not specified. Experience or education: Interested in or connected with mining, geology, metallurgy, or chemistry. *Junior member* Age: Under 33 years at time of application. Experience or education: Qualified to hold subprofessional job in one of the fields indicated above.	*Regular member* Registration: Registration as a professional engineer in the State in which he resides or practices. Usual State requirements are 8 years of practical experience in professional engineering or graduation from an approved engineering school plus 4 years practice in engineering and the passing of an examination.

Minimum Education and Experience Requirements for Application for Beginning Federal Civil Service Position as Junior Professional Assistant with Option as Engineer ($2,644 a year)

(As taken from Civil Service Announcement No. 75, issued October 14, 1947, closed November 4, 1947.)[1]

Optional branches of engineering.—Aeronautical, chemical, civil, electrical, mechanical, metallurgical, mining, naval architecture, and others.

The registers resulting from the examination for engineer will be used to fill all types of professional engineering positions at this level. Applicants must have successfully completed one of the following:

A. A standard professional engineering curriculum leading to a bachelor's degree in a college or university of recognized standing; or

B. Four years of successful and progressive experience in technical engineering. This experience must show a thorough knowledge of the fundamental physical and mathematical sciences underlying professional engineering, and a good understanding (both theoretical and practical) of the engineering sciences and techniques, and their applications to the branch of engineering for which the competitor is applying. The experience must show that the applicant possesses an understanding of engineering equivalent to that which would have been acquired through successful completion of a standard engineering curriculum in a college or university of recognized standing; or

C. Any time-equivalent combination of (A) training and (B) experience above.

Minimum Education and Experience Requirements for Application for Federal Civil Service Position as Engineering Aid ($1,822 to $2,644 a year)

(As taken from Civil Service Announcement No. 17, issued August 29, 1946, closed October 10, 1946.)[1]

A. Experience—Except for the substitution of education provided for below, persons who apply for an engineering aid position must have had experience in engineering, as follows:

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[1] For more complete and later information, consult latest announcements of the Civil Service Commission posted in first- and second-class post offices.

Grade and salary	Total experience	Specialized experience
SP–2, $1,822	3 months	None.
SP–3, $1,954	1 year	3 months.
SP–4, $2,168	2 years	6 months.
SP–5, $2,394	3 years	9 months.
SP–6, $2,644	4 years	9 months.

The Specialized Experience, which may be included in the total experience required, must have been in a specific branch of engineering. This experience must have been at least equivalent in difficulty and responsibility to the work of the grade next below that for which an applicant is rated.

B. Substitution of Education for Experience—Pertinent undergraduate or graduate study in engineering, completed in a college or university of recognized standing, may be substituted year for year for the appropriate required experience. Pertinent study completed in an institution above high-school level will receive appropriate credit in accordance with the courses shown in an application.

Minimum Experience, Education, and Work Sample Requirements for Application for Beginning Federal Civil Service Position as Draftsman ($1,954 a year)

(As taken from Civil Service Announcement issued July 15, 1946, closed August 12, 1946.)[1]

1. Sample of work:

   At least one sample of the applicant's drafting work must be submitted with the application.

2. Experience:

   Except for the substitution of education provided for below, applicants must show, as a minimum, 1 year of total drafting experience and 3 months of specialized experience in the option he chooses. Options are: aeronautical, architectural, civil, electrical, map, mechanical, ship, statistical, structural, general. The record must show that he has the ability to perform completely the duties of the position.

3. Substitution of education for experience:

   Substitutions may be made for the required experience described above, as follows:

   (*a*) Successfully completed study at a college or university of recognized standing in architecture or a branch of engineering

[1] For more complete and later information, consult latest announcements of the Civil Service Commission posted in first- and second-class post offices.

pertinent to one of the optional branches listed above may be substituted, year for year, for the required experience.

(*b*) Pertinent residence study, which included one or more courses in drafting, successfully completed at a college or university, a technical institute, a school specializing in drafting, or a technical high school may be substituted for required experience. The amount of experience for which this education may be substituted will be determined by the type of institution attended, the content of the courses, and the applicability of such study to the duties of the position. In no case, will applicants be permitted to qualify solely on the basis of study, unless such study has included courses in drafting sufficient to demonstrate ability to perform the duties associated with drafting positions of the grade under consideration.

(c) Pertinent specialized training or experience acquired while serving in the armed forces of the United States will be accepted on the same basis as civilian training or experience.

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