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FOREWORD

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
February 7, 1956.

Hon. CLINTON P. ANDERSON,
United States Senate.

DEAR SENATOR ANDERSON: As a result of the past activities of the Subcommittee on Research and Development, I have become increasingly concerned about the problem of a shortage of trained scientific manpower which is, in my opinion, adversely affecting the speed at which not only our atomic program but other highly important defense programs are moving.

Due to my increasing concern on this matter I have on my own initiated a rather comprehensive and detailed survey of this problem. In addition to my own work I have had the cooperation of the Legislative Reference Service of the Library of Congress which has resulted in an extremely interesting study of the rate and types of advanced scientific degrees being granted at the present time by academic institutions as well as the past history of the awarding of such degrees. In addition to the foregoing my own office staff has assisted in the preparation of this material.

I feel that this is an extremely interesting study of this problem and is of widespread interest to the point that I would like you to consider favorably its publication as a Joint Committee print. I feel that this study has flowed directly out of my interest as a member of the Joint Committee and would be of benefit to all the other members knowing that many of them share my deep concern on this problem.

If you feel that this can be done I will make the manuscript available to the committee staff for printing purposes.

I very much appreciate your thoughtful consideration of this request.

Sincerely yours,

MELVIN PRICE,
Chairman, Subcommittee on Research and Development.

PREFACE

It should be no secret that the United States is in desperate danger of falling behind the Soviet world in a critical field of competition—the life-and-death field of competition in the education and training of adequate numbers of scientists, engineers, and technicians. But although it is not a secret, the facts have not sunk into the public mind.

Many warnings have been issued, many speeches have been made. They have been reported. But they have not sunk into the mind of the administration and the Congress, even when the warnings came from eminent administration sources. I suggest that the time has come for strenuous measures, for action by the Government, by business corporations, and universities, for what might be called a "crash program" to increase swiftly and steadily the number of adequately trained American scientists and engineers.

The study that follows was prepared, at my request, by Harris Collingwood of the Library of Congress staff. It is a scholarly study that draws on trustworthy documents and reports to describe the results of the enormous effort by the Russians in the training of engineers and scientists and the unhappy effects of our own careless lack of effort in the area.

There is no point in my doing more than summarize the gloomy statistics. The Russians, ever since their 1917 revolution, have put constantly increasing stress on the education of competent technicians, including topflight scientists and engineers, to sustain their drive for industrialization and a truly modern military machine. We have indulged in laissez-faire policies, ignoring the decline of interest among high-school students in mathematics and basic science, offering no incentives to university students to turn themselves toward the fields of technical study in which we need experts to sustain our place in the world.

We are scarcely even with the Soviet Union as regards numbers of engineers and have only a slight lead in numbers of scientists. From here on, the Russians show promise of widening the difference—and to our disadvantage. In 1954 we graduated only half as many college-trained specialists in engineering and science as we did in 1950. In the same year the Soviets turned out more than twice as many as we. Allen Dulles, Director of the Central Intelligence Agency, recently warned that in this present decade the Soviet Union will graduate 1,200,000 university students in the basic physical sciences while we will graduate only 900,000.

Qualitatively the work of the Russians in pure science, applied science, and engineering has always been of high character. It would be a major blunder to imagine that the Soviets lag behind us as abstract thinkers about the universe or as practitioners of theories. The Russians blunder when they insist on a doctrine of genetics that temporarily appears to suit Communist dogma. They don't commit blunders in building a hydroelectric project or a bridge, in mass-producing a swift jet bomber, in testing their nuclear weapons and building their stockpile.

Our problem is what to do about the situation. The facts show that we must do something quickly, that we must not simply wring our hands and talk about the dangers. The dangers are immediate and real. There is a startling correlation between a nation's industrial power and standard of living—and therefore its strength in self-defense—and the size and quality of its reservoir of trained scientific and technical manpower.

I suggest that the Federal Government must take the initiative. Who or what else can? A decisive Federal program can stimulate the cooperation needed from all sectors of our national life.

One way to emphasize Government determination to meet the requirements would be to appropriate Federal funds to expand the science departments and engineering schools of the universities and to provide scholarships for bright young high-school graduates willing to enter these fields. I think this is a prime requisite.

I recognize that the question of general Federal aid to schools is a controversial subject. I have my own opinion in this field, although I am not a member of the House Committee on Education and Labor. I am talking, however, about specific needs of our country for well-educated scientists and engineers, and I am a member of two House committees that have much to do with national defense. I suggest we could reach agreement that, since it is a constitutional Federal function to provide for the common defense, Federal spending is proper to provide enough well-trained engineers and scientists to sustain our security in an age of great scientific "breakthroughs."

Give well-qualified high-school boys and girls the assurance that they have a chance for university education and good professional careers, and they will turn their attention to preparatory courses they need in the science field. High-school and college teachers will gain encouragement from the fact that the Government recognizes the importance of their work. There will be more such teachers and more students will flock to their classes.

Recognition of an imperative need by the Government would encourage corporations, alumni groups, and individual philanthropists or foundations to sustain the effort.

Many corporations already are giving a limited number of scholarships in science to likely boys and girls in high school. The help wanted columns of our newspapers are crowded with pleas for competent technicians, capable of intricate and rewarding work in keeping the Nation well prepared with modern weapons of defense. The trend can be stimulated by proper Federal action and by evidence that the Federal Government means more than lip service in talking about our need for a great increase in our scientific and engineering manpower.

The emphasis must be on Federal leadership because nothing else will do. Only the Federal Government has the resources and prestige to produce a swift new emphasis on the training of an adequate number of qualified young people in the engineering and scientific fields.

MELVIN PRICE,
Chairman, Subcommittee on Research and Development.

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ENGINEERING AND SCIENTIFIC MANPOWER IN THE UNITED STATES, WESTERN EUROPE, AND SOVIET RUSSIA

I. INTRODUCTION

The people of the United States have recently learned that universities and technical institutions in Soviet Russia are graduating engineers in numbers some two and a half times greater than are similar institutions in the United States. We have also been informed that many of the Russian engineers are in no sense inferior to our own.

As it stands—

points out Dean John R. Dunning, of the Columbia University School of Engineering—

nothing can be done to prevent the Russians from gaining on us in scientific and technical manpower at a ratio of 2 to 1. Already we have lost the battle of engineering manpower—at least in numbers.

The Russians have been outproducing us, according to Dean Dunning—

to the point where their total number of engineers is now essentially the same as ours, but on the master's and doctoral levels they appear to have been giving degrees to probably 3 or 4 times as many as we have * * * From the best analysis we can make, it would appear that the Soviets are equal to us; sometimes they're a little behind, but all too often they actually seem to be ahead of us.[1]

The problem has aroused the interest of numerous responsible agencies and individuals. Several reports on some of its phases have appeared in print, and others are in preparation. To the end that Members of Congress may have the benefit of the facts and ideas thus far assembled, the following report has been requested.

The report deals with the situation as it affects the United States, the free countries of the western bloc in Europe, and Soviet Russia. No attempt was made to include material from Canada, or from the American countries south of the Rio Grande. Neither was consideration given the Russian satellites or the other countries of Asia, Africa, or Australia.

In terms of the three great political areas mentioned, the problem is considered in terms of the present availability of scientists and engineers and the backlog of trained individuals now active in the economy of these countries, the numbers being graduated from the universities and colleges, characteristics of the educational preparation in the several countries, and the extent to which high schools and other secondary schools are preparing young people for university and college work basic to engineering and scientific careers.

DEFINITIONS

As considered in this report, an engineer is a person who has a specialized training at the baccalaureate level or higher, in recognized fields of engineering, and who is employed, or qualified for employ-

[1] The Struggle for Engineering Leadership, by John R. Dunning, Mechanical Engineering, March 1955, pp. 210–211.

ment, in a field of specialization above the level of what is described as a technical supporting function. Civil, mechanical, chemical, and electrical engineers are expanded to include aeronautical engineers, and those in military and naval science. Some of the European universities include under "applied science," those who are identified as engineers in the United States.

Moreover, it should be borne in mind that many jobs held by engineers in Russia are competently handled in this country by experienced persons without a formal training in engineering.

The terms "scientist" and "natural sciences" are not subject to sharply defined or agreed upon definitions. Generally speaking, a "scientist" is a person who has received training at the baccalaureate level or above, and who is employed or qualified for employment in his field of specialization. The term "natural sciences" includes mathematics, chemistry, physics, geology, geography, meteorology, and such subjects as agriculture, forestry, and biology.[2]

"Graduate," as applied to either engineers or scientists, is interpreted as covering persons who acquire a first degree in one of the various categories of these two areas, and also those who acquire a subsequent or additional degree, diploma, or suitable certificate. Such an interpretation must necessarily result in some degree of duplication. Persons who receive a bachelor's degree in 1 year may be counted again in a following year when a higher degree is conferred. The extent of this duplication will usually be apparent, however.

SPECIALIZED FIELDS OF TRAINING AND EMPLOYMENT

The major divisions considered in this report, include the following subjects:

I. Engineering (applied sciences):
- (*a*) Civil engineering, including architecture and building.
- (*b*) Chemical engineering, including fuel and petroleum technology.
- (*c*) Mechanical engineering, including aeronautical.
- (*d*) Electrical engineering, including electronics.
- (*e*) Mining engineering.
- (*j*) Metallurgical engineering, including metallurgy.
- (*g*) Others, including general engineering.

II. Pure science:
- (*a*) Biological sciences, including marine biology, biochemistry, biophysics, botany, entomology, genetics, microbiology, zoology.
- (*b*) Chemistry, including physical chemistry.
- (*c*) Physics, including astronomy and electronics.
- (*d*) Geology and earth sciences, including meteorology, geodesy and geophysics, oceanography, minerology, and petrology.
- (*e*) Mathematics.

[2] Adapted from Scientific Personnel Resources, by the National Science Foundation, May 1954, pp. 1-19, and America's Resources of Specialized Talent, by Dael Wolfle.

III. Agriculture and forestry:
- (*a*) Horticulture.
- (*b*) Bacteriology, biochemistry, botany, chemistry, entomology, microbiology, and plant physiology.
- (*c*) Animal husbandry, genetics, nutrition, animal pathology, and animal physiology.
- (*d*) Dairying.
- (*e*) Agricultural engineering.
- (*j*) Dendrology.
- (*g*) Silviculture.
- (*h*) Forest management.
- (*i*) Forest engineering, timber physics, and wood chemistry.

Medical science, dental science, and veterinary science are excluded from consideration in this report.

II. UNITED STATES

A. AVAILABILITY OF ENGINEERS AND SCIENTISTS

Of some 700,000 to 740,000 engineers and scientists in the United States, between 500,000 and 535,000, by reasonable definition, are engineers, and 210,000 to 225,000 are scientists. About 45 percent, or approximately 340,000, are currently employed in the metals, chemicals, petroleum, and rubber industries. Another 160,000 are employed in Federal, State, and local activities, 75,000 in educational institutions, and 175,000 in all other industries.[1]

Private industry provides the largest field of employment for the Nation's engineers and scientists. Well over 400,000 engineers and more than 100,000 physical and life scientists were employed by industry in January 1954. These are many more than are to be found in Government agencies, colleges and universities, and all other fields of employment taken together.

The figures include engineers and scientists in research and development activities as well as those employed in production, administration, and other types of scientific and technical work. In the following list, which the National Science Foundation considers the most comprehensive estimate ever compiled of scientific and engineering employment in American industry, nearly 34,000 scientists and engineers are classified as administrators, rather than as members of a particular profession:

Occupational group	Number employed	Percent distribution	Occupational group	Number employed	Percent distribution
Total scientists and engineers.	553,800	100.0	Physicists	7,500	1.4
			Mathematicians	6,400	1.2
			Agricultural scientists	4,200	.8
Engineers	408,700	73.8	Medical scientists	3,000	.5
Chemists	60,000	10.8	Biological scientists	2,400	.4
Metallurgists	11,300	2.0	Administrators	33,700	6.1
Earth scientists [1]	9,800	1.8	Others	6,600	1.2

[1] Dr. Howard A. Meyerhoff of the Scientific Manpower Commission believes 13,000 is a more realistic number, due to the omission in this tabulation of American earth scientists on foreign assignments and those in consultative capacities.

Source: Science and Engineering in American Industry: Preliminary report on a survey of research and development costs and personnel on 1953–54. National Science Foundation, Washington, 1955, p. 7–8.

Since 1900, engineering, scientific, and professional workers in the United States have increased almost twice as fast as the population.[2] The census of 1890 counted about 30,000 engineers in a total population of 63 million. This was approximately 1 engineer for 290 workers in manufacturing, construction, utilities, and transportation. In 1950, when the population was 151 million, engineers numbered 535,000. This was equivalent to 1 engineer for every 65 workers in manufacturing, etc.[3] A reputable manufacturer recently said:

[1] National Science Foundation, Scientific Personnel Resources, May 1955, pp. 23–26.
[2] Dr. H. H. Armsby, Scientific and Professional Manpower, Office of Education Circular 394, p. 3.
[3] A Policy for Scientific and Professional Manpower, p. 162.

We may even get to the day when you'll have less production people than engineers.[4]

Numbers and distribution of scientists and engineers by field, 1953

It is estimated that there were about 200,000 scientists and 500,000 engineers in the country in 1953.

Distribution of scientists by field, 1953

Field	Number	Percent
Total	200,000	100
Chemists	100,000	50
Agricultural and biological scientists	50,000	25
Earth scientists	23,000	12
Physicists	17,000	9
Mathematicians	7,000	3
Other	3,000	1

Source: Estimates by the National Science Foundation and the Bureau of Labor Statistics, based upon data from a number of sources, including the Bureau of the Census, professional society memberships, college and university graduations, the National Scientific Register, and others.

Distribution of doctor of philosophy scientists by field, 1953

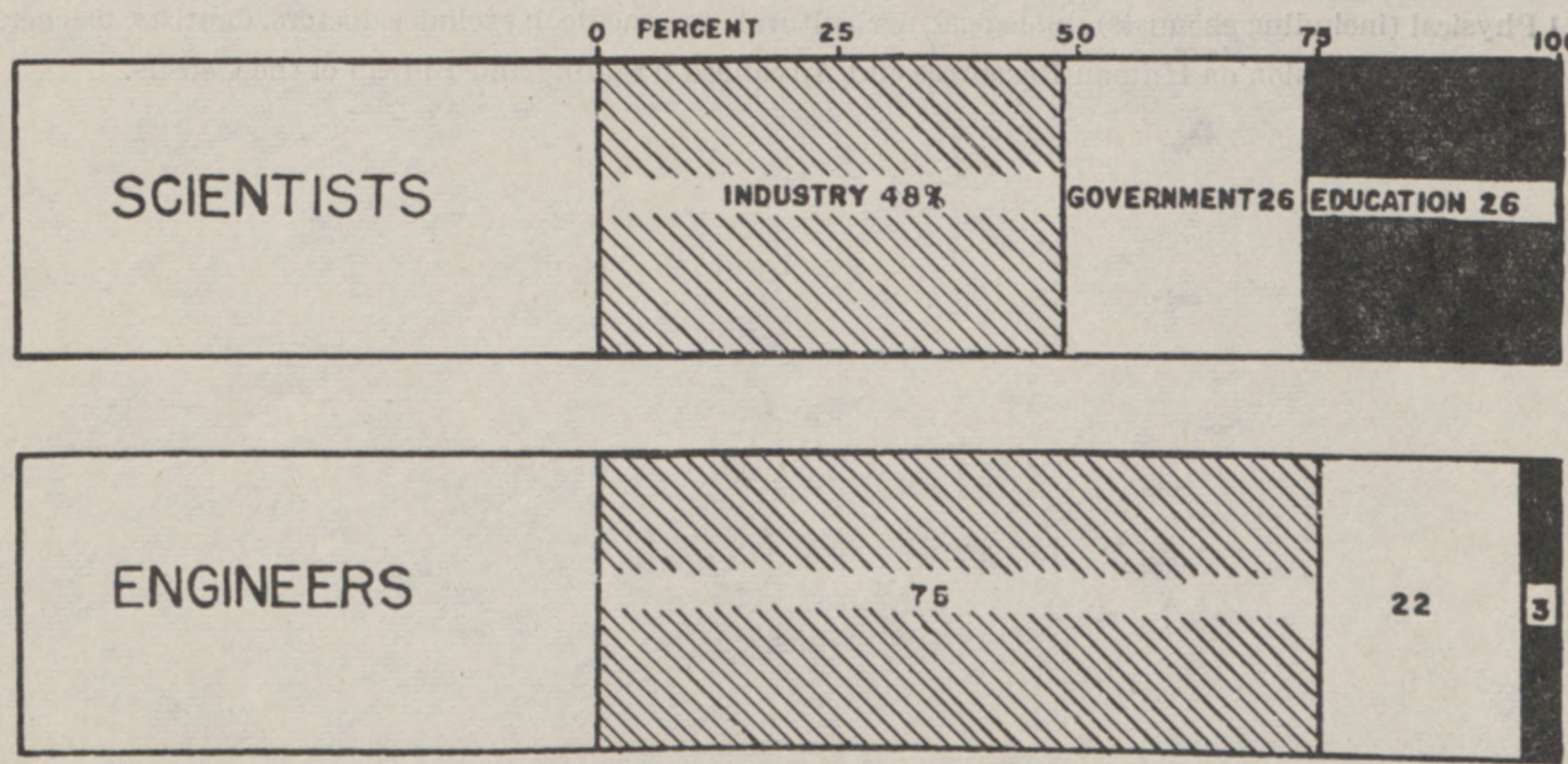
Field	Number	Percent
Total	43,550	100
Physical sciences	23,750	55
Agricultural and biological sciences	17,100	39
Earth sciences	2,700	6

Source: Commission on Human Resources and Advanced Training. Estimates include only scientists with doctor of philosophy degrees under 70 years of age.

[4] Business Week, May 7, 1955, p. 98.

FIGURE III–2

DISTRIBUTION OF SCIENTISTS AND ENGINEERS BY TYPE OF EMPLOYER 1951



SOURCE – BUREAU OF LABOR STATISTICS

NSF-1954

Total labor force and numbers of the labor force in scientific and technical occupations in the United States, 1920–50

Scientific and technical occupations				Engineers	
Year	Total labor force	Number in scientific and technical work	Percent of total labor force	Number	Percent of total labor force
	Thousands	*Thousands*		*Thousands*	
1920	42, 434	293	0. 7	130	0. 4
1930	48, 595	450	. 9	215	. 4
1940	52, 539	548	1. 0	261	. 5
1950	60, 429	1, 019	1. 7	535	. 9

Data from the Bureau of the Census.

Source: A Policy for Scientific and Professional Manpower, New York, Columbia Press, 1953.

Manpower statistics

Total United States population, 1953 census	160, 000, 000
Population, age 14 and over	116, 200, 000
Labor force, age 14 and over	66, 680, 000
Male	47, 390, 000
Female	19, 290, 000
Vital statistics:	
Birth rate, per 1,000, 1950	23. 6
Death rate, per 1,000, 1950	9. 6
Life expectancy, years, 1950	68. 4
Living college graduate engineers	529, 000
Professionally employed engineers	500, 000
Living college graduate scientists	635, 000
Professionally employed scientists [1]	200, 000
Chemists	100, 000
Graduates in sciences, 1953–57, estimated total	137, 000
Graduates in sciences who will join scientific worker force	40, 000
Employment of natural scientists and engineers:	
Metal, chemical, and rubber industries	340, 000
All other industries	175, 000
Federal, State, and civil activities	160, 000
Industrial institutions	75, 000

[1] Physical (including chemists), biological, agricultural, and medical; excludes doctors, dentists, teachers.

Source: Commission on Human Resources and Advanced Training and Bureau of the Census.

Estimated population, and total scientists, engineers, and scientists with doctor of philosophy degree, 1930–53

Year	Population [1]	Total scientists [2]	Engineers	Scientists with doctor of philosophy degree [2]	Year	Population [1]	Total scientists [2]	Engineers	Scientists with doctor of philosophy degree [2]
	Thousands	*Thousands*	*Thousands*	*Thousands*		*Thousands*	*Thousands*	*Thousands*	*Thousands*
1930	123, 077	46.0	[3] 215	6.8	1942	134, 665	110.0		20.0
1931	124, 040	49.5		7.6	1943	136, 497	118.0		21.3
1932	124, 840	52.0		8.5	1944	138, 083	125.0		22.4
1933	125, 579	53.5		9.5	1945	139, 586	128.0		23.2
1934	126, 374	57.0		10.6	1946	141, 389	133.0		23.6
1935	127, 250	61.0		11.7	1947	144, 127	137.0		24.5
1936	128, 053	66.0		12.8	1948	146, 631	146.0	[3] 350	26.0
1937	128, 825	71.0		13.9	1949	149, 188	156.0		27.5
1938	129, 825	77.0		15.0	1950	151, 683	166.0		29.5
1939	130, 880	85.0		16.1	1951	154, 360	176.0		31.5
1940	131, 970	92.0	[3] 261	17.2	1952	157, 022	188.0		33.5
1941	133, 203	101.0		18.5	1953	159, 629	200.0	[4] 500	35.5

[1] Source: 1930–45—U. S. Department of Commerce, Bureau of the Census, Historical Statistics of the United States, 1789–1945. Estimated population on July 1 each year. Figures for 1940 to 1945, inclusive, include Armed Forces outside continental United States.

1946–49—U. S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P–25, No. 71. Figures include Armed Forces overseas. Estimated population on July 1 each year.

1950–53—U. S. Department of Commerce, Bureau of the Census, Current Population Reports, Series P–25, No. 91. Figures include Armed Forces overseas. Estimated population on July 1 each year.

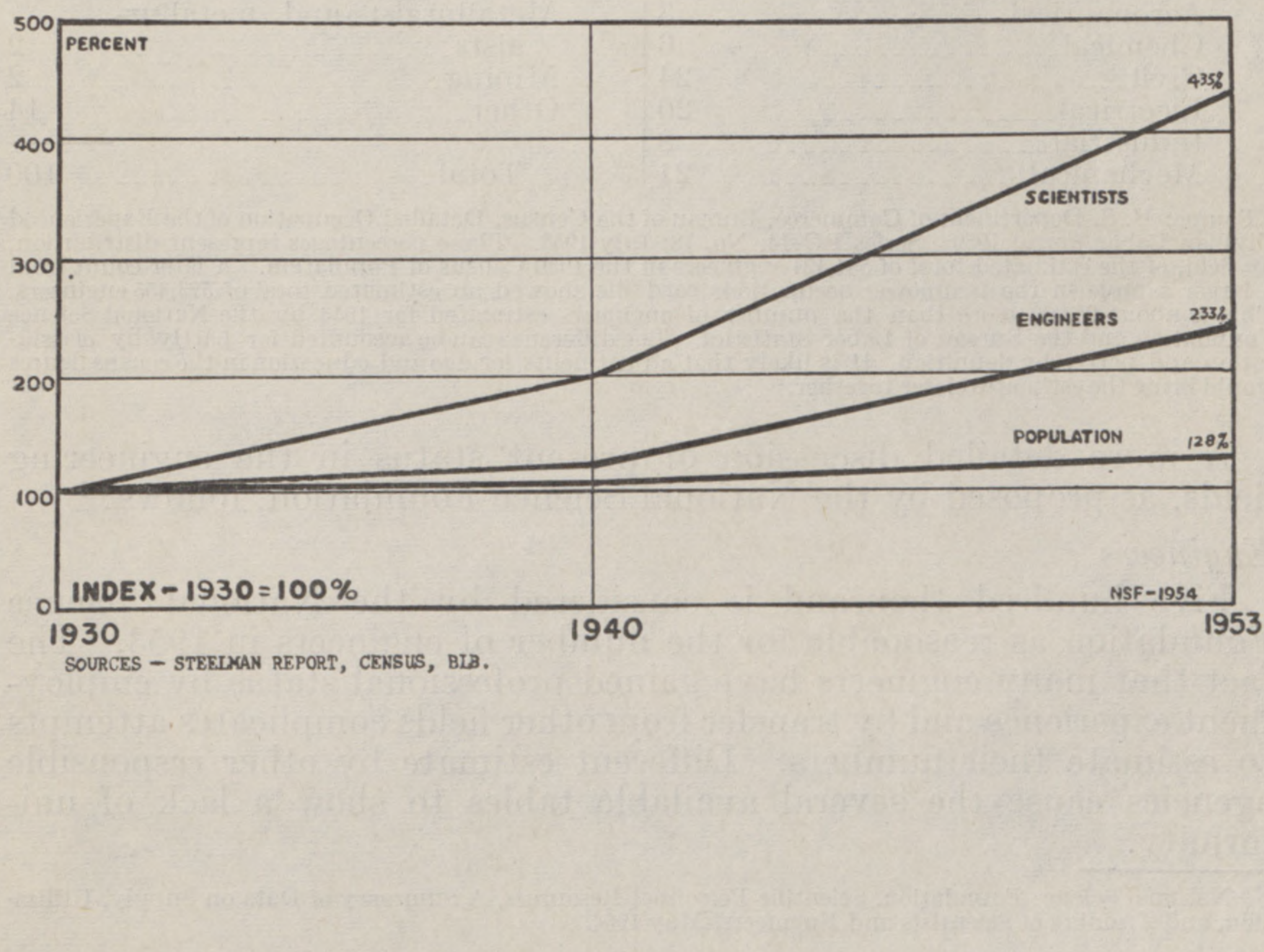
[2] Source: Manpower for Research, vol. IV of Science and Public Policy, a Report to the President, by John R. Steelman, Chairman, the President's Scientific Research Board, 1947, p. 31.

[3] Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

[4] Estimate by the National Science Foundation and the Bureau of Labor Statistics.

FIGURE II–3

RATES OF INCREASE — POPULATION, SCIENTISTS, AND ENGINEERS — 1930-1953



SOURCES — STEELMAN REPORT, CENSUS, BLB.

B. SUPPLY OF ENGINEERS

Estimated number of male engineers by field of employment, 1950 [1]

Manufacturing:			
Durable goods	176,000		
Nondurable goods	55,000		
Total in manufacturing		231,000	
Trade, finance, and service industries	44,000		
Professional service fields	31,000		
Total in trade and service		75,000	
Construction		45,000	
Utilities		25,000	
Communication		16,000	
Mining		12,000	
Transportation		11,000	
Agriculture, forestry, and fishing		1,000	
Total in private industry			416,000
Federal Government		51,000	
State and local government		42,000	
Total in government			93,000
Professors and instructors		8,000	
Others in education		5,000	
Total in education			13,000
Grand total			522,000

[1] Based on 1950 census sample. Excludes about 7,000 women, and others who have retired * * * The Engineering Manpower Commission estimates * * * 450,000 engineers in 1952 on the basis of its correction of census data.

Percentage distribution of engineers by field, 1950

Field:	Percent	Field—Continued	Percent
Aeronautical	3	Metallurgist and metallurgists	2
Chemical	6	Mining	2
Civil	24	Other	14
Electrical	20		
Industrial	8		
Mechanical	21	Total	100

Source: U. S. Department of Commerce, Bureau of the Census, Detailed Occupation of the Experienced Civilian Labor Force: 1950. Series PC-14, No. 18; July 1953. These percentages represent distribution, by field, of the estimated total of 534,424 engineers in the 1950 Census of Population. A later count from a larger sample in the manpower occupations card file showed an estimated total of 523,455 engineers. This is about 25,000 more than the number of engineers estimated for 1953 by the National Science Foundation and the Bureau of Labor Statistics. The difference can be accounted for partly by classification and partly by definition. It is likely that adjustments for age and education in the census figures would bring the estimates closer together.

A more detailed discussion of present status in the engineering fields, as proposed by the National Science Foundation, follows: [5]

Engineers

Five hundred thousand is considered by the National Science Foundation as reasonable for the number of engineers in 1953. The fact that many engineers have gained professional status by employment experience and by transfer from other fields complicates attempts to estimate their numbers. Different estimate by other responsible agencies cause the several available tables to show a lack of uniformity.

[5] National Science Foundation, Scientific Personnel Resources, A Summary of Data on Supply, Utilization, and Training of Scientists and Engineers, May 1954.

Chemical engineers

In 1951, between 35,000 and 40,000 chemical engineers were employed in the United States. Of these, 92.3 percent were employed by private industry, 3.8 percent by educational institutions, and 3.9 percent by Federal, State, and local governments (table IV–94).

Demands for chemists and chemical engineers continue unabated, according to Dr. B. R. Stanerson, in the Chemical and Engineering News for June 13, 1955. Only in the fall of 1946 and the spring of 1947 has the employer-applicant ratio approached the present situation. Then postwar conditions has so reduced the number of recent graduates available for positions as to cause a scramble for technical personnel.

The recent report supports a prophecy by Dr. Joel H. Hildebrand, printed in the same magazine for December 7, 1953, when he cited a deficit of 12,000 in the supply of available chemists and chemical engineers, and estimated the shortage might reach 49,000 by 1955.

Basic to this continued shortage is the observation that thus far no limit has been reached in the discoveries capable of being made in chemistry. And each discovery creates more work for chemists. To this can be added the observation by Dean George R. Harrison, of the Massachusetts Institute of Technology, that the chemical industries have grown fourfold in economic importance since 1950. Meanwhile, the number of chemists and chemical engineers has not even doubled.

According to Dean Harrison:

> About half of all chemists are employed in research and development jobs, so that their importance in the chemical industry, which is rapidly approaching the steel industry and exceeds the automotive industry in magnitude and national importance, far transcends that of the ordinary productive worker. This situation is additionally complicated by the fact that the Government has increased its employment of professional chemists over the past decade from 15 percent of the total number to nearly one-third.

TABLE NO. IV–94.—*Earned degrees conferred in chemical engineering by year, 1947–48 through 1954–55*

Academic year	Bachelor's degrees	Master's degrees	Doctor's degrees
1947–48	3,661	900	72
1948–49	4,206	680	125
1949–50	4,506	699	173
1950–51	3,707	740	171
1951–52	2,857	587	168
1952–53	2,258	431	147
1953–54	2,042	445	133
1954–55	2,027	683	141

Source: U. S. Office of Education.

MECHANICAL ENGINEERS

TABLE NO. IV–95.—*Estimated number of mechanical engineers by decennial intervals, 1910–50*

1910	15,385
1920	39,950
1930	57,617
1940	95,346
1950	171,574

Sources: 1910–40, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. 1950, U. S. Department of Commerce, Bureau of the Census, unpublished, unadjusted estimate from 1950 census of population.

TABLE No. IV-96.—*Percentage distribution of mechanical engineers by industry, 1946*

Total	100.0
Construction	2.5
Manufacturing	67.6
Transportation	1.7
Communication	1.5
Utilities	3.5
Government	10.5
All other	12.7

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV-97.—*Percentage distribution of mechanical engineers by function, 1946*

Administration and management	34.3
Consulting	5.7
Manufacturing and production	10.2
Design, development, and research	39.0
Sales	5.7
Other [1]	5.1

[1] Includes "teaching, college and university," 2.6 percent.

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV-98.—*Earned degrees conferred in mechanical engineering by year, 1939-40 through 1954-55*

Academic year	Bachelor's degree	Master's degree	Doctor's degree	Academic year	Bachelor's degree	Master's degree	Doctor's degree
1939-40	4,770			1947-48	9,264	619	22
1940-41	5,320			1948-49	12,277	823	41
1941-42	5,920			1949-50	14,441	784	46
1942-43	5,920			1950-51	10,798	913	67
1943-44	4,960			1951-52	7,685	660	72
1944-45	3,010			1952-53	5,964	667	84
1945-46	3,910			1953-54	5,419	711	72
1946-47	8,590			1954-55	5,876	748	79

Source: 1939-40 through 1946-47, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. From Journal of Engineering Education. Figures, which are estimated, include industrial engineering. Data adjusted by Bureau of Labor Statistics to include graduates of all engineering schools. 1947-48 through 1952-53, U. S. Office of Education, Earned Degrees Conferred by Higher Educational Institutions.

CIVIL ENGINEERS

TABLE No. IV-99.—*Estimated number of civil engineers by decennial intervals, 1910-50*

1910	46,737
1920	56,488
1930	88,540
1940	89,042
1950	125,568

Sources: 1910-1940, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. 1950, U. S. Department of Commerce, Bureau of the Census. Unpublished, unadjusted estimate from 1950 census of population.

TABLE No. IV-100.—*Percentage distribution of civil engineers by industry, 1946*

Total	100.0
Construction	26.6
Manufacturing	8.1
Transportation	5.8
Utilities	4.1
Government	50.8
All other	4.6

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV–101.—*Percentage distribution of civil engineers by function, 1946*

Administration-management	47. 5
Consulting	8. 4
Operation and maintenance	7. 6
Design, development, and research	29. 6
Sales	1. 2
Other [1]	5. 7

[1] Includes "teaching, college and university," 2.3 percent.

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV–102.—*Earned degrees conferred in civil engineering, by year, 1939–40 through 1954–55*

Academic year	Bachelor's degrees	Master's degrees	Doctor's degrees	Academic year	Bachelor's degrees	Master's degrees	Doctor's degrees
1939–40	2, 420			1947–48	4, 410	600	32
1940–41	2, 050			1948–49	6, 299	734	28
1941–42	2, 160			1949–50	7, 781	689	18
1942–43	2, 080			1950–51	7, 050	630	52
1943–44	1, 930			1951–52	5, 329	583	45
1944–45	1, 260			1952–53	4, 396	566	40
1945–46	2, 400			1953–54	3, 955	560	43
1946–47	3, 250			1954–55	3, 868	683	29

Sources: 1939–40 through 1946–47, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. From Journal of Engineering Education. Data adjusted by the Bureau of Labor Statistics to include graduates of all engineering schools. 1947–48 through 1952–53, U. S. Office of Education, Earned Degrees Conferred by Higher Educational Institutions.

ELECTRICAL ENGINEERS

TABLE No. IV–103.—*Estimated number of electrical engineers by decennial intervals, 1910–50*

1910	15, 125
1920	26, 806
1930	57, 259
1940	55, 667
1950	108, 137

Sources: 1910–40, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. 1950, U. S. Department of Commerce, Bureau of the Census. Unpublished, unadjusted estimate from 1950 Census of Population.

TABLE No. IV–104.—*Percentage distribution of electrical engineers by industry, 1946*

Total	100. 0
Construction	2. 5
Manufacturing	36. 7
Transportation	1. 5
Communication	19. 7
Utilities	16. 7
Government	14. 3
All other	8. 6

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV–105.—*Percentage distribution of electrical engineers by function, 1946*

Administration and management	31. 9
Consulting	5. 7
Design, development, and research	38. 3
Operations	12. 2
Sales	6. 3
Other [1]	5. 6

[1] Includes "teaching, college and university," 2.7 percent.

Source: U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968.

TABLE No. IV-106.—*Earned degrees conferred in electrical engineering by year, 1939-40 through 1954-55*

Academic year	Bachelor's degrees	Master's degrees	Doctor's degrees	Academic year	Bachelor's degrees	Master's degrees	Doctor's degrees
1939-40	2,880			1947-48	6,716		
1940-41	2,860			1948-49	11,042	991	65
1941-42	2,830			1949-50	13,270	1,057	80
1942-43	2,500			1950-51	9,488	1,114	113
1943-44	2,470			1951-52	6,453	1,008	120
1944-45	1,540			1952-53	4,899	880	132
1945-46	2,110			1953-54	4,485	960	111
1946-47	3,990	744	29	1954-55	4,860	1,059	141

Sources: 1939-40 through 1946-47, U. S. Department of Labor, Bureau of Labor Statistics, Employment Outlook for Engineers, Bulletin No. 968. From Journal of Engineering Education. Estimated data adjusted by Bureau of Labor Statistics to include graduates of all engineering schools. 1947-48 through 1952-53, U. S. Office of Education, Earned Degrees Conferred by Higher Educational Institutions.

C. ENGINEERS BEING GRADUATED

First engineering degrees

The 22,236 bachelor's or first professional degrees in engineering conferred by higher educational institutions of the United States in 1953-54, was the smallest number since 1946-47 when 19,000 similar degrees were granted. The engineering degrees of 1953-54 constituted less than 12 percent of all the first professional degrees of that year. The percentage has declined steadily since 1948-49, when the several fields of engineering claimed over 17 percent of all first professional degrees. After June 1955, the trend in numbers of engineering graduates is expected to rise.[6] This will pick up a trend begun in 1920. In that year only about 5,000 bachelor's degrees in engineering were conferred. Thereafter, for 30 years, neither war nor depression seemed to halt the flow of engineers. The high mark was in 1950, when 52,732 received first degrees. Thereafter, termination of "GI bill" benefits for many, coupled with manpower demands accompanying the Korean crisis caused the numbers to plummet.

In 1954, only 22,236 first professional engineering degrees were conferred, as contrasted with the 1949-50 peak of 52,732, but in 1955, the Office of Education reported an increase to 22,589 engineering graduates at the bachelor's level. Based on present enrollments, the Bureau estimates about 30,000 will graduate in 1956, 34,000 in 1957, 37,000 in 1958, and 41,000 in 1959.[7]

The Bureau's estimates carry on to a possible 43,000 graduates in 1964. Its officials suggest this figure may be too low because of the current interest in engineering, coupled with reports of attractive salaries and other forms of opportunity. Larger enrollments are expected. These, in turn, will require upward revisions in the prospective graduates.

Lest these annual increases be considered adequate, the Office of Defense Mobilization warns that "only a minority of these graduates will be immediately available for employment, since many will enter the Armed Forces upon leaving school. However, additional new engineers are becoming available for employment in industry as they

[6] Engineering Enrollment and Degrees, 1954. U. S. Department of Health, Education, and Welfare, Office of Education, Circular No. 421, 1955. p. 5-6.

[7] U. S. Department of Health, Education, and Welfare, Office of Education, Circular No. 418, Earned Degrees Conferred by Higher Educational Institutions, 1953-1954.

are discharged from the services." Accordingly, ODM concluded in 1954 that the supply of engineering graduates during much of the coming decade will be less than demands expected under conditions of partial mobilization and high levels of general business activity.[8]

Recent reports of unfilled jobs and generalizations in regard to the dynamic status of America's economy discourage attempts to specify the number of engineers needed in the future. According to the Engineering Manpower Commission the current need is for approximately 35,000 new engineers a year. However, recent studies have led the Commission to promise a revision upward early in 1956. Meanwhile, the Scientific Manpower Commission estimates the need for new engineers will accelerate annually by 3,000 to 4,000, for the next several years. This is on the assumption that this country will experience neither a depression nor a major war, and that the national production will increase about 3 percent annually. Thus, while engineer graduates from American universities and colleges are presently scheduled to reach 43,000, or more, in 1964, no relief is promised in the growing deficit revealed in 1955, when 35,000 new engineers were needed, but only 23,000 graduated.[9]

In support of an estimated need for 30,000 to 35,000 four-year engineering graduates each year, Karl O. Werwath, president of the Milwaukee School of Engineering, says: "This is about 200 per million population and parallels closely existing ratios in other modern industrial nations of the world today." [10]

Engineering enrollments and degrees in the United States and outlying parts, by level: 1949–54

Year [1]	Enrollments				Degrees			
	Total	Bachelor of science	Master of science [2]	Doctor of philosophy	Total	Bachelor of science	Master of science [2]	Doctor of philosophy
1954	214,414	193,692	17,441	3,281	27,003	22,236	4,177	590
1953	193,333	171,725	18,607	3,001	28,499	24,164	3,743	592
1952	176,549	156,080	17,539	2,930	35,013	30,286	4,141	586
1951	165,637	145,997	16,765	2,875	47,635	41,893	5,156	586
1950	180,262	161,592	15,869	2,801	28,130	52,732	4,904	494
1949	219,712	201,927	15,242	2,543	50,415	45,200	4,798	417

[1] Fall of the year for enrollment and year ending June 30 for degrees.
[2] Includes master's and other predoctoral.

Source. Engineering Enrollments and Degrees, 1954, p. 1.

Engineering students occupied 6.6 percent of total enrollment in 1952; 9.5 percent in 1953; and 10.9 percent in 1954. Despite this trend toward annual increases, Dr. Henry H. Armsby holds no encouragement for hope of relief in the shortage of graduate engineers through 1960.[11]

[8] U. S. Office of Defense Mobilization, Manpower Resources for National Security, January 6, 1954, pp. 46–49.

[9] Based on material provided by Dr. Howard Meyerhoff, Director, Scientific Manpower Commission, December 21, 1955.

[10] Karl O. Werwath, the Role of the Technician in Our Nation's Future, American Engineer, September 1955, p. 17.

[11] Op. cit., p. 3.

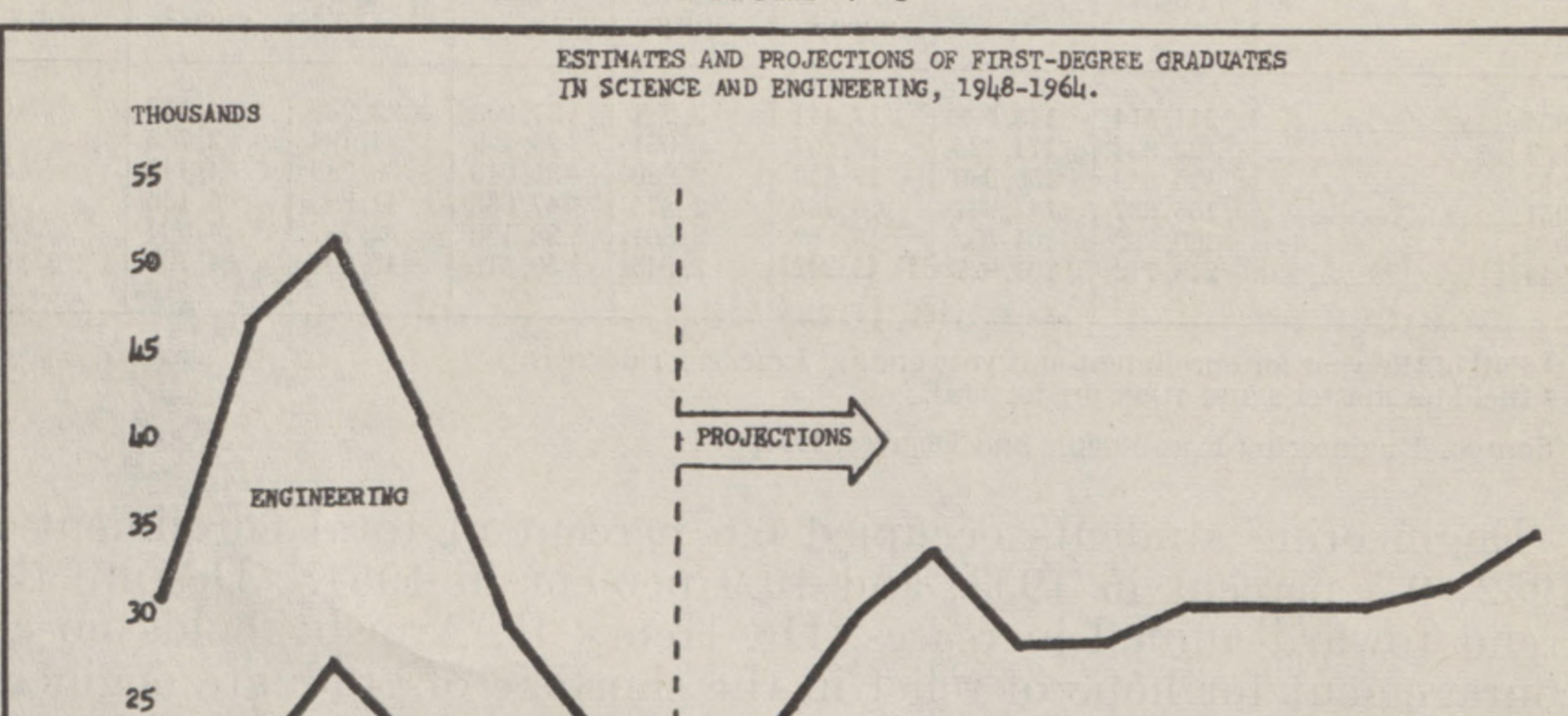
Enrollments and engineering degrees, record and forecast, 1935–65, by Henry H. Armsby, Mar. 3, 1955

Freshman students				Engineering degrees					
				Bachelors			Masters		
Academic year	Total	Engineering	Ratio (3)–(2)	Academic year	Number of degrees	Ratio (6)–(3)	Academic year	Number of degrees	Ratio (9)–(6)
	Thousands	*Thousands*	*Percent*		*Thousands*	*Percent*		*Thousands*	*Percent*
1935–36	367	24	6.5	1938–39	13	54	1939–40	1.3	10
1936–37	----------	30	----------	1939–40	14	47	1940–41	1.4	10
1937–38	368	33	9.0	1940–41	13	40	1941–42	(1)	(1)
1938–39	----------	32	----------	1941–42	(1)	(1)	1942–43	.6	----------
1939–40	418	32	7.7	1942–43	14	44	1943–44	.5	4
1940–41	----------	33	----------	1943–44	11	33	1944–45	.5	5
1941–42	379	35	9.2	1944–45	4	11	1945–46	1.0	25
1942–43	----------	36	----------	1945–46	7	20	1946–47	3.1	45
1943–44	251	17	6.8	1946–47	19	53	1947–48	4.3	23
1944–45	----------	18	----------	1947–48	31	182	1948–49	4.8	15
1945–46	475	42	8.8	1948–49	47	112	1949–50	4.9	11
1946–47	696	93	13.4	1949–50	52	56	1950–51	5.2	10
1947–48	593	64	10.8	1950–51	42	66	1951–52	4.1	10
1948–49	569	53	9.3	1951–52	30	56	1952–53	3.7	12
1949–50	558	42	7.5	1952–53	24	57	1953–54	4.2	17
1950–51	517	34	6.6	1953–54	22	65			
1951–52	472	40	8.5				1954–55	2.2	10
1952–53	537	52	9.7	1954–55	23	57	1955–56	2.3	10
1953–54	566	60	10.5	1955–56	30	57	1956–57	3.0	10
1954–55	642	66	10.3	1956–57	34	57	1957–58	3.4	10
				1957–58	37	57	1958–59	3.7	10
1955–56	643	64	10.0	1958–59	37	57	1959–60	3.7	10
1956–57	670	67	10.0	1959–60	38	57	1960–61	3.8	10
1957–58	684	68	10.0	1960–61	39	57	1961–62	3.9	10
1958–59	683	68	10.0	1961–62	39	57	1962–63	3.9	10
1959–60	714	71	10.0	1962–63	40	57	1963–64	4.0	10
1960–61	763	76	10.0	1963–64	43	47	1964–65	4.3	10

[1] No report.

NOTE.—Figures above double line are from reports of Office of Education and American Society for Engineering Education. Figures below double line are estimates.

FIGURE V–6



1st degrees granted in engineering in the United States and outlying parts: 1948–49 to 1954–55

Year	Male recipients of bachelor or 1st professional degrees	All (male and female) 1st degrees in engineering	1st degrees in engineering, in relation to all male 1st degrees (percentage)
1954–55	183, 602	22, 589	12. 30
1953–54	187, 500	22, 236	11. 86
1952–53	200, 820	24, 164	12. 03
1951–52	227, 029	30, 286	13. 34
1950–51	279, 343	41, 893	15. 00
1949–50	329, 819	52, 732	15. 99
1948–49	264, 168	45, 200	17. 11

Beginning with the class of 1955, the Office of Education expects a progressive increase in the numbers of engineering graduates. Some 43,000 are forecast for 1964. Support for much of this prophecy is based on present engineering enrollments in 218 institutions. Of this number, 150 have been accredited by the Engineers' Council for Professional Development.

Almost two-thirds (62.4 percent) of all first engineering degrees conferred in 1953–54 were in the following 3 fields:

	Percent
Mechanical engineering	24. 4
Electrical engineering	20. 2
Civil engineering	17. 8

Graduate engineering degrees

The desire on the part of many engineers to work for a doctor's degree continues strong, but the 590 doctorates conferred in 1953–54 showed no significant change from the 592 conferred in 1952–53. There was an 11.6 percent increase, however, in the number of master's and other predoctoral degrees conferred in 1952–53 as compared with the prior year.

Until the fall of 1954 every post-World War II year witnessed increases in graduate engineering enrollment. A net decline of 886 graduate students occurred, however, in the fall of 1954. When broken down this showed a decrease among those enrolled for work leading to a master's or other predoctoral degree, but an increase in the number enrolled for a doctoral degree. Enrollment in chemical engineering was greater in the fall of 1954 than in civil engineering. Approximately three-fifths (58.9 percent) were enrolled in the 3 major fields as follows:

	Percent
Electrical engineering	30. 6
Mechanical engineering	16. 9
Chemical engineering	[1] 11. 4

[1] Ibid., p. 6–7.

The following tables show the trends in numbers of doctoral degrees granted, and also in those for bachelor's and master's degrees:

Doctoral degrees granted in engineering annually, 1912–55

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	2	1927	10	1942	47
1913	---	1928	28	1943	22
1914	4	1929	34	1944	30
1915	2	1930	49	1945	37
1916	2	1931	25	1946	89
1917	5	1932	47	1947	94
1918	4	1933	75	1948	257
1919	1	1934	97	1949	360
1920	5	1935	63	1950	417
1921	1	1936	48	1951	520
1922	4	1937	70	1952	529
1923	5	1938	59	1953	518
1924	5	1939	44	1954	590
1925	2	1940	77	1955	599
1926	11	1941	76		

Sources: (1) Data for 1912–47, National Research Council. (2) Data for 1948–53, U. S. Office of Education. (3) Data for 1954, U. S. Office of Education, Circular No. 421.

Bachelor's and master's degrees granted in engineering annually, 1948–55

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	31, 096	4, 198	1952	30, 549	4, 091
1949	43, 604	4, 647	1953	24, 189	3, 566
1950	52, 246	4, 496	1954	22, 236	4, 078
1951	41, 473	4, 825	1955	22, 589	4, 484

Source: U. S. Office of Education (1954 data, Circular No. 421).

D. DEMAND FOR ENGINEERS

"Military demands and an annual requirement of 30,000 civilian engineers a year cannot be met from the graduating classes of the next 5 years." [12]

This is based upon records and estimates submitted by the Office of Education, and previously quoted. It should be recalled, however, that the Office of Education estimates that by 1964 some 43,000 engineering graduates can be expected. This is possibly the basis for a slightly more optimistic estimate by the Commission on Human Resources and Advanced Training to the effect that the 5 years ending with 1957 will graduate an average of 31,000 new engineers a year. Meanwhile, the demand for engineering graduates increases beyond the supply. Approximately 40,000 is the number needed early in 1956. No less critical is the need for those who will receive a doctor's degree in engineering. According to the Commission on Human Resources and Advanced Training, only 2,350 will have received doctor's degrees in engineering during the same 5 years. The supply will not be sufficient to meet the needs of college faculties and of industries where engineers with advanced degrees are needed.

All estimates which include the demands and liabilities of military service, support the belief that the shortage of engineers could continue several years longer.

[12] America's Resources of Specialized Talent.

Engineering graduates in the classes of 1954 through 1960 will have accumulated to the number of about 225,000. However, assuming continuation of the present economic expansion coupled with a status of "partial mobilization," our needs will approximate 285,000. Should this country enter a period of full mobilization, engineer shortages will be further aggravated.

The demand for engineers resulted in active competition among many industrial firms for the 1955 crop of graduates. Of the 420 who graduated in June from Pittsburgh's Carnegie Institute of Technology, 1 official reported 6 to 10 job offers to each. Another company official said that were the 400 competing companies to divide the graduates of Massachusetts Institute of Technology, "we'd get seven-tenths of a man each." [13]

One company that currently hires about 800 new men a year, figured a cost of close to $400 to recruit an engineer. Another, looking for 30 aircraft designers, spent $30,000 for advertising in July 1955. A personnel director figured that each man hired cost his company about $1,000, and a Los Angeles manufacturer put the figure of hiring and moving an engineer at $2,500.[14]

Pay scales vary according to area and field of employment. In California, engineers with 5 years' experience in the aircraft industry earn from $6,600 to $9,100 a year, while close to $9,600 is quoted for electrical men. A Midwest aircraft manufacturer says similar men can get $5,200 to $10,000 a year, and in Pittsburgh from $6,000 to $12,000 a year. These are examples from newspapers printed in mid-1955. Moreover, they are for industry and give no consideration to the admittedly lower salaries usually paid by Federal and State agencies.

The National Science Foundation reports that—

> industrial research scientists and engineers with no experience beyond the bachelor's degree averaged $285 per month in 1949, as compared with $311 in 1951 and $355 in 1953. Similarly qualified scientists and engineers employed by the Government averaged $269 per month in 1949, $263 in 1951, and $324 in 1953; 5 years after receipt of the bachelor's degree, industrial scientists with the doctor of philosophy degree earned an average monthly salary of $470 in 1949, $478 in 1951, and $567 in 1953. Comparable Government salaries for the same years were $450, $467, and $509, respectively.
>
> Information about income of engineers employed in industry and Government was obtained by the Engineers Joint Council in 1953. According to this study, 12 percent were earning less than $4,500 per year, 35 percent between $4,500 and $5,999, 41 percent between $6,000 and $9,999, and 12 percent were earning $10,000 or more per year. The average starting salary in 1953 was $341 per month in industry, and $313 per month in Federal, State, and local governmental agencies.[15]

A comparison with other learned professions shows the income of engineers averages lower than those of physicians and surgeons, and lawyers and judges, but higher than those of clergymen. Salary and income surveys also indicate that the pay of engineers in public service is lower than in industry.[16]

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[13] Elusive Engineers, Wall Street Journal, March 30, 1955, p. 1.

[14] The Ante Gets Higher and Higher, Business Week, May 7, 1955, p. 104.

[15] National Science Foundation, Scientific Personnel Resources, p. 16. The Scientific Manpower Commission reports that $365 per month is an average starting salary in 1956 for industrial research scientists and engineers.

[16] The American Engineer, August 1955, pp. 25 and 46. Op. cit., Scientific Personnel Resources, pp. 25–59.

E. SUPPLY OF SCIENTISTS

Some 205,000 college graduates with degrees in scientific fields were reported in 1953 as professionally employed in the physical, biological, and agricultural sciences in the United States. When those in the medical fields are added the number reaches 237,000. These are part of more than 635,000 holders of college degrees in science and do not include those employed in the actual practice of medicine. Nearly half of all who are employed in the scientific fields are in chemistry. They include all who were so clearly scientists that none would argue about their qualifications, plus college teachers in the natural sciences, and college graduates working at comparable levels in scientific fields, regardless of whether their job title may have classed them as technicians.

Supply of scientists in 1953 [1]

	Chemists	Physical scientists	Earth scientists	Biological scientists	Total
Estimated number in 1953	84,000	56,000	45,000	52,000	237,000
College graduates employed in field	58,000	41,000	30,000	46,000	175,000
Percentage with college degrees	69	73	67	88	74
Percent men	91	76	94	75	87
1950 census total (rounded)	82,100	37,800	11,800	18,500	154,200
Estimated number with degrees in science living in 1953	176,000	168,000	60,000	232,000	636,000
Estimated number of living with doctor of philosophy degrees in 1953	15,500	8,250	2,700	13,800	40,250

[1] America's Resources of Specialized Talent, p. 81.

As of 1955, approximately 109,000 persons under 70 years of age are credited as holding doctor of philosophy degrees from American universities. At successive 5-year intervals, the estimated totals were, or will be, as follows:

1945	59,000	1960	136,000
1950	77,000	1965	169,000
1955	109,000	1970	212,000

In 1949–53, 37 percent of these doctors of philosophy were in natural sciences, 7 percent in engineering, and 6 percent in applied biology.

Despite this steady rise, along with that of professionally trained men and women with bachelor's and master's degrees, Wolfle [17] points out that the high level of manpower demand in the fields of engineering and science may not be reached for years.

The long-term trend in the production of doctorates in science, shows a tendency to double the number each decade. More degrees in science were awarded in 1953 than ever before, but a decline has now set in, which promises to continue for several years. This is shown in table V–1, and in the corresponding chart, Production of Doctors of Philosophy in Science, 1910–50 (pp. 27 and 28). The sharp dip in the chart reflects a loss of nearly 5,000 doctorates during the World War II years 1942–48. The "GI bill" helped restore the rise in the curve, but has not yet filled out the losses.

[17] Wolfle, Dael, America's Resources of Specialized Talent.

Estimated number of natural and physical scientists,[1] 1950

Scientific field	Total	College professors and instructors	Other
Chemists	81,676	5,929	75,747
Biologists	13,300	5,414	7,886
Physicists	10,785	3,659	7,126
Geologists and geophysicists	9,938	993	8,945
Agronomists	8,876	3,761	5,115
Psychologists	8,804	4,251	4,553
Mathematicians	6,826	5,507	1,319
Other natural and physical scientists, including medical scientists	13,752	3,448	10,304
Total	153,957	32,962	120,995

[1] A Policy for Scientific and Professional Manpower, p. 47.

The following figures are selected from a count of faculties in colleges, universities, and junior colleges in the continental United States for the 2d semester of the academic year 1954–55: chemists, 5,916; physicists, 4,208; geologists, 1,205; psychologists, 3,929; and mathematicians, 5,290. Source: Educational Directory, University of Chicago Press.

Some of these figures include persons who are not highly trained, but who work under highly trained scientists. They may have no more than a bachelor's degree, but their contribution to scientific achievement may be indispensable. It should also be noted that about one-fifth of all scientists are teachers. They are drawn in varying proportions from the several fields of science. For example, teaching occupies about 2 percent of the engineering profession, about 25 percent of those in physics, and 50 percent of the mathematicians. Needs of replacement are figured at 4 percent a year. These must be measured against current graduations, industrial and governmental demands, and those of the military services.

The following data assembled in 1951, from scientific societies in the United States, by the National Scientific Register, indicate backlogs in several classifications of science:

Astronomers

Between 300 and 400. The Astronomical Society numbers about 700 members, but many are amateurs (tables IV–5 and IV–6).

Chemists

Approximately 100,000, of whom more than two-thirds were employed in manufacturing industries, 14 percent in educational institutions, and 8 percent by Federal, State, and local governments.

Every year the chemical industry needs from 5,000 to 10,000 new chemists and chemical engineers. Yet no more than 5,000 degrees will be granted, according to estimates.[18]

(Tables IV–8 and IV–9).

Mathematicians

On the basis of degrees granted, society membership, and other evidence, there are probably more than 2,000 mathematicians at the doctoral level at the present time.

[18] Careers and Opportunities in Science, Pollack, pp. 76–77.

TABLE IV–5.—*Doctoral degrees granted in astronomy annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	2	1927	9	1942	7
1913	11	1928	3	1943	14
1914	2	1929	8	1944	5
1915	7	1930	4	1945	2
1916	6	1931	11	1946	7
1917	5	1932	8	1947	5
1918	0	1933	10	1948	13
1919	1	1934	11	1949	11
1920	4	1935	11	1950	16
1921	5	1936	5	1951	10
1922	4	1937	9	1952	14
1923	6	1938	12	1953	18
1924	7	1939	5	1954	15
1925	3	1940	6	1955	16
1926	7	1941	11		

Sources: (1) Data for 1912–47, National Research Council; (2) data for 1948–54, U. S. Office of Education.

TABLE IV–6.—*Bachelor's and master's degrees granted in astronomy annually, 1948–55*

Academic year	Bachelor's degrees	Master's degrees	Adademic year	Bachelor's degrees	Master's degrees
1948	21	10	1952	23	22
1949	20	10	1953	19	10
1950	30	22	1954	13	19
1951	27	14	1955	11	13

Source: U. S. Office of Education.

TABLE IV–8.—*Doctoral degrees granted in chemistry annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	78	1927	270	1942	588
1913	68	1928	278	1943	538
1914	71	1929	310	1944	491
1915	85	1930	317	1945	324
1916	115	1931	390	1946	311
1917	108	1932	420	1947	417
1918	75	1933	417	1948	569
1919	54	1934	500	1949	749
1920	96	1935	470	1950	953
1921	134	1936	482	1951	1, 046
1922	150	1937	497	1952	1, 031
1923	185	1938	426	1953	999
1924	251	1939	482	1954	1, 013
1925	250	1940	527	1955	1, 005
1926	257	1941	672		

Sources: (1) Data for 1912–47, National Research Council: (2) data for 1948–54, U. S. Office of Education.

TABLE IV–9.—*Bachelor's and master's degrees granted in chemistry annually, 1948–55*

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	7, 429	1, 360	1952	6, 819	1, 409
1949	9, 132	1, 427	1953	5, 943	1, 211
1950	10, 619	1, 576	1954	5, 791	1, 098
1951	8, 258	1, 462	1955	5, 920	1, 173

Source: U. S. Office of Education.

More than 2,500 Ph. D.'s in mathematics were granted between 1912 and 1951. Many have entered other fields such as the natural sciences, engineering, education, and business (tables IV–21 and IV–22).

Physicists

Between 17,000 and 20,000 physicists are presently employed in the United States. Only 4,000 have doctoral degrees. Less than half are employed in educational institutions, about 40 percent in manufacturing, 15 percent in various Government agencies, nearly 2 percent in transportation and communications, and 5 percent in research and consulting services. The situation as regards physicists in 1953 was summed up as follows:

There are fewer than 20,000 physicists in the United States and only 4,000 have doctoral degrees. There is a shortage of physicists to supervise research projects for industry and Government and a shortage of physicists with all levels of training to assist in translating new scientific developments into the field of engineering.[19]

TABLE IV–21.—*Doctoral degrees granted in mathematics annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	22	1927	46	1942	85
1913	21	1928	44	1943	44
1914	25	1929	61	1944	41
1915	23	1930	75	1945	35
1916	34	1931	73	1946	53
1917	30	1932	75	1947	109
1918	23	1933	78	1948	128
1919	7	1934	82	1949	126
1920	19	1935	77	1950	160
1921	16	1936	84	1951	184
1922	20	1937	76	1952	206
1923	28	1938	62	1953	241
1924	32	1939	91	1954	227
1925	24	1940	103	1955	250
1926	47	1941	95		

Sources: (1) Data for 1912–47, National Research Council; (2) data for 1948–54, U. S. Office of Education.

TABLE IV–22.—*Bachelor's and master's degrees granted in mathematics annually, 1948–55*

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	4, 266	711	1952	4, 721	802
1949	5, 040	893	1953	4, 396	677
1950	6, 392	974	1954	4, 090	706
1951	5, 753	1, 109	1955	4, 034	761

Source: U. S. Office of Education.

[19] Chemical Engineering News, May 25, 1953, p. 2204. In American Journal of Physics, April 1954, p. 184.

TABLE IV–27.—*Doctoral degrees granted in physics annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	30	1927	92	1942	146
1913	22	1928	78	1943	124
1914	23	1929	101	1944	55
1915	31	1930	91	1945	39
1916	35	1931	94	1946	65
1917	32	1932	113	1947	137
1918	17	1933	123	1948	198
1919	18	1934	121	1949	266
1920	19	1935	150	1950	358
1921	28	1936	147	1951	443
1922	57	1937	158	1952	485
1923	54	1938	148	1953	478
1924	58	1939	165	1954	485
1925	59	1940	148	1955	511
1926	76	1941	191		

Sources: (1) Data for 1912–47, National Research Council; (2) data for 1948–54, U. S. Office of Education.

TABLE IV–28.—*Bachelor's and master's degrees granted in physics annually, 1948–55*

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	2, 126	706	1952	2, 247	886
1949	2, 828	841	1953	2, 005	721
1950	3, 414	922	1954	1, 952	714
1951	2, 788	973	1955	1, 996	729

Source: U. S. Office of Education.

Agricultural and biological scientists

The National Science Foundation and the Bureau of Labor Statistics estimate the United States has about 60,000 agricultural and biological scientists. Of these, the Commission on Human Resources and Advanced Training believes about 17,000 had doctoral degrees in 1953. These represent widely varied fields of specialization, such as agricultural sciences, animal sciences, plant sciences, genetics, and biology.

Earth scientists

Between 20,000 and 25,000 earth scientists are in this country, of whom the 1946 National Roster of Scientific and Specialized Personnel listed 8,487 as geologists, geophysicists and meteorologists. About 2,700 had doctor of philosophy degrees, and were under 70 years of age. The United States Office of Education and the National Research Council report the conferring of 2,582 doctoral degrees in earth sciences between 1912 and 1953 (tables IV–46 and IV–47).

Geologists

About 12,000 geologists, including those grouped with "earth scientists," were reported by the Bureau of Labor Statistics in 1951. Over 60 percent were specializing in petroleum and gas, about 10 percent in fields of general geology, 8 percent in economic geology, and 20 percent in other fields of geology. Of these, nearly three-fourths were in private industry. The remainder were about evenly divided among colleges and universities, and Federal, State, and local governments.

Geophysicists

About 3,000 "earth scientists" regarded themselves in the geophysical fields. These included geodesy, seismology, terrestrial magnetism and electricity, oceanography, volcanology, hydrology, technophysics, and geophysical exploration.

Meteorologists

In 1951, the Bureau of Labor Statistics estimated less than 2,500 were employed in meteorology, although 2,821 were reported as having highest competence in that field (tables IV–69 and IV–70).

TABLE IV–39.—*Bachelor's and master's degrees granted in agricultural, biological, and health sciences annually, 1948–54*

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	17,921	3,034	1952	24,333	5,000
1949	26,591	3,802	1953	22,033	4,447
1950	34,626	4,713	1954	[1] 19,580	[1] 3,707
1951	28,886	4,954			

[1] Includes subtotals for agriculture, biological sciences, public health, and medical sciences (not elsewhere classified), in table 7, earned degrees conferred by higher educational institutions, 1953–54. Comparable figures for 1953 were 21,819 and 4,362, respectively.

Source: U. S. Office of Education.

TABLE NO. IV–46.—*Doctoral degrees granted in earth sciences annually, 1912–53*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	23	1926	42	1940	79
1913	15	1927	58	1941	74
1914	13	1928	42	1942	82
1915	30	1929	58	1943	53
1916	20	1930	83	1944	35
1917	28	1931	46	1945	27
1918	16	1932	52	1946	45
1919	5	1933	76	1947	75
1920	20	1934	83	1948	74
1921	18	1935	81	1949	116
1922	23	1936	77	1950	165
1923	42	1937	59	1951	183
1924	45	1938	80	1952	163
1925	42	1939	69	1953	165

Sources: (1) Date for 1912–47, National Research Council. (2) Date for 1948–53, U. S. Office of Education.

TABLE NO. IV–47.—*Bachelor's and master's degrees granted in earth sciences annually, 1948–53*

Academic year	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	1,172	318	1951	2,821	622
1949	1,851	385	1952	2,174	577
1950	3,186	544	1953	1,821	567

Source: U. S. Office of Education.

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TABLE IV-52.—*Doctoral degrees granted in geology annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	23	1927	42	1942	56
1913	14	1928	35	1943	36
1914	13	1929	45	1944	17
1915	26	1930	63	1945	15
1916	17	1931	39	1946	28
1917	24	1932	45	1947	54
1918	14	1933	66	1948	57
1919	5	1934	55	1949	88
1920	17	1935	62	1950	113
1921	11	1936	64	1951	123
1922	22	1937	42	1952	116
1923	34	1938	58	1953	133
1924	41	1939	49	1954	136
1925	25	1940	55	1955	154
1926	27	1941	53		

Source: (1) Data for 1912–47, National Research Council. (2) Data for 1948–54, U. S. Office of Education.

TABLE IV–53.—*Bachelor's and master's degrees granted in geology annually, 1948–55*

Academic yer	Bachelor's degrees	Master's degrees	Academic year	Bachelor's degrees	Master's degrees
1948	1, 172	318	1952	2, 102	486
1949	1, 851	385	1953	1, 719	517
1950	3, 043	493	1954	1, 632	412
1951	2, 717	565	1955	1, 795	507

Source: U. S. Office of Education.

TABLE No. IV–69.—*Doctoral degrees granted in meteorology annually, 1912–55*

Academic year:	Number	Academic year—Con.	Number	Academic year—Con.	Number
1912	--	1927	--	1942	3
1913	--	1928	--	1943	2
1914	--	1929	--	1944	--
1915	--	1930	--	1945	1
1916	--	1931	--	1946	5
1917	1	1932	--	1947	4
1918	1	1933	--	1948	--
1919	--	1934	2	1949	--
1920	--	1935	1	1950	12
1921	--	1936	--	1951	12
1922	--	1937	1	1952	10
1923	--	1938	4	1953	13
1924	--	1939	2	1955	2
1925	--	1940	--		
1926	--	1941	1		

Source: Data for 1912–47, National Research Council. Data for 1948–53, U. S. Office of Education.

TABLE No. IV–70.—*Bachelor's and master's degrees granted in meteorology annually, 1948–54*

Academic year	Bachelor's degree	Master's degree	Academic year	Bachelor's degree	Master's degree
1948	----------	----------	1952	72	91
1949	----------	----------	1953	102	50
1950	143	51	1954	60	45
1951	104	57			

Source: U. S. Office of Education.

F. SCIENTISTS BEING GRADUATED

First degrees in science

Bachelor's or first professional degrees in the biological, physical, and agricultural sciences were conferred on 31,178 persons during the school year ending June 30, 1954. These included 9,366 in the biological sciences of anatomy, bacteriology, biochemistry, biology, botany, entomology, physiology, and zoology; 13,970 in the physical sciences, including astronomy, chemistry, geology, mathematics, metallurgy, meteorology, physics, and physical sciences; and 7,832 in the agricultural sciences, including animal husbandry, forestry, and agriculture. The total of 31,178 is lower even than the 32,806 who were in the graduating class of 1947–48. Sharply contrasting with this is the record class of 61,001, graduated in 1949–50.

A corresponding decline is evident in the numbers who have received master's degrees in science, but the recipients of doctor's degrees have been increasing from year to year. In 1898, only 105 received degrees of doctor of science. From that year until 1953–54, when similar degrees were conferred upon 3,813 candidates, the number receiving such degrees has practically doubled with each decade. The trend was broken during 1942 to 1948, but is now back on the established upward line. The most noticeable acceleration was in 1949–50, due to culmination of enrollments under the GI bill and employment opportunities resulted from hostilities in Korea. The pattern is revealed in the following table:

Degrees granted in the United States, 1900–55 [5]

Year	Bachelor's and 1st professional degrees [2] (1)	Master's and 2d professional degrees (2)	Col. 2 as percent of col 1 (3)	Doctoral degrees (4)	Col. 4 as percent of col. 1 (5)
1900	25,324	1,583	6.3	369	1.5
1910	34,178	3,771	11.0	429	1.3
1920	48,622	4,143	8.5	690	1.4
1930	122,484	14,969	12.2	2,299	1.9
1940	186,500	26,731	14.3	3,290	1.8
1950	433,734	58,219	13.4	6,633	1.5
1952	331,924	63,587	19.1	7,683	2.3
1953	304,857	61,023	20.2	8,309	2.7
1954	292,880	56,823	19.7	8,996	3.1
1955	287,401	58,204	20.2	8,840	3.1

[1] Based on data provided by the U. S. Office of Education.
[2] Includes doctor of medicine, doctor of dental surgery, bachelor of laws, and similar 1st professional degrees.

Source of data, 1900–1950: A policy for scientific and professional manpower, p. 54.

An increase in the number of graduates is expected after 1955. The total number of candidates to receive first professional or bachelor degrees in the several fields of science may again reach 60,000 by 1970. This surmise was worked out by the Commission on Human Resources and Advanced Training. It assumes that the number of 21-year-olds graduating from college will continue to increase at about the same rate as between 1920 and 1940, before the effects of the war were felt.[20]

[20] A Policy for Scientific and Professional Manpower, p. 52.

Earned degrees in science, conferred in higher educational institutions, by field of study, or aggregate United States: 1947–48 to 1953–54 [1]

Field of study	Bachelor's and 1st-professional				Master's and 2d-professional				Doctor's			
	1947–48	1949–50	1951–52	1953–54	1947–48	1949–50	1951–52	1953–54	1947–48	1949–50	1951–52	1953–54
Agriculture	6, 843	14, 999	9, 595	7, 832	1, 141	1, 505	1, 608	1, 302	191	368	412	515
Animal husbandry	592	1, 697	1, 022	1, 203	99	135	136	140	13	26	42	64
Forestry	849	2, 394	1, 219	904	195	290	225	127	11	26	17	30
Agriculture, all other	5, 402	10, 908	7, 354	5, 725	847	1, 080	1, 247	1, 035	167	316	353	421
Biological sciences	10, 612	15, 639	11, 196	9, 366	1, 383	2, 171	2, 307	1, 610	419	625	764	1, 077
Anatomy	111	123	105	53	29	65	64	47	9	15	34	33
Bacteriology	624	870	566	439	174	327	321	242	65	74	92	131
Biochemistry	270	175	150	195	131	144	175	105	65	116	99	145
Biology	6, 739	10, 428	6, 960	5, 847	346	549	570	435	65	81	132	147
Botany	353	494	346	293	169	299	254	197	73	126	101	171
Entomology	35	127	58	61	91	89	110	83	27	52	56	55
Physiology	174	133	116	98	85	147	136	93	32	36	63	85
Zoology	2, 306	3, 289	2, 034	1, 696	358	551	569	323	83	125	154	221
Biological sciences (not elsewhere classified)	----------	----------	861	684	----------	----------	108	85	----------	----------	33	89
Physical sciences	15, 351	30, 463	16, 866	13, 970	3, 207	4, 421	3, 856	3, 080	977	1, 784	1, 926	2, 601
Astronomy	21	30	23	13	10	22	22	19	13	15	14	19
Chemistry	7, 429	10, 619	6, 819	5, 791	1, 360	1, 576	1, 409	1, 098	569	953	1, 031	1, 098
Geology	1, 172	3, 043	2, 102	1, 632	318	493	486	412	57	113	116	412
Mathematics	4, 266	6, 392	4, 721	4, 090	711	549	802	706	128	160	206	227
Metallurgy	337	476	260	33	102	120	107	31	12	46	55	31
Meteorology	----------	6, 143	72	93	----------	51	91	38	----------	12	10	38
Physics	2, 126	3, 414	2, 247	1, 952	706	922	886	714	198	358	485	714
Physical sciences (not elsewhere classified)	----------	6, 346	622	366	----------	710	53	62	----------	127	9	62
Grand total	32, 806	61, 001	37, 657	31, 168	5, 731	8, 097	7, 771	5, 930	1, 587	2, 777	3, 102	3, 813

[1] Statistics of Higher Education, Faculty, Students, and Degrees, 1949–50, and 1951–52; Earned Degrees Conferred by Higher Educational Institutions, 1947–48 to 1953–54. U. S. Department of Health, Education, and Welfare, Office of Education.

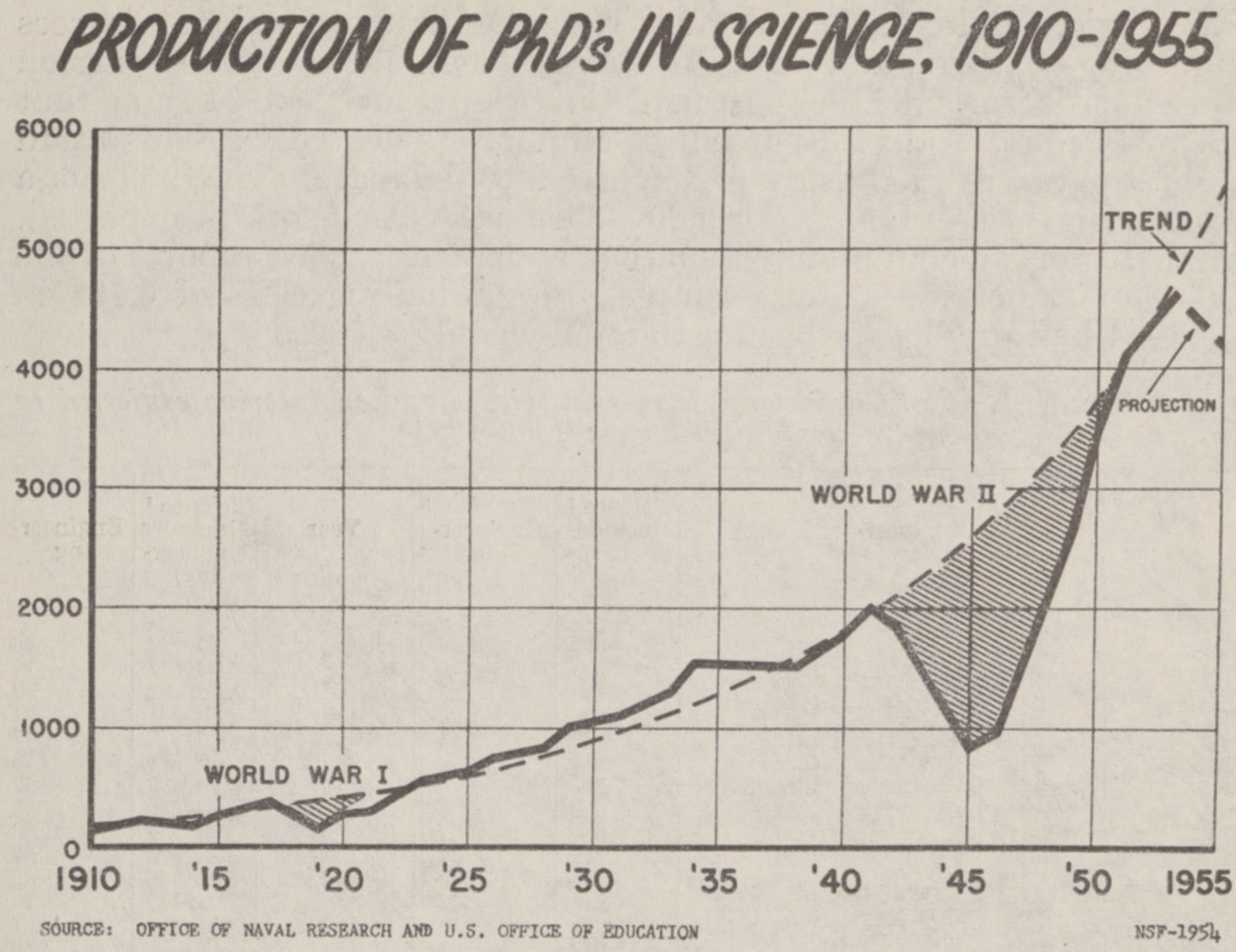
Biologists and chemists are now receiving first professional degrees in largest numbers, and chemists take the lead among those going on to earn a doctor's degree. In fact, the records for 1953–54 show that chemists comprised 11.3 percent of all doctor's degrees.[21] This trend of graduates in chemistry is expected to increase. In 1955–56 a graduating class of at least 6,000 chemistry bachelors is expected. That this may be an underestimate is indicated by past reports of the Office of Education. For example, the graduating class of 5,791 in 1953–54 had previously been estimated as only 4,500.[22]

TABLE NO. V-1.—*Earned doctor's degrees in science and engineering conferred in the United States: 1898–1954*

Year	Science [1] (includes engineering)	Engineering	Year	Science [1] (includes engineering)	Engineering	Year	Science [1] (includes engineering)	Engineering
1898	[2] 105		1917	372	5	1936	1,547	48
1899	106		1918	293	4	1937	1,517	70
1900	102		1919	180	1	1938	1,522	59
1901	127		1920	323	5	1939	1,651	44
1902	103		1921	332	1	1940	1,812	77
1903	134		1922	444	4	1941	2,034	76
1904	129		1923	575	5	1942	1,833	47
1905	143		1924	612	5	1943	1,535	22
1906	140		1925	639	2	1944	1,194	30
1907	143		1926	747	11	1945	833	37
1908	184		1927	796	10	1946	956	89
1909	194		1928	842	28	1947	1,475	94
1910	180		1929	1,021	34	1948	[4] 2,112	[4] 257
1911	239		1930	1,072	49	1949	2,708	360
1912	[3] 273	[3] 2	1931	1,145	25	1950	3,509	417
1913	234		1932	1,238	47	1951	4,132	520
1914	241	4	1933	1,333	75	1952	4,319	529
1915	309	2	1934	1,550	97	1953	4,631	518
1916	332	2	1935	1,524	63	1954	[5] 5,106	[5] 594

[1] Figures in the column for engineering degrees are included in figures for science degrees.
[2] Science, James McKeen Cattell, editor. Data for 1898–1907 from 26:276–82; Aug. 30, 1907. Data for 1908–11 from 36:129–39; Aug. 2, 1912. (From the Production of Doctorates in the Sciences: 1936–48, Scates, Douglas E., Murdoch, Bernard C., and Yeomans, Alice V.) Figures for period 1898–1911.
[3] Source: The National Research Council. Figures for 1912–47.
[4] Source: U. S. Office of Education. These totals were found by adding subtotals for selected fields in Earned Degrees Conferred by Institutions of Higher Education. Figures for 1948–53.
[5] Source: Op. cit., 1953–54. Selected fields: Agriculture, biological science, engineering, foreign languages, geography, home economics, mathematics, physical sciences, psychology, anthropology, and sciences (without major).

[21] Earned Degrees Conferred by Higher Educational Institutions, 1953–54, p. 8.
[22] Graduates in Chemistry, by R. B. Stanerson, Chemical and Engineering News, June 8, 1953, pp. 2376–2379.



G. DEMAND FOR SCIENTISTS

Commenting on the increased demand for personnel in most fields of science, as stimulated by the defense program, and by the recent growth in research and development expenditures, the Director of the Office of Defense Mobilization foresees a continuing upward trend in the scientific manpower requirements. On the other hand, he expresses the belief that a falling off in the number of graduates will result in holding down the future supply. He also assumes that large percentages of science graduates will find employment outside their fields of specialization. Thus, on the basis of established figures and trends, the Commission on Human Resources estimated that although 137,000 will be graduated in the sciences during the 5-year period 1953–57, not over 40,000 will join the science labor force.[23]

H. LOSSES AMONG SCIENTISTS

On the basis of figures gathered during the year ending December 31, 1953, from 874 companies employing 58,670 scientists, the Scientific Manpower Commission concluded that industry is adding 5,000 to 7,000 new scientists to its payroll each year. The number hired in 1953, however, was nearly 500 less than were hired in 1952. This, in turn, reflects a drop of about 12 percent in the number graduated. As regards more recent years, Dr. Howard A. Meyerhoff, executive director of the Commission, writes:

> Industry failed to get all the scientists it needed in 1953 and again in 1954, when there was a further decline of 4 to 5 percent in the number of scientists graduating with bachelor's degrees. The dwindling numbers must have been a

[23] Op. cit., pp. 46–49.

factor, but other factors cannot be ignored—for example, the heavy drain for military service, especially after Korea, when many deferments were terminated." [24]

Scientists lost during 1953

Reason:	Number
To enter military service	463
To continue education	556
By death or retirement	189
For another scientific position	1, 941
For a nontechnical position	319
Other reasons	1, 582
Total	5, 621

I. HIGH SCHOOL REGISTRATIONS

In 1954 the United States had 27,873 secondary schools, of which 88 percent were publicly supported, and 12 percent private. In terms of enrolled pupils, 89 percent were in public schools and 11 percent in private schools.[25]

In 1952–53, enrollment in public and private high schools in the United States was estimated by the Office of Education to be 6,600,000. In 1949–50 the enrollment was 5,706,734. That same year 1,233,000 students graduated from high school, and 438,000 entered college. On this basis, the 1952–53 enrollment of 6,600,000 may graduate 1,426,000 in 1957, and 508,000 may enter college.

If the percentage of children between 14 and 17 who are enrolled in high school remains the same as it was in 1950, high-school enrollment will increase gradually each year through 1955, and more rapidly between 1955 and 1965. By the later date it will reach 10.8 million * * *. If the proportion increases from approximately three-fourths today to as much as 85 percent, present enrollment will be almost doubled by 1965.[26]

J. PREPARATION FOR COLLEGE

From the viewpoint of those who see future shortages in engineers and scientists, the problem is further complicated by steady reductions in the relative numbers of boys and girls who are taking mathematics, chemistry, and other courses basic to college work in engineering and science.

In 1948–49, the Office of Education estimated that enrollments in mathematics and science were in the following proportions:

Enrollments in mathematics and science—United States high schools

Subject	Percentage of high school body enrolled, 1948–49 [1]	Estimated enrollment (base—5,706,734) [2]	Subject	Percentage of high school body enrolled, 1948–49 [1]	Estimated enrollment (base—5,706,734) [2]
Algebra	26. 8	1, 529, 405	General science	21. 2	1, 209, 828
General mathematics	13. 1	747, 582	Biology	19. 6	1, 118, 520
Plane geometry	11. 1	633, 447	Chemistry	7. 6	433, 712
Solid geometry	1. 7	97, 014	Physics	5. 5	313, 870
Trigonometry	2. 0	114, 135	Earth science	. 4	22, 827

[1] Office of Education.
[2] Prorated by author.

[24] The Scientific Manpower Commission, on basis of 874 companies.
[25] 1919–20 to 1949–50, Bureau of the Census and Commission on Human Resources and Advanced Training, 1959–60 to 1964–65, Bureau of the Census. P. V–16, NSR report.
[26] Scientific and Professional Manpower, p. 209.

High school enrollments for four of these subjects were estimated and projected by the National Science Teachers Association, as follows:

Year	General science	Biology	Chemistry	Physics
1943	1,340,000	1,423,000	651,000	421,000
1948	1,295,000	1,136,000	539,000	370,000
1954	1,317,000	1,252,000	595,000	365,000
1958	1,522,000	1,695,000	758,000	416,000
1968	2,480,000	2,499,000	1,090,000	675,000

A decline in the percentage of students taking chemistry ended about 1900. It has since held on a fairly even level through the present century. This is shown in the following table:

Percentage of students of the public high schools of the United States enrolled in chemistry since 1890 [1]

Year	Percent
1890	10.10
1895	9.15
1900	7.72
1905	6.76
1910	6.89
1915	7.38
1922	7.40
1928	7.07
1934	7.60
1949	7.60

[1] For years 1890 to 1928, from Hunter, G. W., Science Teaching at Junior and Senior High School Levels, American Book Co., 1934. Presented in Physical Sciences in Secondary Schools, by Alexander Efron. Teachers College, Columbia University, New York, 1937. For years 1934 to 1949, Office of Education.

Technically trained men and women—

writes Dr. Kenneth E. Brown, specialist for mathematics with the Office of Education [27]

are needed to increase our standard of living in times of peace and safeguard our Republic in times of war. Mathematics is the language of these scientific workers. If our supply of specialized personnel is to meet the Nation's demands, more able pupils must receive training in mathematics. The mathematics preparation of scientific personnel should begin before they reach college.

A look at the present high school enrollments in mathematics is not encouraging. Plane geometry is one of the high school subjects normally required for college entrance and as a prerequisite to mathematics or scientific training. A recent study of mathematics education in the high schools showed that the number of pupils taking this subject is less each year. In 1934 there were 767,171 pupils enrolled in plane geometry in the high school, in 1949 the enrollment was 693,280 and in 1953 only 659,300. The total number of pupils in high school is increasing, but the enrollment in geometry is decreasing.

Our Nation needs more and more persons trained in basic mathematical understandings. The high school enrollments indicate that this is not taking place. Even in algebra—the mathematics that is basic to an elementary consideration of quantity in any field of knowledge—the percent of pupils enrolled is smaller each year. In 1934, 30.4 percent of the high school pupils were enrolled in algebra. In 1949 there were 26.8 percent, and in 1953 approximately 24.6 percent.

The number of pupils enrolled in mathematics decreases from grade to grade in high school. Data for the school year 1952–53 from 857 randomly selected high schools indicated that the number of pupils in 10th grade mathematics was equal to 34 percent of the number of pupils in that grade, while in the 11th grade it was 23 percent, and in the 12th grade only 10 percent.

The need for pupils trained in mathematics—a language of modern civilization—stands out in bold relief. The enrollments in mathematics are not meeting the demand.

[27] Mathematics a Key to Manpower, by Kenneth E. Brown, School Life, November 1953.

Number and percentage of pupils in mathematics in the last 4 years of public secondary day schools, 1889–90 to 1952–53

Year	Algebra		Geometry		Trigonometry	
	Number	Percent	Number	Percent	Number	Percent
1890	92, 150	45. 4	43, 294	21. 3	----------	----------
1900	292, 287	56. 3	142, 235	27. 4	9, 915	1. 9
1910	420, 207	56. 9	228, 170	30. 9	13, 812	1. 9
1915	569, 215	48. 8	309, 383	26. 5	17, 220	1. 5
1922	865, 515	40. 2	488, 825	22. 7	32, 930	1. 5
1928	1, 020, 323	35. 2	573, 668	19. 8	36, 855	1. 3
1934	1, 367, 210	30. 4	767, 171	17. 1	59, 858	1. 3
1949	1, 448, 966	26. 8	693, 280	12. 8	108, 551	2. 0
1953	1, 475, 900	24. 6	659, 300	11. 6	107, 000	1. 9

Many of the specialized courses such as astronomy, meteorology and geology, previously included in high school curricula, have now practically disappeared, and physics is on a downward trend.

Percentage of secondary school students enrolled in physics courses in the Nation for the indicated years since 1890 [1]

Year:	Percent	Year—Continued	Percent	Year—Continued	Percent
1890	22. 21	1915	14. 23	1948	5. 40
1895	22. 77	1922	8. 93	1949	5. 50
1900	19. 04	1928	6. 85	1952	4. 30
1905	15. 66	1934	6. 30		
1910	14. 61	1947	5. 50		

[1] Ibid.

The typical American high school in 1935–37 scheduled physics and chemistry as 1-year elective sciences for the 2d, 3d, or 4th year of the comprehensive senior high schools, or the 10th, 11th, or 12th year of the junior-senior high school. As the high school lost its selective, college preparatory character and became a complete, postprimary, self-sufficient school for all adolescents between the ages of 12 and 18 many of the traditional subjects were dropped out. Ability grouping, or the sectioning of students into groups of approximately equal mental ability, has been adopted in some progressive schools as a means of meeting the new psychology.[28]

The situation revealed in these few figures has led Dr. B. R. Stanerson, assistant secretary of the American Chemical Society, to make the following observation:

> Problems of major proportions are being created by the great expansion in numbers of students, the tendency to provide high school education for all with the unavoidable trend toward mediocrity, the high cost of education, the shortage of teachers, the shift of educational emphasis away from traditional academic subjects to vocationalism, and other factors. There are those who believe that secondary school education is drifting into the worst crisis of its history.[29]

The need of encouraging the more capable of the Nation's young people to continue their training into college and graduate study presents a problem of major importance. Figures compiled by the United States Office of Education show that of the pupils who entered high school in 1934–35, nearly 46 percent failed to graduate. During the succeeding years the percentage fluctuated, but of the pupils who entered high school in 1946–47, only 37.5 percent graduated in 1950.

[28] Op. cit., Hunger, G. W.
[29] Chemical and Engineering News, March 21, 1955, p. 1213.

That the attrition continues at an increasing rate is indicated from a study made of high school students with especially high intelligence quotients. On the basis of data from many sources, the Commission on Human Resources and Advanced Training estimates that of the pupils with the equivalent of I. Q. 120, or above, 99 percent graduate from high school. Of these, however, only 53 percent enter college. Dropouts during college reduce the number graduating from college to about 40 percent of those who graduated from high school. Thus the total loss of eligible high school graduates will be about 40 percent. To carry these data further, only about 2 percent of all college graduates will obtain a doctor's degree. This represents about 0.25 percent of the total age group.

Application of these studies to high school graduates who have the makings of engineers or scientists show that only half go to college and only about 40 percent of those who enter are able to finish college. Thus, 8 of every 10 potential engineer-science students do not get a college degree. Thereafter, fewer than 3 percent of the college graduates go on to become doctors of philosophy. Thus, of 1,000 selected high school graduates, about 200 could be expected to complete a college course in engineering or science, and scarcely 6 would go on for a doctor's degree.

Sidney Steele, of Atlas Powder Co., in an address before the Association of Industrial Chemical Engineers, said:

> The kind of person coming into industry during the past 15 to 20 years has been changing. Two unrelated trends are noticeable—one in the direction of declining scholarship, the other in the direction of increasing specialization. There is a growing body of opinion that the decline in scholarship starts with a watering-down of public school curricula and standards.
>
> It is no longer common practice to turn out high school graduates that have an adequate working knowledge of spelling, arithmetic, English, grammar, geography, and history.[30]

Since engineering and science courses are looked upon as "too hard" by those not accustomed to study, or who simply "don't know how," Mr. Steele expresses a hope that industry will voice a demand for upgrading secondary school curricula and standards as part of a long-range plan to increase engineering college enrollments.

Following is an estimate of future high school and college graduating classes, compiled by the Commission on Human Resources and Advanced Training, based on, (1) the number of babies born each year; and (2) the changing percentages of youths who have, during past years, completed high school or graduated from college:

On this basis, the college graduates of 1960, with first degrees comparable to a bachelor of science, may number 326,000, and by 1970, despite some fluctuations that reflect earlier birth records, there may be 591,000.

The graduating class of 326,000 in 1960 may be compared with 292,880 who got similar degrees in 1954. Of this class, the 22,236 engineers represent 7.6 percent, and the 31,168 graduates in science are about 10.5 percent. If the 1960 college graduating class numbers 326,000 and includes 38,000 engineers, they will represent 6.4 percent of the total. Similarly, some 50,000 graduates in science will be less than 8.5 percent of the entire class. Thus, our growth in population promises to be accompanied by correspondingly larger enrollments in

[30] Chemical Engineering, March 1954, p. 189.

college and by increased numbers of graduates. At the same time, we face the prospect of continued attrition in the proportion of those who will graduate in engineering and science.

Projected high school and college graduates [1]

Year	High school graduates	College graduates	Year	High school graduates	College graduates	Year	High school graduates	College graduates
1954	1,274,000	286,000	1960	1,777,000	326,000	1966	2,364,000	439,000
1955	1,327,000	272,000	1961	1,873,000	329,000	1967	2,401,000	437,000
1956	1,396,000	283,000	1962	1,801,000	350,000	1968	2,416,000	532,000
1957	1,400,000	288,000	1963	1,778,000	378,000	1969	2,583,000	608,000
1958	1,475,000	292,000	1964	2,155,000	427,000	1970	----------	591,000
1959	1,582,000	307,000	1965	2,446,000	454,000			

[1] Commission on Human Resources and Advanced Training, presented in America's Resources of Specialized Talent, p. 171.

K. SUMMARY AS APPLIED TO THE UNITED STATES

From 1900 to 1950, engineering and scientific professional graduates in the United States increased almost twice as fast as did the population. More recently, however, the number of students being prepared for college work, and the number of those graduating in engineering and science, has declined. The peak was reached in 1950, when 52,732 first professional or bachelor's degrees were granted in engineering and 61,001 similar degrees were granted in the several subjects grouped under natural science.

In 1954, the colleges and universities of this country granted first professional or bachelor's degrees to 22,236 in engineering, and 31,168 in the science subjects grouped under agriculture, biology, mathematics, and the physical sciences. At present the United States has between 700,000 and 750,000 actively employed engineers and scientists. That sufficient additions may be made to restore the normal losses, keep pace with new needs, and meet those of the relatively immediate future, the Bureau of Labor Statistics estimates that something more than 30,000 new engineers will be needed each year. Because so many graduates in science use that degree as a foundation for medicine and other professions, a comparable number of scientists will also be needed. Should world conditions develop so as to warrant this country in abandoning its present program of partial mobilization in favor of a more aggressive one, the need for a more abundant force of engineers and scientists would be quickly apparent.

Graduates in engineering and science who received degrees with the class of 1950 represented nearly 25 percent of the entire class. Those of 1954 represented about 18 percent, and if present predictions are fulfilled, those of the class of 1960 will comprise a bare 15 percent of the whole.

Without attempting to analyze the reasons for this decline in interest in engineering and science at a time when our population is increasing and when the maintenance of an advanced position in technological and scientific fields is a matter of national concern, this study reveals two conditions that warrant further consideration. One is the rather long history of declining interest at the high-school level in many of the subjects basic to college work in engineering and science, such as mathematics, chemistry, and physics. The other is the heavy student loss between high school and college graduation. Of all high-school graduates whose qualifications are such as to warrant their striving to become engineers and scientists, about one-half cease further schooling to go into the business of earning a livelihood. Of the half who go on to college only about 40 percent graduate. Thus of every 10 high school pupils with capacities for potential careers in engineering or science, only 2 graduate from college. From there on, the attrition is even greater, for of all college graduates less than 3 percent continue their studies to earn a Ph. D. degree.

Inadequate teaching staffs in the secondary schools and in colleges and universities is a third condition that warrants attention. Time did not permit its consideration in this study, but such observations as were possible indicate these shortages are most acute in the fields of chemistry, mathematics, and physics.

III. WESTERN EUROPE

A. AVAILABILITY OF ENGINEERS AND SCIENTISTS

Available records of the numbers of engineers and scientists now working in the countries of Western Europe are incomplete and have little continuity. However, among the data assembled by the OEEC, are fairly complete records of seven countries, viz, Austria, Belgium, Italy, Netherlands, Norway, Sweden, and the United Kingdom. This group, which represents a total population of 134 million, each reporting for 1 of the years 1947 to 1954, showed a combined force of 111,396 engineers and 112,849 scientists. Of the latter, 91,604 were "pure" scientists, 21,245 were in the fields of agriculture and forestry.

Ten other countries of Western Europe for which reports are briefed in the following pages provided no data on scientific manpower. They have a total population of 153,730,900. Combining the 2 sets of figures, a population for 17 countries in Western Europe of approximately 288 million is indicated. On the basis of the data from 7 countries, an estimate would credit all 17 countries of Western Europe with having 239,500 engineers and 242,700 scientists. Of the science group, 45,700 are in agriculture and forestry.

Another estimate could be made on the assumption that the "backlog" of available engineers and scientists in Western Europe and similar figures for the United States bear comparable relations to the current crop of graduates from the universities and technological institutions of these two areas. To be specific, data presented in the following pages indicate that in 1953, the universities and colleges of Western Europe graduated 13,609 first degree engineers and 14,324 with a bachelor's degree in science. This total of 27,933 engineers and scientists is 52 percent of the 53,507 who were graduated in the United States in 1954. These included 22,329 engineers and 31,178 scientists. On the basis of a present "backlog" of 535,000 engineers and 225,000 scientists in the United States, a prorated estimate would credit the countries of Western Europe with having 278,000 engineers and 107,000 scientists.

Recognizing that both of these are estimates, it is assumed that the countries of Western Europe have between 239,500 and 278,000 engineers, and between 107,000 and 242,700 scientists. A rough average of 250,000 engineers and 175,000 scientists, might be considered as a reasonable figure.

Engineers and scientists in 7 countries of Western Europe

Country	Population [1]	Engineers [2]	Scientists	Agriculturists	Year
Austria	6,949,000	12,649	------------	4,344	1951
Belgium	8,778,000	9,329	2,287	1,969	1947
Italy	47,138,235	5,322	7,687	3,252	1951
Netherlands	10,488,000	6,444	3,630	930	1947
Norway	3,375,000	6,952	------------	------------	1953
Sweden	7,192,316	9,700	------------	1,750	1954
United Kingdom	50,368,455	61,000	78,000	9,000	1954
Total	134,289,006	111,396	91,604	21,245	----------

[1] Government and U. N. estimates as printed in the World Almanac, 1955.
[2] OEEC reports as summarized in following pages.

A widespread shortage of technically trained industrial manpower in Europe was revealed during discussions held in London during March 1955. This was at the Conference on the Functions and Education of the Chemical Engineer in Europe, sponsored by the OEEC, and organized by the Institution of Chemical Engineers in cooperation with the British Department of Scientific and Industrial Research.[1] One reason for calling the conference was a report of the Technical Assistance Mission of the OEEC, in which attention was drawn to the needs of the chemical engineering profession and the relatively strong position held by the United States.

The United Kingdom, and Europe in general, was described as without sufficient numbers of highly trained and skilled technologists for designing, constructing, and operating modern process plants. To correct this the conference pointed to the necessity of providing more schools of chemical engineering in universities and technical colleges where scientists, technologists, and technicians can be trained.

B. STUDENT ENROLLMENT

Universities and institutions of higher learning in Western Europe [1]

Country	Institutions		Students enrolled	
	1936–39	1948–49	1936–37	1948–49
Austria	12	13	19, 222	31, 859
Belgium	4	11	11, 566	19, 147
Denmark	10	10	9, 433	13, 905
Finland	9	11	8, 866	15, 146
France	48	54	115, 737	167, 035
Irish Republic	2	2	5, 745	7, 749
Italy	34	37	71, 512	180, 149
Luxembourg	------	------	------	------
Netherlands	93	94	15, 973	29, 668
Norway	1	1	5, 374	8, 561
Portugal	------	------	7, 101	11, 593
Spain	12	12	29, 249	46, 926
Sweden	14	15	11, 370	14, 626
Switzerland	9	9	------	17, 348
United Kingdom:				
England and Wales	50	56	------	63, 063
Northern Ireland	4	4	1, 568	2, 489
Scotland	5	5	------	15, 444
Total	307	334	312, 716	644, 708

[1] World Handbook of Educational Organization and Statistics.

C. NUMBERS BEING GRADUATED

During the academic year 1952–53, the universities and other institutions of equivalent level in 12 countries of Western Europe granted 27,933 first professional or bachelor's degrees in engineering and science. No data were available for Finland, Northern Ireland, Germany, Luxembourg, Portugal, Spain, or Turkey.

Engineering graduates, including those who had majored in architecture, civil and mechanical engineering, mining, and mine surveying, were granted a total of 13,609 degrees.

During the same year, 14,324 degrees were conferred in the several areas of science. These included 11,311 to those who had specialized in pure science, including chemistry, physics, mathematics, and biology. Colleges and universities in the same countries also conferred

[1] The Times Review of Industry, April 1955, pp. 17–19.

3,013 first professional degrees in the agricultural sciences, including forestry.

Data collected from 334 universities and institutions of higher learning in 15 countries of Western Europe show a total enrollment of 644,708 students in 1948–49. Of these, 33,321 were in engineering, 84,908 in pure science, and 11,078 in the agricultural sciences. This total of 129,307 students enrolled in engineering and science, represents about 20 percent of the entire student body.

During the same year, engineering enrollment in comparable institutions in the United States was 219,712. More recently, in 1954, the enrollment was 214,414 which was higher than any of the intervening years. That of 1953 was 193,33, or 13.4 percent of the male students of the total college population of that year.

Graduates in engineering, pure science and agricultural science from Western European universities and other institutions of equivalent level, 1938–53 [1]

Country	Engineering		Pure science		Agricultural science	
	1938	1953	1938	1953	1938	1953
Austria	--------	386	--------	95	--------	139
Belgium	--------	335	--------	210	--------	140
Denmark	310	799	30	58	156	169
France	1,969	3,399	110	288	127	232
Diplome d'Ingenieur Doctor	21	62	--------	--------	--------	--------
Doctorat d'Universitè	--------	--------	--------	53	--------	--------
Ireland:						
First degrees	88	163	63	84	15	31
Higher degrees	2	6	24	38	1	5
Diplomas	--------	--------	--------	2	11	20
Italy	1,013	1,866	649	2,436	442	774
Netherlands:						
Bachelors	215	681	216	434	68	186
Postgraduates	210	670	198	287	70	194
Norway	121	243	32	92	74	91
Sweden:						
First graduate degree	239	492	--------	--------	42	100
Licentiate of technology	--------	35	32	52	--------	--------
Dissertations	2	12	19	21	9	11
Switzerland	201	399	157	215	28	56
United Kingdom	1,829	4,061	3,312	6,946	217	865
Total	6,220	13,609	4,842	11,311	1,260	3,013
Increase in percentage during the 15-year period, 1938–53	118.8	--------	133.6	--------	139.1	--------

[1] Assembled from reports to OEEC, 1954.

First professional degrees in engineering and science awarded by institutions of higher learning in Western Europe, 1947–50 [1]

Country and year of record	Engineering	Science	Agronomy
Belgium, 1948–49	--------	282	177
Finland, 1948–49	[2] 367	[3] 56	[4] 308
France, 1948–49	[5] 3,099	--------	--------
Portugal, 1948–49	157	--------	--------
Spain, 1947–48	--------	458	--------
Sweden, 1948–49	475	710	32
Switzerland, 1948–49	(6)	(6)	(6)
England and Wales, 1947–48	1,612	3,143	374
Scotland, 1947–48	174	396	102
Total	5,884	5,045	993

[1] World Handbook of Educational Organization and Statistics, UNESCO, 1951. (Figures selected from tables.)
[2] Includes 12 specializing in chemistry.
[3] Includes architects.
[4] Includes agriculture and forestry.
[5] Certificates in physics, chemistry, and biology.
[6] Not available.

Licentiates and doctorates in engineering and science awarded by institutions of higher learning in Western Europe .1947–48 [1]

Country and year of record	Engineering		Science		Agronomy	
	Licentiate	Doctorate	Licentiate	Doctorate	Licentiate	Doctorate
Belgium, 1948–49	(2)	(2)	(2)	(2)	(2)	(2)
Finland, 1948–49	(2)	(2)	(2)	(2)	(2)	(2)
France, 1948–49	(2)	(2)	1,358	112	(2)	(2)
Portugal, 1948–49	(2)	(2)	97	(2)	76	(2)
Spain, 1947–48	(2)	(2)	(2)	(2)	(2)	(2)
Sweden, 1948–49	(3)	11	(3)	197	(3)	8
Switzerland, 1948–49	(3)	297	(3)	265	(3)	136
England and Wales, 1947–48	[4] 729	[5] 241	[4] 284	[5] 519	[4] 192	[5] 13
Scotland, 1947–48	[4] 272	[3] 3	[4] 27	[5] 57	[4] 6	(5)
Total	1,001	532	1,766	11,150	274	157

[1] World Handbook of Educational Organization and Statistics, UNESCO, 1951. (Figures selected from tables.)
[2] Not available.
[3] Licentiates and doctorates grouped together.
[4] Diplomas.
[5] Higher degrees.

D. STANDARDS OF SCHOLARSHIP

High standards of scholarship prevail in the universities, colleges, and technical institutions of all of the European countries. The same is generally true of the secondary schools. In some countries, as in France, a tendency toward two types of secondary schools was noted. This appears to provide an opportunity to group the pupils according to their economic and cultural backgrounds. A common criticism is that this can result in the creation of an "intellectual elite." This is not characteristic of all the countries of Western Europe, however, and is generally being supplanted by programs which give equal opportunity for talent, regardless of economic, professional, or social background.

E. SECONDARY EDUCATION

During the years 1947 to 1950, 17 of the countries of Western Europe were reported as having 11,922 public and private secondary schools, of which about two-thirds were publicly supported. Similar schools reported from the same countries in the period from 1935 to 1939 numbered only 5,521. As of the more recent date, 2,333,120 pupils were enrolled. These schools are comparable with the public and private high schools of the United States.

Boys and girls were in nearly equal numbers in Finland, the Republic of Ireland, Portugal, Sweden, and the United Kingdom countries. Over the remainder of Western Europe, boys exceeded girls, in the proportion of nearly 90 percent in France down to about 20 percent in Austria.

No data were found to show the proportion of graduates from secondary schools who go on to college.

"Natural science," as taught in most of these schools, includes biology, zoology, mineralogy, geology, physiology, anatomy, and allied subjects. These are taught in the secondary schools of all the Western

European countries, so that students get a thorough grounding in many of them. They are compulsory, however, in relatively few countries.

Mathematics, chemistry, and physics, assume greater importance in the curricula as shown by the tendency in nearly all countries to require a satisfactory showing before giving the pupil a passing certificate.

Summary of secondary school statistics [1] *(Western Europe)—Numbers of secondary institutions, and students in 1947–50*

Country	Public and private secondary schools 1947–50	Student enrollment 1947–50	Percentage female
Austria	729	119,764	20
Denmark	415	86,605	----------
Finland	327	5,147	55
France	2,500	54,049	10
German Federal Republic	(2)	----------	----------
Greece	(2)	----------	----------
Ireland	416	47,065	45
Italy	1,007	178,557	35
Luxembourg	12	3,605	33
Netherlands	372	89,916	33
Norway	118	54,681	36
Portugal	335	51,159	45
Spain	1,029	212,210	35
Sweden	612	193,956	52
Switzerland	108	13,212	34
United Kingdom:			
England and Wales	3,664	1,197,400	50
Northern Ireland	77	19,386	50
Scotland	201	7,408	----------
Total	11,922	2,333,120	----------

[1] World Handbook of Educational Organization and Statistics, UNESCO, 1951.
[2] Data not available.

F. REPORTS BY COUNTRY

Except as otherwise credited, the following summaries, in terms of several of the Western European countries, are from reports of the Manpower Committee of the Organization for European Economic Cooperation. They were submitted during the fall and early winter of 1954.[2]

Austria

On the basis of a June 1, 1951, census, Austria had 12,649 engineer graduates from institutes of higher learning. These were distributed according to the following categories:

Construction, architecture, and land improvement	4,496
Mechanical, including "gas, firing, and electrotechnics"	3,949
Mining, metallurgy, and surveying	1,116
Other engineers	3,088
Total	12,649

[2] Report of the Manpower Committee. Reply to Questionnaire Mo(54)25. Output and Employment of Scientists and Engineers Graduating from Universities and Other Institutions of Equivalent Level Organization for European Economic Cooperation, Paris, October, November, and December 1954 Mimeographed.

No data are available as to the number of chemists, or those in applied mathematics.

Of a total of 4,344 graduates in the broad field of agriculture, 2,011 had completed a graduate course in agriculture and forestry, 972 were described as "research personnel and scientists" and 101 as auxiliary scientific personnel.

In 1951, only 387 or about 3 percent of the 12,649 engineers in Austria were unemployed. Reduction of unemployment among engineers was reported in November 1954, but a surplus of qualified, professional personnel still existed. There was also a surplus of scientists in some of the teaching professions and in medical fields.

A drop from 628 to 481, and from 178 to 138 in the "second comprehensives" granted in technology and agriculture, as shown in the accompanying chart, reflects long-standing decline in the number of highly qualified scientific personnel graduating from Austria's institutions of higher learning. Exceptions were in the number of second comprehensives and doctor's degrees conferred in mining and metallurgy, and in the doctor's degrees conferred in philosophy.

Natural science is compulsory in all secondary schools in Austria, and two periods a week are devoted to the selected subjects. Courses cover 8 years of school and the pupils are 11 to 19 years of age.

Austrian institutes of technology, and agriculture and forestry, graduates in engineering and science, 1951 to 1953

Field of specialization	1951–52	1952–53
Applied mathematics and physics	47	46
Architecture	147	78
Chemistry	70	49
Civil engineering	115	109
Mechanical engineering	239	195
Metallurgical engineering	7	24
Mine surveying	6	3
Mining	33	38
Paper and pulp technique	6	-----------
Productivity engineering	4	4
Agriculture	88	67
Forestry	55	40
Fermentation techniques	14	12
Land improvement	21	19
Total	852	684

University graduates in some phases of science and engineering

Year	Agriculture		Philosophy	Technology		Mining and Metallurgy	
	2d comprehensive examination	Conferring of doctor's degree	Conferring of doctor's degree	2d comprehensive examination	Conferring of doctor's degree	2d comprehensive examination	Conferring of doctor's degree
1935–36	90	11	528	508	66	-----------	11
1951–52	178	13	426	628	94	44	2
1952–53	138	22	516	481	66	50	3

Belgium

As of December 31, 1947, Belgium had approximately 9,329 engineers and 4,256 scientists. These were among 53,798 persons with higher educational diplomas, of whom 49,549 were men. This university trained group represented 1.55 percent of the active population. At that time, 525 were unemployed and 7,017 "followed no occupation," leaving 46,256 actively employed persons with higher educational diplomas. For purposes of this report engineers are considered as roughly synonymous with those who received degrees in "Applied sciences," and scientists as including those who graduated in "Pure sciences."

Persons in Belgium with higher educational qualifications

[General census of Dec. 31, 1947]

Situation	Pure sciences	Applied sciences	Agronomy
Persons in employment	1,892	8,212	1,631
Persons unemployed	27	129	46
Persons following no occupation	368	988	291
Total	2,287	9,329	1,968

Natural science is taught in Belgium in all sections of secondary education. Pupils between 12 and 15 years of age devote 2 periods a week to the subject while those between 15 and 18 years of age devote 1 period a week to natural science. Periods are increased to two a week during the final year. Natural science is compulsory and counts as much toward the secondary school-leaving examination as do other subjects.[3]

Since 1939, universities and higher educational institutions in Belgium have shown a steady increase in the number of persons qualifying in the biological, physical, geographical, and mathematical sciences, and also in electricity and metallurgy. A slight drop was indicated in the number of students electing agriculture and civil, mechanical, and mining engineering. Details are set forth in the following table:

[3] Teaching Natural Science in Secondary Schools, UNESCO, International Bureau of Education, Publication No. 139, Geneva 1952.

Number of persons graduating from universities and technical institutions in Belgium: 1939–56

Categories	Description of degree or other qualification	Degrees or other qualifications obtained in—		Estimates		
		1939	1953	1954	1955	1956
I. AGRICULTURAL GROUP						
Agriculture and forestry	Agricultural technician	93	109	95	93	118
Veterinary science	Veterinary surgeon	30	31	34	29	53
Subtotal		123	140	129	122	171
II. PURE SCIENCE						
Biological sciences	Degree in zoology	9	13	16	19	64 (zoology and botany)
	Degree in botany	2	6	10	15	
	Certificate in biochemistry	1	4	12		
	Certificate in bacteriology		4	7		
Chemistry	Degree in chemistry	35	101	104	119	165
Physics	Degree in physics	14	21	24	42	76
Geology	Degree in geology and mineralogy		3	5	4	20
	Degree in geography	1	20	34	47	45
	Geological technician	6	5			
Mathematics	Degree in mathematics	33	33	42	51	125
Subtotal		101	210	254	297	495
III. APPLIED SCIENCES						
Civil engineering	Building engineer	71	66	65	82	79
	Architectural engineer	3	5	2	5	8
	Town-planning engineer	2	2	1	3	5
	Clerk of works in civil engineering	8	9	19	22	27
	Clerks of works in town-planning and colonial development		7			
Chemical technology	Chemical engineer	12	14	14	17	13
Mechanical engineering	Mechanical engineer	28	32	31	19	9
	Aeronautical engineer	11	3	1		
	Naval architect	1	4	2	2	2
Electricity	Electrical engineer	42	52	63	77	40
	Electrical and mechanical engineer	37	77	95	75	84
Mining	Mining engineer	32	59	63	46	36
Metallurgical technology	Metallurgical engineer	10	31	27	26	32
Subtotal		257	361	382	374	335
Grand total		481	711	767	793	1,001

Denmark

Without giving the number available, a considerable shortage of civil engineers of university level was reported in Denmark. Apparently this reflects heavy demands by the military service. Slow progress in construction was accompanied by a surplus of architects. A report from the University of Copenhagen in late 1954 indicated that employment prospects for graduates in mathematics, physics, chemistry, and astronomy, were better than for those with degrees in biochemistry, botany, geography, geology, and zoology.

Forestry graduates were in marked surplus. The normal Danish demand is for about 6 new forestry graduates a year, but 130 graduated during the decade 1944–53. For some years to come forestry graduates are expected to be in surplus.

Natural science is taught in all secondary schools in Denmark, and to all grades, including children from 11 to 18 years of age. It is always compulsory. Two periods per week are required in practically all classes but those of the final year, when four periods a week are required. In the final examination of the senior secondary school natural science counts only half a point.

The Danish Technical University has recently expanded its facilities to provide for about 500 students of whom about one-fifth are chemical engineers. In the following table engineers and chemists are included in "Applied science":

Graduates from universities and institutions of equivalent level in Denmark

Year	Agricultural science	Pure science	Applied science	Total
1938	156	30	310	496
1953	169	58	799	1,026
1954	167	48	(1)	(1)
1955	141	(1)	(1)	(1)
1956	166	(1)	(1)	(1)

[1] Not available.

Degrees awarded in pure science and applied science are broken down as follows:

Degrees awarded in pure science, Denmark

	1938	1953	1954
Biological science	15	27	26
Chemistry	2	11	2
Physics	9	6	9
Geology and earth sciences	1	4	4
Mathematics	3	10	7
Total	30	58	48

Degrees awarded in applied sciences, Denmark

	1938	1953
Civil engineering:		
Constructional engineers	76	109
Engineers other than civil engineers	18	123
Architects	32	81
Chemical	36	72
Mechanical:		
Civil engineers	23	106
Other engineers	76	174
Electrical:		
Civil engineers	26	65
Other engineers	23	69
Total	310	799
Civil engineers total	161	352
Other engineers total	117	366

University authorities in Denmark have expressed the opinion that the number of graduates in the pure science group, including biological science, chemistry, physics, geology and earth sciences, and mathematics will differ little from those of the past 2 years.

Finland

No record could be found of the present numbers, or backlog of available engineers and scientists in Finland.

From 11 institutions of higher learning in Finland, 367 graduates received first degrees in engineering in 1949. That year, 56 received first degrees in science, and 308 in agronomy. Thus, a total of 731 might be described as being added to the scientific manpower of that country.

Student enrollment at Finland's institutions of higher learning increased from 115,737 in 1937 to 167,035 in 1949. Part of this increase was made possible by the opening of two new establishments during the period.

Finnish secondary schools include botany, zoology, and geography in their natural science curricula. These subjects are optional for pupils from 16 to 19 years of age in the final 3-year course, and they may choose psychology and philosophy instead of science. Marks obtained for natural science, as taught in these schools, count as much toward promotion and graduation as do those of other subjects.

France

During the 15 years from 1938 to 1953 engineers graduating from French universities and similar institutions increased from 1,969 to 3,399. During the same period those graduating in pure science increased from 796 to 1,349. During approximately the same period 6 new institutions of higher learning were recognized, to bring the total to 54 in 1949.

This increase in the numbers of scientific and technical persons is still short of the numbers needed. This is evidenced by reports that such shortages are suggested as a reason for the "backwardness of certain French firms in industrial competition." Salaries paid scientists and researchers in French industries are described as so low that many are not "dissuaded from transferring elsewhere."

Education, as applied to science and technical matters, is the field in which most serious shortages exist. Shortages of suitable candidates for administrative and higher educational careers were also reported.

Number of graduates from French universities or other similar institutions

Subject	1938	1953
I. Agricultural group:		
Agriculture (engineering diploma)	332	425
Brewery-miller's trade and forestry (engineering diploma)	26	15
Veterinary science (doctor's diploma)	127	232
Total	----------	672
II. Pure science:		
"Licence d'enseignment" (teaching diploma):		
Mathematical science	----------	248
Physical science	----------	222
Natural science	----------	219
Total	----------	689
"Licence ès-sciences": "Licences libres" (general diplomas)	----------	660
Total "licence" diplomas	796	1,349
"Diplome d'etudes supèrieures en vue du doctorat":		
Mathematical science	----------	12
Physical science	----------	126
Natural science	----------	150
Total	110	288
"Diplome d'ingnéieur-docteur" (doctor of engineering)	21	62
"Doctorat d'universitè" (university doctorate)	----------	53
III. Applied science engineering diplomas:		
(a) General studies	895	1,227
(b) Chemistry/physics	214	411
(c) Electricity-electrotechnics	449	784
(d) Metallurgy	30	44
(e) Mining	77	93
(f) Aeronautics-mechanics-navigation	147	248
(g) Shipbuilding	4	11
(h) Optics and chronometry	1	18
(i) Textiles	20	80
(j) Papermaking	8	14
(k) Ceramics	6	12
(l) Public works	118	313
(m) Architecture	----------	144
Total	1,969	3,399
Grand total	----------	5,823

Graduates in the fields of chemistry, electricity, and electrotechnics, mechanics, radio telecommunications, and textiles have increased in numbers during the period from 1938 to 1953. An even greater increase was shown in the agricultural sector.

In the field of pure science enrolled students numbered 1,349 in 1953. Current registrations indicated they would increase to 1,500 in 1954, and to nearly 1,800 in 1955.

Rigid competitive entrance examinations which promise to become stiffer with each year, will hold down the number of admissions, and result in little or no increase in the number of engineering graduates for several years.

In the first stage of French secondary education, to which children between 10 and 12 years of age are admitted, natural science is compulsory. During the early part of the second period, however, it is replaced by physical science, and during the final year by philosophy, mathematics, and experimental science. The aim of natural science teaching is to acquaint pupils with typical examples of the animal and plant kingdoms, and to teach them the technique of accurate observation.

Public secondary education in France as described by Alexander Efron [4] is made available through a system of lycees and colleges

[4] Op. cit.

for boys and girls and cours secondaires for girls. Secondary education proper begins with the age of 10 to 11. The numbering of classes or grades in the French secondary school follows the reverse of the American order. Accordingly, the first cycle of secondary work includes the sixth, fifth, fourth, and third classes.

Many of the larger lycees maintain advanced classes for pupils who have received adequate training and who wish to prepare for entrance in certain higher schools and universities. The degree of selection is implied by the fact that the primary school population is 4,500,000, and the number of vacancies in the secondary schools is only 150,000 to 200,000. It follows that the lycee is dedicated to the task of training the intellectual elite, and science teaching is fundamentally a training in intellectual discipline which contributes to the secondary school objective of general culture.

In 1935, time was allotted to physics and chemistry as indicated in the following table:

Allotment of time, in hours per week, for physics and chemistry (French secondary schools)

	Classe de seconde		Classe de premiere		Mathematiques		Classe phylosophie	
	1st semester	2d semester	1st semester	2d semester	1st semester	2d semester	1st semester	2d semester
Physics (hours per week)	1	1	2	2	2	2	2	1
Chemistry (hours per week)	1	0	1	0	2	2	1	1
Total hours per week for each semester	2	1	3	2	4	4	3	2
Average per year	1½		2½		4		2½	
Laboratory work (hours per week)	1½		1½		1½		1½	

As a rule, laboratory work is divided equally between physics and chemistry. There are 38 weeks of work in the school year from October 1 to July 15 (4 weeks off for holidays).

More recent figures presented by Le Bureau Universitaire de Statistique in Paris[5] indicate that mathematics is a required subject in all public and private schools of France. As previously noted, enrollment during 1947–50 in some 2,500 public and private secondary schools was reported as 54,049. In 1950–51, as shown in the following table, 54,275 were recorded as taking mathematics, or courses in which mathematics is a recognized part.

Instruction in the 2e degré

[Comparable to the first year in an American college]

	1949–50	1950–51
Public school:		
Preparatory mathematics (for university study)	14,062	12,030
Finishing mathematics, science, and philosophy	30,961	30,993
Private school:		
Classes terminale—Mathematics, science, and philosophy	10,920	11,252
Total	55,943	54,275

[5] Recuil de Statistiques, Scholaires et Professionelles, 1949–51, France, Le Bureau Universitaire de Statistique, Paris.

German Federal Republic

An active demand was underway for all types of engineers in the fall of 1954. Unemployment appeared limited to those in the older age groups, and to those whose long unemployment or employment in fields other than their own had caused them to lose touch with present techniques.

Civil engineers with qualifications in architecture and construction were in demand because of the building activity. Graduate engineers with abilities in roadbuilding and underground engineering were also in short supply. The rehabilitation of German industry has led to a shortage of mechanical engineers, especially those in the field of power techniques. Shipbuilding activities have resulted in more demands for qualified shipbuilding engineers than can presently be met. A few cases of unsatisfied demand for young metallurgists and mining engineers was noted. Electrical engineers appeared to be among the few with especial abilities whose supply was sufficient to meet requirements.

German industries were in the market for young chemists, physicists, and geologists, especially those who had specialized in the petroleum industry. On the other hand, while a definite slack was noted in the demand for biologists, astronomers, and meteorologists, the demand for teachers of mathematics was active.

In general, opportunities for agriculturists and foresters were limited. This was partly explained by the influx of expellee and refugee farmers from Eastern Europe and the Soviet occupation zone.

Natural science is a compulsory subject in all secondary schools of the German Federal Republic. Zoology, botany, physiology, and anatomy, grouped as Naturkunde, are taught to pupils 11 to 16 years of age, generally for 2 periods a week. Biology is taught for 2 periods a week to pupils from 11 to 19 years of age.

The same importance is generally attached to natural science as to other subjects in the curriculum. In promotion and final examinations, biology was only slightly lower than languages, mathematics, and physics.

Greece

Little was available for Greece other than an indication that natural science is compulsory in the grammar schools and schools of commerce. However, it ranks below mathematics and modern Greek in promotions. Three periods a week are devoted to subjects such as mineralogy, botany, zoology, anthropology, and biology.

Irish Republic

Four institutions in the Irish Republic have colleges of engineering and agriculture.[6] Of these, 2 are reported as having increased their enrollments from 5,745 in 1936–37, to 7,749 in 1949–50.[7] Graduation data for the same years are not available, but data submitted by the Manpower Committee of OEEC indicate an almost unbroken rise in student enrollment at the universities of the Irish Republic. During

[6] World's Universities, British Universities Encyclopaedia Ltd., London.
[7] World Handbook of Educational Organization and Statistics, UNESCO, 1951.

1926–27 there were 3,037 students; in 1938–39 enrollment rose to 5,046; and in 1952–53 to 7,601. Over a somewhat shorter span, the numbers receiving degrees, are shown below:

Degrees and diplomas awarded in certain university faculties in Ireland

Faculty	1938–39			1952–53		
	First degrees	Higher degrees	Diplomas	First degrees	Higher degrees	Diplomas
Agriculture, forestry, dairy science	15	1	11	31	5	20
Science	63	24		84	38	2
Engineering (civil, mechanical and electrical)	80	2		148	6	
Architecture	8			15		

Engineers and scientists in these classes appeared to be in sufficient numbers to meet the needs for their services within the Irish Republic.

Natural science subjects are optional at the three levels of secondary schools. Only the Irish language and mathematics rate higher in the final, or leaving examinations.

A 2-year course is required in any of the following subjects: physics, chemistry, physics and chemistry (joint course), agriculture science, botany, physiology and hygiene, general science, or domestic science. In general 3 hours a week are devoted to each science subject.

Italy

A surplus of engineers and scientifically trained persons in Italy was reported in the fall of 1954, which led to the conclusion that the country was confronted with an old problem of intellectual unemployment. The Government was then attempting to meet this by opening more public administration posts to competitive examinations, and by raising the standards in various grades of education. No indication was given concerning the part then being played by industry.

Approximately 16,261 persons with degrees in agricultural sciences, pure science, and applied sciences or engineering, were reported from 20 provinces in 1951. A breakdown of the available data indicates that as of 1951, Italy had approximately 5,322 graduates in engineering and 10,939 in science. As in other countries, many of the engineers and even more of the scientists were probably in fields other than those which could be classed strictly as engineering or science.

Graduates in agricultural science, pure science, and applied science, living in 20 Provinces of Italy in 1951

Agricultural sciences (biochemistry and agricultural chemistry, agricultural engineering, zoology)	3, 252
Pure science (physics—including astronomy and electronics, mineralogy and petrography, geophysics, geology, and paleontology)	7, 687
Applied science (degree of civil engineer, chemical technology, mechanical engineering—including aeronautics and naval architecture)	5, 322
Total	16, 261

During the decade from 1939 to 1949, student enrollment at universities and institutions of higher learning in Italy more than doubled, increasing from 71,973 to 180,149. During the same period three new educational institutions were recognized to bring the total in 1949 to 37. Keeping pace with this institutional growth, graduates in applied science, or engineering, also more than doubled. Some fluctuations are forecast, but the class of 1956 promises to be only 4 short of the 2,187 graduated in 1952. An even greater spurt was evidenced among those who graduated in pure science. From only 649 graduates in 1938, the classes burgeoned a good threefold to 2,141 in 1952. Moderate increases indicated through 1956 promise about 2,304 graduates in that year. Graduates in the agricultural sciences are showing somewhat less vigorous growth.

Secondary schools of Italy are of two kinds: those whose curricula include foreign languages, history and geography, and mathematics; and the gymnasia, whose curriculum includes Italian, Latin, Greek, history and geography, philosophy, natural science, mathematics and physics, and history of art. At the end of the 5-year course a diploma gives access to university facilities.

Natural science in correlation with chemistry and general geography, is compulsory in the various secondary schools of Italy. Pupils are 16 to 18 years of age. In the 5-year scientific secondary schools, natural science is taught to pupils ranging from 15 to 18 years of age. The same importance is attached to natural science as to other subjects in promotion and final examinations.

Number of graduates from universities or institutions of equivalent level in Italy

Degree courses by groups	Known data		Forecasts			
	1938	1951–52 average	1953	1954	1955	1956
Agricultural sciences: Agriculture and forestry	292	409	353	351	365	356
Pure science	649	2,141	2,436	2,376	2,296	2,304
Mathematical sciences	126	326	363	360	330	334
Mathematics and physics	63	465	527	527	486	449
Physics	51	112	128	152	154	167
Chemistry	234	576	565	472	415	417
Industrial chemistry	30	216	238	245	256	260
Natural sciences	142	349	455	432	406	384
Biological sciences	1	81	134	150	183	185
Geological sciences	2	16	26	38	66	108
Applied sciences	1,013	2,187	1,866	2,210	2,327	2,183
Civil engineering school	371	853	647	757	818	827
Industrial and aviation engineering school	478	1,057	950	1,106	1,137	999
Mining school	16	26	17	22	26	21
Industrial chemistry school	3	20	21	25	30	30
Naval architecture and mechanical engineering school	27	42	31	45	33	29
Architecture	118	189	200	255	283	277
Total	1,954	4,328	4,302	4,586	4,623	4,487

Luxembourg

The Grand Dutchy of Luxembourg made a systematic survey of the employment of scientists and engineers in October 1954. No figures were reported, but as of that date, all qualified nationals, with training in science and engineering, were employed.

Luxembourg has no university or other institution of higher learning, but the primary and secondary schools are described as of a higher order.

Natural science is compulsory in all secondary establishments. There, the boys and girls are 12 to 19 years of age. The natural science program is included in each of the seven classes. One hour a week is devoted to such subjects as zoology, botany, the study of man, and microscopy. An inadequate mark in natural science has less serious consequences relative to graduation than one in language or mathematics.

Netherlands

In 1947, the Netherlands had a working force of 6,444 engineers, and 4,560 in the sciences. The latter figure includes 930 credited as being graduates in the agricultural sciences. These numbers were nearly twice those reported 17 years earlier in 1930.

The decade ending in 1949 saw university and college enrollment in 94 institutions in the Netherlands double—from 15,973 in 1939, to 29,668 in 1949.

During the somewhat longer period from 1938 to 1953, first degree engineering graduates increased from 215 to 681, and those with postgraduate degrees from 210 to 670. Graduates in the agricultural sciences increased from 68 in 1938 to 186 in 1953, and those with postgraduate degrees from 70 to 194. Somewhat slower increases were evident among graduates in the pure sciences, as first degrees were conferred on 216 in 1938, and on 438 in 1953. During the same period, those receiving postgraduate degrees built up from 198 to 287.

The insufficient supply of trained personnel in engineering and science was evident in October 1954, when industrial leaders in the Netherlands were reported to be complaining because qualified persons were not available to fill some of the highly specialized, high level positions.

No material increase in the numbers of postgraduate students in engineering and science is expected until after 1959. Meanwhile, small enrollments indicate that the number of available civil engineers will drop until it about equals those who leave the labor force. Such a situation, it has been pointed out, can hold back the construction of public works, many of which are vital to the safety of the Netherlands.

Natural science subjects are compulsory for boys and girls in the secondary schools, but mathematics, physics, and elementary chemistry have priority in the final examinations.

The relative place of scientists and engineers in the Netherlands [1]

	1930	1947
Total working population	3,179,000	3,866,000
Postgraduates:		
Agricultural science	248	930
Veterinary science	364	768
Pure science	1,621	3,630
Applied science (engineers)	4,265	6,444
Total	6,479	11,772
Pro 100,000 of the working population:		
Agricultural science	8	24
Veterinary science	11	20
Pure science	51	96
Applied science (engineers)	134	166
Total	204	306

[1] OEEC report in the Netherlands, Oct. 26, 1954.

Granting of 1301 bachelor's degrees in science and engineering by universities in the Netherlands in 1953, appears to have attained a peak from which a somewhat steady decline is forecast through 1959. This is shown in the following table:

Persons graduating from colleges and universities in the Netherlands

Year	Agricultural sciences		Pure science		Applied sciences		Total	
	Bachelors	Postgraduates	Bachelors	Postgraduates	Bachelors	Postgraduates	Bachelors	Postgraduates
1935–39 (average)	68	70	216	198	215	210	499	478
1953	186	194	434	287	681	670	1,301	1,151
1954	165	185	375	285	635	650	1,175	1,120
1955	140	160	375	280	565	580	1,080	1,020
1956	125	155	375	305	495	505	995	965
1957	125	145	380	285	440	450	945	880
1958	125	130	385	275	420	395	930	800
1959	130	115	385	270	405	380	920	765

A partial breakdown of graduates in engineering and science is shown in the following tables:

Persons graduating from the Netherlands Technical University

Year	Civil (including architecture)	Chemical	Mechanical (including naval and aircraft)	Electrical	Mining	Physical	Others	Total
Bachelors:								
1935–39 (average)								215
1953	160	82	218	148	15	47	11	681
1954	175	100	165	115	20	40	20	635
1955	150	95	145	95	20	40	20	565
1956	120	90	130	30	20	35	20	495
1957	95	80	125	70	20	30	20	440
1958	80	80	120	70	20	30	20	420
1959	75	80	120	65	15	20	20	405
Engineers (postgraduates):								
1935–39 (average)	56	39	56	36	11	12		210
1953	191	108	192	97	23	46	13	670
1954	175	105	195	110	20	35	10	650
1955	150	100	170	100	15	30	15	580
1956	120	95	145	90	15	25	15	505
1957	95	90	135	75	15	25	15	450
1958	75	80	125	60	15	25	15	395
1959	75	75	120	55	15	25	15	380

Persons graduating from pure science university faculties in the Netherlands

Year	Bachelors, total	Postgraduate study						
		Mathematics (including astronomy)	Physics	Chemistry	Biological sciences	Pharmacology	Geology	Total
1935–39 (average)	216	22	35	57	24	57	11	198
1953	434	26	58	103	42	26	30	287
1954	375	45	55	100	35	30	20	285
1955	375	45	55	100	30	30	20	280
1956	375	45	60	105	40	30	25	305
1957	380	45	55	100	35	30	20	285
1958	385	40	55	95	35	30	20	275
1959	385	40	50	90	35	30	20	270

Norway

Norway had 6,952 engineers with qualifications of a university level in January 1953. These figures include all under the age of 65, some of whom may have been unemployed by choice.

Looking to the future, Norway can be expected to require a net annual increment of about 350 engineers, for 20 years to come. Shortages are already retarding industrial development and research. They are also holding back the education of future scientists and engineers. These shortages had their origin in the war years, but have since been accelerated by the industrial development now underway, research and construction by the military agencies, and the inability of existing educational institutions to expand. A breakdown follows:

Mining engineers	164
Construction engineers	2, 133
Electrical engineers	1, 403
Chemical engineers	935
Mechanical engineers	2, 040
Physical engineers	13
Others	264
Total	6, 952

In 1953, the demand for qualified engineers in Norway was so active as to leave vacant only the most exacting posts. Planned development of the country is such as to warrant belief that demands for scientific and engineering personnel will increase.

Shortages of qualified engineering and scientific staffs are felt in industry and in university circles. On the one hand they tend to reduce the pace of industrial development and research. At the other extreme, the shortages have created new interest in the education of future scientists and engineers.

Broken studies, limited curricula, and reduced teaching personnel of the war years, are credited among the origins of the recent shortages. More particularly, however, the intensified demand for qualified engineers and scientists reflects Norway's present economic and industrial development. There is reported an awareness on the part of industry that it must overcome the isolation which accompanied the war years and catch up in the development of scientific and industrial technology.

Defense research and construction draw heavily upon engineers and scientists from industrial sectors to further aggravate the marked shortages at the top professional levels as well as among new graduates.

Natural sciences are compulsory in the secondary schools of Norway. Of the several subjects, chemistry is given major emphasis, but classes also include botany, zoology, mineralogy, and geology. In examinations the various branches of natural science are treated orally, and regarded as less important than mathematics and chemistry, for which a written examination is required.

All Norwegian engineers are graduates of the Norwegian Technical University. In the following table they are included in figures for the applied sciences. Demands for engineers presently exceed the normal graduating class of this institution, so their numbers are increased by engineers and scientists who graduate abroad. For example, from 1949 to 1953 an average of 150 Norwegians each year were trained in all fields of engineering at foreign universities.

Numbers graduating from universities and other institutions of equivalent level in Norway

PURE SCIENCE

	1938	1953	1954	1955	1956
Biology, zoology	12	16			
Chemistry	3	14			
Physics	6	18			
Geology, geography:					
Meteorology	6	35			
Mathematics	5	9			
Total	32	92			

APPLIED SCIENCES

	1938	1953	1954	1955	1956
Civil engineering and architecture	37	85	87	84	77
Chemical engineering	21	26	23	28	30
Mechanical engineering	34	61	59	45	72
Electrical engineering	24	53	41	44	42
Mining, Metallurgical	4	10	10	14	12
Others	1	8	7	9	7
Total	121	243	227	224	240

Portugal

Reports concerning numbers of engineers and scientists in Portugal are inadequate, but in 1949 first degrees in engineering were conferred upon 157 candidates. During the previous year, 97 first degrees or licentiates, were given in science, and 76 in agronomy. The enrolled student body in institutions of university grade was 11,593 in 1949. This represented an increase from 7,101 in 1939.

Natural science is taught in the three stages of the secondary school system of Portugal, and is preparatory to vocational education. It ranks equal with other subjects in final examinations.

Spain

The 12 universities or comparable institutions of learning in Spain reported an enrollment of 46,926 in 1949. In 1939 this had been but 29,249. In 1948, first degrees in science were conferred upon 458 candidates. No record was found of the numbers granted in engineering or the agricultural sciences.

Two periods a week of natural science are taught to students in the Spanish secondary schools. Chemical symbols, atomic weights, and elementary geological formations are among the subjects taught to 13-year-old pupils in the 3d year. Mineralogy, crystallography, botany, and zoology are included in courses given to 15- to 16-year-olds in the 6th year, and dynamic geology, geology of the Iberian Peninsula, classes of rocks, and soil in relation to agriculture are among the courses given to 16- and 17-year-olds in the 7th year.

Sweden

As of 1954, Sweden had records of 11,450 living graduates in engineering and the agricultural sciences who were under 65 years of age. No records were found as to the number of graduates in the "pure" sciences. Of the graduates for whom records are available, 9,700 were engineers and 1,750 were agricultural scientists and foresters.

A shortage of engineers in 1954 was focused especially upon those trained in civil engineering and physics. As a consequence, posts intended for those with a master of engineering were often filled by persons of less training, and by university trained chemists. The field has also been opened to engineers from other countries, especially of Scandinavian origin. Judging from the number who had transferred to other industries, a surplus of engineers trained in shipbuilding then existed.

Graduates in agricultural sciences and forestry appeared to be in fair balance with demands for their services.

The degree of master of engineering usually requires 4 years' study at the Royal Academy of Technology in Stockholm and the Chalmers Institute of Technology in Gothenburg. Graduates include engineers, mining engineers and architects.

Reports show that 492 master of engineering degrees were conferred in 1953. This compared with 475 in 1949, and 239 in 1938. Production of engineers is now on a slightly rising plateau. In 1946, enrollment at the Royal Academy in Stockholm and the Chalmers Institute in Gothenburg was 1,642 and 810, respectively. In 1953, these enrollments had increased to 1,876 and 1,255. Enrollment of women has also shown a steady increase. By 1957 a total of 636 graduates from the two institutions is forecast. Most of these will be engineers but some architects will be included.

A similar forecast is made for those receiving bachelor of science degrees. This is based on the presentation of 62 degrees in 1946, 126 in 1953, and 157 degrees in 1954. On the assumption that about 34 percent of the entering enrollment will graduate, prospects appear reasonable for about 143 graduates in 1955, 185 in 1956, and 203 in 1957.[8]

Science and engineering graduates from institutions of university grade in Sweden, 1954

	1954	1939
Graduates in agricultural science	950	------
Graduate foresters	800	------
Masters of engineering	9,700	6,833
Total	11,450	6,833
Breakdown of masters of engineering:		
Civil engineers	2,000	1,506
Architects	800	456
Breakdown of masters of engineering—Continued		
Chemical engineers	1,200	843
Mechanical engineers and shipbuilders	2,500	1,900
Electrical engineers	2,000	1,394
Mining engineers	600	443
Physicists	100	9
Surveyors	500	282
Total	9,700	6,833

The 138 master of science degrees conferred by the 3 Swedish universities in 1953 compare favorably with 104 conferred in 1951 and 112 in 1952.

The number of licentiate degrees and dissertations for a doctorate in science at the science faculties, classified by subjects, is shown in the following table:

[8] Figures for 1946, 1953 and 1954 submitted by the Swedish Embassy.

Subjects	Licentiate degrees		Dissertations	
	1938	1953	1938	1953
Botanics, zoology, or heredity	13	16	6	7
Chemistry	5	17	7	3
Physics, mechanics, or astronomy	3	9	3	4
Geography or geology	7	6		
Mathematics	4	4	3	2
Total	32	52	19	21

Forecast for Swedish scientists.—A forecast of the number of master of science degrees expected in the years 1954–58 at the science faculties can be based on the number of students admitted in the preceding 5-year period. In 1953 the number of masters of science degrees correspond to 29 percent of the number of students admitted in 1948. On the assumption that this percentage remains constant the following master of science degrees are forecast:

1954	132	1957	158
1955	134	1958	173
1956	122		

Graduates from Swedish universities.—The following table shows the number of bachelor of science degrees conferred at the universities of Uppsala, Lund, and Stockholm in 1938 and 1953:

Bachelor of science examinations comprising at least 3 subjects in the subject groups indicated below	Number of bachelor of science degrees	
	1938	1953
Mathematics, physics, chemistry, mechanics, astronomy, geography, geology	27	86
Botanics, zoology, heredity	2	19
Botanics, zoology, chemistry, geography, geology	15	31
Mathematics, insurance calculus, economics	5	8
Other combinations	1	12
Total	50	156

The number of master of science degrees conferred in the same years is shown in the following table:

Master of science examinations comprising at least 2 teaching subjects in the subject groups indicated below	Number of civil-service examinations	
	1938	1953
Mathematics, physics, chemistry, astronomy, mechanics, geography, geology	28	89
Botanics, zoology, chemistry, geography, geology	20	49
Total	48	138

Natural science is taught in all sections and classes of the 1,029 Swedish secondary schools. As of 1950, boys were in a slight minority in a total enrollment of 212,210. The first period, or realskola, to which pupils 11 to 13 years are admitted, devotes 2 hours a week to natural science, and the gymnasium, to which pupils 15 or 16 years of age are admitted, devotes 1 to 3½ hours a week to similar subjects.

In each of these periods, natural sicence covers geography (including geology), biology (including botany, zoology, physiology, anatomy, and genetics), physics (including astronomy), and chemistry (including mineralogy). Final, as well as promotion examinations, recognize natural science as having the same importance as other subjects.

The following table shows the number of examinations passed at the Swedish institutes of technology, broken down by divisions:

Department	Master of engineering examination		Licentiate of technology examination, 1953	Dissertations	
	1938	1953		1938	1953
Civil engineering	67	87	3		
Architecture	26	38			
Chemical engineering	42	49	15	1	5
Mechanical engineering	39	118	2	1	
Aeronautics and shipbuilding	5	36	3		
Electrical engineering	31	90	6		2
Mining and metallurgy	14	25			
Physics	2	10	6		3
Surveying	13	39			
Total	239	492	35	2	10

Forecast for Swedish engineers.—The following estimate of the number of graduations to be expected from the Swedish institutes of technology in the years 1954–57 is based on the number of new students admitted in 1950–53 and on the assumption that 7 percent break off their studies without graduating, whereas the remainder are assumed to pass examinations after 4 years' studies.

Departments	Estimated number of master of engineering examinations			
	1954	1955	1956	1957
Civil engineering	117	128	124	134
Architecture	43	54	47	53
Chemical engineering	60	67	63	73
Mechanical engineering	139	81	126	104
Aeronautics and shipbuilding	45	51	49	58
Electrical engineering	143	147	121	153
Mining and metallurgy	26	33	33	33
Physics	19	19	19	19
Surveying	19	19	14	9
Total	611	599	596	636

Judging by this forecast, the total number of graduations would appear to be increasing very substantially as compared with 1953.

Switzerland

No data are available as to the numbers of graduates in the fields of science or engineering. Shortages of electrical engineers were reported in 1954. They were especially acute among those conversant with low-voltage currents. Chemists and persons in several other sectors of science were reported in demand by responsible Swiss trade and professional groups. A shortage of highly qualified persons in certain branches of scientific research also exists. All of these shortages are expected to continue as long as Switzerland's economic activity remains at its present high level.

The 9 universities and institutions of higher learning had enrollments of 17,348 in 1949. That year licenciates and doctorates were conferred upon 297 in engineering, 265 in science, and 136 in agronomy. Growth in the general interest in engineering and science is shown by the following figures from the Swiss universities:

First degrees comparable with a bachelor of science were conferred on 399 in engineering in 1953. In 1938, similar degrees had been given to 201 candidates. Records for pure science showed 215 degrees in 1953, and 157 in 1938. In the agricultural sciences, 56 degrees were conferred in 1953, and 28 in 1938.

In November 1954, the needs of the Swiss economy were so well known that many young people were expected to take up technical sciences during the coming years. This will probably be in even larger number than indicated in the following table:

Numbers graduating from universities and other institutions of equivalent level in Switzerland

Year	Agricultural sciences	Pure sciences	Applied sciences	Total
1938 or substituted year	28	157	201	386
1953 or substituted year	56	215	399	670
1954	60	225	410	695
1955	65	135	530	730
1956	67	145	550	762
1957 (if possible)	69	155	570	794

Natural science is compulsory at the junior and the senior stages of the 108 public and private secondary schools in Switzerland. In 1950 enrollment in these schools was 13,212, of whom two-thirds were boys, The number of subjects and the length of the courses varies from canton to canton; usually two periods a week are devoted to natural science.

United Kingdom

As of 1954, the universities and institutions of higher learning had graduated 61,000 under the all-inclusive heading "Applied Science." Most of these would be recognized as engineers. The same group of institutions had also graduated 78,000 in pure science and 9,000 in agriculture and forestry. This total of 148,000 engineers and scientists represented less than 0.65 percent of the working population. For lack of better figures, these may be accepted as the present backlog of available engineers and scientists. That this number has been steadily growing, is indicated by data which show that the graduates in engineering, science, and agriculture numbered about 88,000 in 1938. As of that year, this group represented but 0.4 percent of the working population.

Universities and comparable institutions in England, Wales, and Scotland have increased from 59 in 1939, to 65 in 1949. During the latter year, 80,996 students were enrolled. The six additional institutions evidence the increased numbers of young men and women who are seeking a higher education, as well as the economic demands of these countries. These demands are demonstrated by more than doubling the number of degrees given in engineering and pure science during a period of 15 years. During the same period, degrees granted in agriculture and forestry multiplied by 4. In 1938, for example, 1,829 degrees were granted in engineering. In 1947 this had increased to 3,031, and in 1953, to 4,061. Similarly, there were 3,312 degrees granted in pure science in 1938, 4,326 in 1947, and 6,946 in 1953; and in agriculture and forestry the graduates of 1938 numbered 217, in 1947 they were 687, and in 1953 they were 865.

A shortage of engineers and scientists, estimated at from 1,300 to 2,500, has been reported in Great Britain. It varies according to the skill of the men, but as may be expected, the highest qualified men are in shortest supply. This applies particularly to aeronautical engineers, and those needed for research and development work.[9]

Chemists, physicists, chemical engineers, mechanical engineers, electrical engineers, and engineers trained in metallurgy were in shortage. The many specializations in the profession of metallurgical engineering served to emphasize the difficulty of matching qualified men with vacancies. Only in civil engineering was supply and demand described as in balance.

Chemists and physicists for research and for carrying out ideas produced by research were in short supply. Geologists and geophysicists for overseas posts were in demand, but prospects for employment within the United Kingdom were poor. Mathematicians who desired teaching posititions were in short supply, but others were described as "probably slightly greater than demand." Personnel trained in the biological sciences was reported as in slight surplus, but in some highly specialized categories there was a shortage.

Shortages were apparent in some highly specialized agricultural sciences such as poultry husbandry, agricultural chemistry, bacteriology, and agricultural economics. Those qualified in agriculture and forestry, however, were reported as sufficient to meet the demand.

The establishment of chairs of chemical engineering in the British universities and colleges of technology marks the acceptance of chemical engineering as a fourth primary technology, along with civil, mechanical, and electrical engineering. This new phase of the engineering profession is complementary to the older technologies but is not competitive with them. The efficiency of these new schools is expected to be greatly helped by their close links with industry. Two of the existing chairs owe their foundation to industry, which partly supports the others. In all of them, opportunities are provided for vacation jobs with industry.

Chemical engineering includes the processing of foods and essential constituents such as vitamins, production of chemical fertilizers, treatment of ores, further exploration of possibilities in the chemistry of wood and the production of cellulose, synthetic fibers, and uses of lignin, a wide variety of applications to atomic energy, the treatment of seawater and polluted water preparatory to its availability for potable purposes, and the production of synthetic pharmaceuticals such as DDT, antimalarials like paludrine, and such antibiotics as penicillin and aureomycin.[10]

In 1950, the United Kingdom, including England and Wales, Scotland, and Northern Ireland, had 3,942 public and private secondary schools, with an enrollment of 1,224,194 pupils. In common with most of the English-speaking countries of the world, the teaching of general and elementary science begins in the early school years, but the selection of subjects is left to the discretion of the individual school administration.

[9] Fine, Benjamin, Russia Is Overtaking United States in Training of Technicians, New York Times, November 7, 1954, p. 1.

[10] The Financial Times, London, May 19, 1955, p. 6.

The English grammar school curriculum, where the age range is 11 to 18 years, may include 2, 3, or 4 years of physics, chemistry, biology, and other general science subjects. The fifth and sixth years include physics, chemistry, and biology, which are generally taught as separate subjects.

In England and Wales natural science includes botany, zoology, some physiology, a little geology, and anatomy. Mineralogy and geology are occasionally linked with geography. Modern secondary schools, with an age range of 11 to 15 years, concentrate mainly on general science, whose importance in promotion and final examinations is equal with that of other subjects.

Natural science is taught in the secondary schools of Northern Ireland, but is not on the compulsory schedule.

The first 3 years of Scottish secondary schools require physics, chemistry, botany, and zoology. Geology, astronomy, and other subjects are taught at the discretion of the teacher. After the third year, pupils who elect to continue with science subjects must choose two subjects from among the following list: physics, chemistry, botany, zoology, zoology with human physiology, and engineering (applied mechanics and heat engines).

The growing number of university graduates in England, Scotland, and Wales reflects the new scientific discoveries and the development of new techniques in industry. Such activities call for increasing numbers of scientists and engineers, and increasing proportions of technically trained personnel in industry. This trend is shown in the following table:

Degrees and diplomas awarded by British universities and other institutions of equivalent level [1]

PURE SCIENCE

	1937–38	1952–53	Estimate		
			1953–54	1954–55	1955–56
Biological sciences	185	445	450	440	440
Chemistry	506	1, 204	1, 204	1, 210	1, 210
Physics	192	647	660	700	690
Geology and earth sciences	26	133	130	140	150
Mathematics	271	524	580	580	580
Other degrees and diplomas	1, 552	2, 762	2, 780	2, 745	2, 765
Higher degrees	580	1, 231	1, 230	1, 210	1, 230
Total	3, 312	6, 946	7, 020	7, 025	7, 065

APPLIED SCIENCES

	1937–38	1952–53	1953–54	1954–55	1955–56
Civil engineering, including architecture and building	65	367	380	380	380
Chemical, including fuel and petroleum technology	6	133	140	130	130
Mechanical, including aeronautical	27	263	260	260	260
Electrical, including electronics	64	219	250	250	250
Mining	22	87	100	100	100
Metallurgical, including metallurgy	31	84	110	115	115
Other degrees and diplomas, including general engineering [2]	11, 462	2, 513	2, 410	2, 430	2, 450
Higher degrees [3]	152	395	380	385	415
Total	1, 829	4, 061	4, 030	4, 045	4, 100

[1] Northern Ireland is not included.

[2] This is a residual figure and includes, besides general and ordinary degrees, some degrees and diplomas which fall properly under one or other of the headings above but which, on available information, cannot be so classified.

[3] No breakdown is possible.

G. SUMMARY AS APPLIED TO WESTERN EUROPE

A total of about 250,000 graduate engineers and 175,000 graduates in the various fields of science constitute what can be called the engineering and scientific backlog of the western bloc of Europe. That these technically trained men and women are scarcely sufficient to meet the needs of the present active programs of industry and the military agencies of the several countries is apparent from reports received by the Organization for European Economic Cooperation, in 1954, and from less inclusive but more recent accounts in the European press.

During the academic year ending in the spring of 1953, the 334 universities and institutions of higher learning in 15 countries of Western Europe granted no less than 27,933 first professional degrees in engineering, and 14,324 first professional or bachelor's degrees in the several fields of science.

This marks a steady increase since the close of World War II, and present enrollments in the secondary schools as well as at the university level, indicate a steady addition to these members during the next 5 or 6 years.

Standards of scholarship are generally high throughout Europe. These are maintained by varying degrees of rigid entrance requirements. The same is true in the secondary schools where a tendency is noted for programs that give equal opportunity for talent, regardless of the economic, professional, or social background of the pupil.

Mathematics, chemistry, physics, and the national language are given recognition and emphasis in the curricula of secondary schools in nearly all the countries of Western Europe. Indication of this is the general requirement for a satisfactory showing before a pupil is promoted. Natural sciences, such as biology, zoology, mineralogy, geology, and physiology, are also available in the secondary schools, but the emphasis on proficiency is less. This is shown by reports that requirements for promotion are less demanding in these fields.

IV. SOVIET RUSSIA

A. AVAILABILITY OF ENGINEERS AND SCIENTISTS

Authoritative sources indicate that in 1954 Russia had more than 540,000 engineers and about 190,000 agricultural specialists. In addition, about 160,000 scientists were included among the teaching staffs of higher educational establishments and in research institutions.[1]

The number of trained engineers in the U. S. S. R. increased from 41,000 in 1929, to 283,500 in 1940, to 428,000 in 1950, and to 541,000 in 1954, according to Nicholas DeWitt, of the Russian Research Center, at Harvard University. In 1940, engineers who had completed courses in Russian institutions of higher learning comprised 33.5 percent of some 850,000 trained professionals. In 1954, trained professionals numbered 2,036,000 of whom engineers accounted for 26.6 percent. The lowered percentage of engineers reflects the increase in student enrollment during this period.

Agricultural scientists numbered 97,300 in 1940, 140,000 in 1950, and 189,000 the end of 1954. These include specialists in agronomy, land conservation, electrification and mechanization of agriculture, forestry, and veterinary medicine. In 1940, scientists represented 11.4 percent of all Soviet professionals, but in 1952, the proportion had dropped to 9 percent.

DeWitt estimates, as of 1950, that 73 to 78 out of 10,000 in the present Russian population of some 200 million had completed courses in higher education.[2] Of these, the preceding figures indicate about 35 percent are engineers and trained agricultural scientists. By way of comparison, the United States had about 320 persons with higher education per 10,000 population in 1953.

Another measure of Soviet scientific manpower is the growing number of scientists in research and teaching. A recent summary indicates that about 100,000 scientists are engaged in research and development in the Soviet Union compared with about 200,000 in the United States. Thus, the total Soviet research and development effort might be estimated at about one-half that of the United States. The same source estimated that about half of all Soviet scientists are engaged in teaching and research in higher educational institutions. This compares with similar activities by about 35 percent of American scientists.

> Soviet papers report that in 1952 the Soviet Union had 2,900 research establishments, as compared with 1,560 in 1940. The number of research scientists had also doubled and was estimated at 68,000 in 1952, of which about 45,000 were believed to be working in basic research fields.[3]

In 1940, according to DeWitt, about 32 percent of all professionals were women. By 1950, the proportion had increased to about 50 percent. The medical and educational professions were the first in which women sought representation; but by 1952, about 20 percent

[1] DeWitt, Nicholas. Soviet Professional Manpower. National Science Foundation, Washington, 1955, p. 254.
[2] Ibid., p. 237.
[3] Nation's Business, September 1954, p. 46.

of all Russian engineers were women. In this country, women engineers constitute only a fraction of 1 percent of the total number.

B. INSTITUTIONS OF HIGHER EDUCATION

Soviet higher educational establishments can be divided into two distinct groups—universities and technical institutes. Enrollment in an average university in 1950 was about 3,000 regular students. The 2 largest institutions, Moscow and Leningrad Universities, each had more than 10,000 students.

Specialized higher educational establishments are usually called institutes, although one of the top-notch engineering schools is the Bauman Highest Technical School in Moscow. Another is the Leningrad Maritime School, which trains marine engineers and other specialists. Enrollment is generally around 1,000 students, but some in the engineering field have 3,000 to 8,000.

The Soviet Union operates today some 890 higher educational establishments offering regular training. Two tables follow which indicate the distribution in terms of fields of specialization, and the growth in numbers during the past 40 years. They are from different sources and no attempt was made to make them agree.

Higher educational establishments in the U. S. S. R.[1]

Field	Number of institutions			
	1929	1939	1949	1954
Engineering	32	165	166	177
Agricultural	38	85	90	109
Socio-Economic	11	47	32	35
Educational	60	375	462	382
(Universities)	(20)	(22)	(32)	(33)
Health	11	78	86	88
Total	152	750	836	791
Extension training establishments, independent units	-------	-------	16	23
Divisions	-------	-------	410	-------

[1] Soviet Professional Manpower, p. 181.

Without attempting to appraise the comparative values of information from different sources, the following data of recent origin is submitted:

Educational institutions and numbers of students in Soviet Russia [1]

Year	Number of higher educational institutions [2]	Number of secondary special educational institutions	Students in higher educational institutions [3]	Pupils in secondary special educational institutions
			Thousands	*Thousands*
1914	91	------------	112	36
1928	129	1, 650	177	254
1932	645	3, 096	509	754
1939	750	3, 733	620	945
1945	768	------------	539	938
1950	880	3, 543	841	1, 298
1954	890	[4] 4, 000	1, 087	1, 790

[1] Barker, G. R., Specialist Training in the U. S. S. R., the [London] Times Educational Supplement, Apr. 29, 1955, pp. 408–409.
[2] Universities and institutes, including correspondence colleges and departments.
[3] Numbers in this column have been adjusted to conform with DeWitt, p. 298.
[4] Approximate.

Nowhere in the world is there a heavier concentration of professional training in a few select urban centers than in Soviet Russia. In support of this, DeWitt points to Moscow, with about 90 institutions and over 280,000 students, and to Leningrad, with about 50 higher educational establishments and an enrollment of 150,000. In 1939, 50 percent of the entire Soviet enrollment in the curriculum of industry, construction, transportation, and communications was concentrated in 3 cities—Moscow, Leningrad, Kharkov—which together hold less than 5 percent of the nation's population.

Moscow University's new skyscraper provides for 17,000 regular students, 5,000 extension students enrolled in 12 divisions, and 180 departments, with a teaching staff of 2,300 and about 100 academicians. Many smaller and less conspicuous institutions offer training to smaller numbers of carefully selected engineering students. Upon graduation, these, like those from the great urban universities, represent the cream of the technocratic crop.

The technical institutes train engineers in various branches of specialization, which include machine building, aviation, power and communication, mining and metallurgy, construction, transportation, etc. In the fall of 1950, some 20 polytechnical institutes covering more than 1 field, and 159 specialized institutes devoted to a single field of study, had about 272,000 students. Since 1950, an increase of 15 percent is reported to have taken place. During the same period a marked increase was reported in the number of research laboratories. There has also been a corresponding improvement in their equipment. Growth is also evident in the number of the teaching staff.

Russia maintains 7 "aviation institutes" that give a 5½-year degree roughly equivalent to an American "BS-and-one-half degree." Current graduating classes from these institutions number between 1,700 and 2,000. A comparable figure for the United States was 1,481 in 1950, but the average is closer to 750 a year.

These 7 Soviet institutes train engineers in aircraft structure, engines, and propulsion devices, service and flight-control equipment, and aircraft armaments. In addition, training is provided in such specialties as aerodynamics, hydrodynamics, heat transfer, gyros and stabilization devices, ballistics, electronic control devices, and automaton techniques.

Other aviation schools of professional level in the U. S. S. R. include an industrial academy for aircraft industry management and planning personnel, a topnotch military aviation academy, 4 major military aviation schools, and 2 civil aviation military schools. The Red airforce operates a number of engineering schools also, none of which are on a professional level.

Six of the seven aviation institutes provide graduate training, as do the military aviation engineering academy, the research institute of the Academy of Research, and four major research institutes operated by the Ministry of Aircraft.[4]

[4] Aviation Week, March 21, 1955, p. 32.

C. STUDENT ENROLLMENT

Rapid industrialization in the Soviet, which began in 1929, was accompanied by an increased demand for trained specialists. This was reflected in steadily increased enrollment in all establishments for higher education. By 1932, this had reached some 500,000, or about half the resident college enrollment in the United States as of that time. Enrollments dropped in 1933, but quickly resumed their upward climb so as to reach 620,000 by 1939. This can be compared with an enrollment of about 1,500,000 university and college students in the United States in 1940. The impact of the Soviet wars with Germany reduced enrollment to less than 230,000 in 1942. Graduating engineers dropped during the succeeding 3 years below 10,000. By 1945, however, student enrollment had been restored to nearly 540,000. Thereafter, the rise continued to 734,000 in 1948, to 1,062,000 in 1953, and to 1,087,000 in 1954. Enrollment in higher educational institutions of the United States was 2,148,284 in 1948, 2,250,701 in 1953, and 2,499,750 in the fall of 1954.

That increases in the Soviet university population may continue beyond the fifth 5-year plan which ended in 1955 is indicated by the numbers of pupils reported as attending secondary schools.

During the 20 years from 1929 to 1949, engineering students in Soviet institutions averaged nearly 30 percent of the total enrollment. Enrollment in all fields of education has so increased in subsequent years that despite a larger number of engineering students, their percentage in terms of the total is lower.

Soviet higher education enrollment by field, 1929–49

	1929		1939		1949	
	Thousands	Percent	Thousands	Percent	Thousands	Percent
Total regular training enrollment	191.1	100.0	619.9	100.0	774.5	100.0
Engineering	62.8	32.9	201.5	32.5	239.3	30.9
Agriculture	34.0	17.8	56.6	9.1	78.7	10.2
Socio-Economic	18.3	9.6	27.7	4.5	38.0	4.9
Educational	49.9	26.1	221.1	35.7	312.9	40.4
Health	26.1	13.6	113.0	18.2	105.6	13.6
Additional enrollment:						
Party schools	13.1		None		None	
Extension training	42.9		250.0		346.0	
Grand total of enrollment	247.1		869.9		1,120.5	

Source: Soviet Professional Manpower, p. 160.

D. NUMBERS BEING GRADUATED

In 1951, Soviet universities and other institutions graduated 30,000 engineers with 5½ years of training, including 3 years of close specialization. This is only a thousand more than the 29,000 engineers who graduated during the academic year 1939–40, and was exceeded only by those specializing in education. By 1954 it had burgeoned to 53,000. Moreover, university and college enrollments in the Soviet, and the continued orientation of Soviet higher education toward the training of specialists in engineering, agriculture, and medicine, suggest further increases during the next several years.

Plans to step up the number of graduates from all Russian universities and institutions of higher learning to 330,000 or possibly to 370,000 by 1956, were revealed in one of the Soviet Party Congresses. The number of engineers who will be included in these large classes is based on reports that more than 70,000 first-year engineering students were accepted in 1950. This supports reports of 53,000 first degrees in engineering granted in 1954, and the possibility of 63,000 in 1955.

Lack of current data combined with the record of violent changes in past years, many of them resulting from the Soviet managed economy, discourages attempts to estimate specific numbers of future graduates. That they will continue to rise appears the only course consistent with the Soviet policy of using military power and economic strength as political weapons.

Graduate engineers from universities and colleges in the United States and Russia [1]

Year	United States [2]	Russia		Year	United States [2]	Russia	
1935	----------	[3] 35,000	[4] 37,200	1950	52,000	28,000	----------
1936	----------	----------	35,800	1951	42,000	29,000	30,000
1937	----------	----------	34,600	1952	30,000	30,000	30,000
1938	----------	[3] 31,300	31,300	1953	24,000	40,000	40,000
1939	13,000	28,400	28,400	1954	22,000	53,000	[4] 53,000
1940	14,000	29,300	[4] 29,300	1955	23,000	[6] 63,000	----------
1941	13,000	27,500	27,500	1956	[6] 30,000	----------	----------
1942	([5])	13,400	13,400	1957	[6] 34,000	----------	----------
1943	14,000	9,700	9,700	1958	[6] 37,000	----------	----------
1944	11,000	9,300	9,300	1959	[6] 41,000	----------	----------
1945	4,000	9,200	9,200	1960	[6] 38,000	----------	----------
1946	7,000	11,000		1961	[6] 39,000	----------	----------
1947	19,000	15,000	[4] 32,000 (1946–49)	1962	[6] 39,000	----------	----------
1948	31,000	29,000		1963	[6] 40,000	----------	----------
1949	47,000	25,000		1964	[6] 43,000	----------	----------

[1] Dr. Alan T. Waterman, Nation's Business, September 1954, p. 42.
[2] Dr. Henry H. Armsby, Office of Education, Dec. 20, 1955.
[3] (1937–55) Status and Trends in Soviet Scientific and Technical Manpower Resources, May 4, 1955, p. 16.
[4] Nicholas DeWitt, Soviet Professional Manpower, July 1955, p. 164, and pp. 350–351.
[5] No report.
[6] Estimated.

Distribution by field of graduation from Soviet higher educational establishments

	1928		1940		1946–50 average annual		1954	
	Thousands	Percent	Thousands	Percent	Thousands	Percent	Thousands	Percent
Total graduations	28.7	100.0	102.4	100.0	130.3	100.0	173.0	100.0
Engineering	8.9	31.0	29.3	28.6	32.0	24.6	53.0	30.6
Agricultural	6.4	22.3	10.1	9.9	10.1	7.8	18.0	10.4
Socioeconomic	2.0	7.0	5.0	4.7	6.9	5.3	8.0	4.6
Educational	5.2	18.1	40.6	39.8	59.6	45.7	70.0	40.5
Health	6.2	21.6	17.4	17.0	21.7	16.6	24.0	13.9
Additional:								
Party schools	None	--------	None	--------	--------	--------	--------	--------
Extension training	None	--------	([1])	--------	--------	--------	57.0	--------
Grand total	28.7	--------	102.4	--------	130.3	--------	230.0	--------

[1] Negligible.

Source: Soviet Professional Manpower, p. 164.

After the postwar recovery, the years 1947 through 1952 saw annual graduations of engineers stabilized in the neighborhood of 30,000. This was about the same numerical level as prevailed during the prewar years. In 1953 there were some 53,000 engineering graduates. This was some 75 percent over the late prewar years.

Engineering and science graduates outnumber those in the United States, but total numbers of all subject matter specialties in graduating classes in the Soviet Union are still substantially smaller than in this country. The Soviet graduates of 1954 were about 40 percent fewer than the number of bachelor and first professional degrees awarded by American colleges. The composition of graduating classes in the two countries is revealed in the following table:

Structure of graduating classes in the U. S. S. R. and in the United States

Field	U. S. S. R., 1954, graduations by field of study		United States, 1954, bachelors and first professional degrees by field of study	
	Number	Percent	Number	Percent
Total	173,000	100	358,699	100
Engineering of all types	53,000	30.6	22,329	6.3
Agriculture, including agronomy, forestry, animal husbandry, veterinary medicine	18,000	10.4	[1] 7,832	2.2
Health and medical sciences	24,000	13.9	[2] 23,616	6.6
All other fields (of which university, physical and biological sciences, mathematics are included)	78,000	45.1	304,922	84.9
Additional: Extension training (predominantly in other fields)	57,000			

[1] Does not include veterinary medicine.
[2] Includes veterinary medicine.

Sources: Russian Research Center, Harvard University, and U. S. Department of Health, Education and Welfare, earned degrees, 1953-54, Circular No. 418, pp. 4-5.

In the Soviet Union more than 50 percent of the graduates had majored in engineering, natural science, and the medical sciences, while in the United States, scarcely more than 15 percent were in these fields. As compared with 1953, the proportion of Americans in engineering and science had dropped from 18.6 percent.

The increase in the relative share of women among Soviet higher education students is shown in the following percentages:

Percent of women among Soviet professionals (year end)

	1929	1940	1951
Engineering	14.7	19.4	
Agricultural	9.2	24.4	
Socioeconomic	8.2	26.1	
Educational	21.0	37.0	
Health	47.2	56.9	
All fields (average)	23.5	32.6	50.5
Total number, women professionals	68,000	277,000	830,000

Source: Soviet Professional Manpower, p. 241.

A total of only 65 women were among the 22,329 graduates in engineering from American universities and colleges in 1954. Among those who graduated in agriculture and forestry, women constituted nearly 2 percent, but 30 percent of the graduates in medical sciences were women.

About 13,500 graduate degrees in pure science were granted each year in the U. S. S. R. from 1946 to the end of 1950. Dr. DeWitt reports that Russian authorities plan to double these numbers in 1955.

Russia's postwar gains in training for advanced degrees in engineering and science caused Dr. DeWitt to warn against any attitude of complacency on the part of American leaders.

The entire field—of Soviet educational and scientific effort—still awaits thorough objective investigation by Western scholars; and—

he wrote—

as quantitative findings concerning Soviet efforts tend to suggest, it is high time to undertake the task.[5]

Speaking on a similar theme, Dr. J. H. Hildebrand, president of the American Chemical Society, described the Russians as taking more seriously than we, the copybook maxim that "knowledge is power." They are educating their best students to the limits of their capabilities, at government expense, and thus are able to graduate nearly three times as many college-trained engineers and scientists each year as do similar establishments in the United States. These circumstances led him to conclude that "the Communist world can well afford to wait while our present educational practices run their course."

We are pitted against forces who have more land, more resources, and more people than we have.

Continued Dr. Hildebrand:

If we let them get ahead of us in education, the national disaster for us and our way of life is inevitable. Our hope lies in an enlightened people from whom we can obtain the essential leadership necessary to build the kind of world in which we all want to live.

Commenting on the increased number of scientists employed in all fields of Russian research, Dr. DeWitt writes:

The substantial gain in the size of the trained professional labor force, which doubled between 1940 and 1952, appeared primarily as a result of the capacity of the Soviet educational system to turn out graduates * * * to some extent it was caused also by the preferential treatment of professionals through deferments and evacuation during the course of the war.[6]

Noting that Russia's rate of production of well-trained engineers and scientists seems to be higher than ours, Dr. Harry C. Kelly, of the National Science Foundation, expresses the belief that they are competent and their quality is being improved by specialized training. He believes, however, that the Russian emphasis on technological training is at the expense of the humanities and the liberal arts.[7]

About one-half of the Soviet university graduates have majored in the humanities and the other half in science. Since 1949 at least 50 percent of the humanities majors and about 29 percent of the science majors are assigned as teachers in the upper grades of the secondary schools. Presumably, the better students became research scientists.

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[5] Professional and Scientific Personnel in the U. S. S. R., by Nicholas DeWitt, Science, July 2, 1954, pp. 1–4.

[6] DeWitt, Nicholas, Soviet Professional Manpower (ms.).

[7] Science, July 2, 1954, p. 54.

E. SCHOLASTIC REQUIREMENTS

Soviet higher education, as reported by Dr. Nicholas DeWitt, is designed to turn out trained and qualified persons to serve the State, and thus build up military, political, and economic power. He quotes the following description of the goal as included in a Soviet model charter, approved in September 1938:

> * * * the organization of pedagogical and scientific work with the aim of preparing highly qualified specialists, capable of completely mastering the newest achievements of progressive science and technology, of connecting theory and practice in a Bolshevik way, and combining industrial experience with science; the idealogy and political education of students and their teachers on the basis of the doctrine of Marx, Engels, Lenin, and Stalin; the carrying out of research work aiding socialist construction; the popularization of scientific and technical knowledge and the newest accomplishments of science and technology among the broad masses of workers.

Dr. DeWitt describes Soviet educational philosophy as resting on the premise that science and technology are best advanced through central planning of education and research; that scientific and educational efforts are essential to the social, economic, political, and military interests of the nation; and that basic truths of human life, of nature and the universe, and of social, political and economic reality, have been discovered, proclaimed and are beyond debate.

The task of the teacher is to demonstrate and apply these truths rather than to question them or to seek alternative truths.

Based on Dr. DeWitt's observations, it appears that the training given Soviet engineers and scientists has marked excellencies and equally marked deficiencies. The secondary and professional education compares favorably with our own. Uniform standards at all levels are enforced by nationwide examinations. All this focuses Soviet secondary education toward education for a technical career. Factors in the Soviet educational system which combine to produce graduates of high quality in science include study courses of 15 years or more, emphasis on scientific subjects, and rigorous scholastic competition. Competent observers conclude that this combination should make them as professionally competent as scientific graduates in the United States.

Subordination of Soviet technical education to government direction is described as the most serious weakness in the system. Rigid curricula without benefit of elective courses, little opportunity to change the course because of personal choice, and inadequate textbooks, are listed as other weaknesses. Textbooks are described as detail-crammed technical manuals, or translations of Western works. Many are general and very conservative. To these defects may be added the heavy burdens on the teaching staffs. Engineering teachers and those in the physical sciences are described as having a student load two-thirds greater than in this country, with about twice as many hours devoted to teaching.

Entrance requirements to higher educational establishments in the fields of engineering and natural science stress mathematics and the sciences. Since most institutions have limited quotas, competition for entrance is keen. Moreover, the examinations are not on the basis of what the entrants have studied in secondary school, but on what they are expected to know. This additional factor of selection is a severe test of the teaching abilities as well as of the student. Those from rural schools where the quality of instruction is not always the best may lose out, while urban secondary school graduates with comparatively poor grades, but with better instruction, may be accepted.

Mathematics, physics, chemistry, foreign language, and Russian language and literature, are required for entrance to colleges and universities in engineering fields. Some establishments give those whose applications have been accepted 2-month preparatory or refresher courses during the summer. The present academic selections have been used since December 1935. Previously, about 15 percent of entering students were from regular secondary schools. By 1939, graduates from secondary schools comprised 60 percent, and their present proportion probably exceeds 90 percent.

In 1954, many educational establishments were reported as receiving 3 to 4 applications for each vacancy. The pressure of applicants is especially acute in large universities in metropolitan centers, where specialists in aviation, engineering, mining, and geology are prepared. Some institutions report from 5 to 12 applicants for each vacancy. More vacancies than applicants have also been noted in some of the small provincial institutions. Generally speaking, this situation results in larger institutions, and some small ones, effectively enforcing high standards of scholarships.

Training offered by Soviet universities in the scientific field, according to Dr. DeWitt, is commonly based on 5,200 to 5,400 instruction hours of 45 minutes each. Attendance is required. Scientific subjects include foreign language, general physics, analytical geometry and calculus, biology, general inorganic chemistry, some geology, and theoretical and applied mechanics. Electives or optional courses are not generally permitted.

Soviet engineering training culminates in the so-called diploma project, to which 4 to 6 months are usually devoted, to the exclusion of all other courses. It is a more extensive undertaking than the American thesis.

Soviet training in chemical engineering is based on a curriculum of some 4,700 instruction hours, of which about 15 percent is spent in indoctrination, and military and physical training. As in the case of mechanical engineering, no general liberal arts courses are offered. In general, the required time for physics and chemistry is less than in American institutions.

Dr. DeWitt compares the above schedule with the MIT curriculum, which is based on about 3,200 instruction hours. The latter includes some 360 hours in the humanities and social sciences, and about 240 in military science and athletics.

A comparison of Soviet training with our own reveals that the chemistry major in a Soviet university spends at least one-third more time on chemistry subjects than does an American chemistry major. No radical difference in the range of subjects was noted, but Soviet texts fail to discuss some of the more recent theories in quantum mechanics, molecular structures, nuclear chemistry, and certain other select advanced topics. Other than in such instances, the curriculum gives the impression that the Soviet student is required to learn more about analytical geometry and calculus, physics, thermodynamics, mechanics, strength of materials, and other sciences than the American student.

Textbooks, according to Dr. DeWitt, present a real problem in the Soviet system. Professors who have the ability, energy, and possible freedom to write textbooks are often discouraged by the severe criticisms to which they are subjected. This is as nothing, however, compared to the possible hazards to their advancement, their job, and to life itself. To avoid this, many textbooks are the product of committee or group action, and are subject to continuous additions with inadequate editing. As a result, Russian textbooks are described as compilations or manuals, rather than books such as an American university would consider suitable for instruction.

Some of the textbooks have been criticized as placing too great an emphasis on humanism, and as exuding too much of the spirit of Westernism. A conference called by the Hungarian Academy of Sciences on February 25, 1933, severely reprimanded academicians, scholars, engineers, artists, and university professors for their anti-Marxist, idealistic mentality.[8]

Perhaps the solution to the Soviet shortcoming in this respect is to be found in part by the following observation.

Within recent months, Western scientists in limited numbers have been permitted to visit certain Russian scientific institutions and research centers.

These observers were impressed by the availability of vast numbers of English language scientific books and periodicals in the libraries of these Soviet institutions and research centers. As described by them, large portions of the reading rooms and stacks looked not unlike those to be found in Western universities and research centers.

These same Western visitors were singularly impressed by the fact that their Russian counterparts, as well as their junior scientists and advanced students speak English with scarcely a trace of accent. Interestingly enough, these Soviets preferred to carry on their conversations in English and were nonplussed when one of these observers who spoke Russian tried to do so. It was as if the Soviets feared that during the process of translation from English to Russian, some important scientific point might be lost.

The import of this is clear. The Soviets have availed themselves of the vast store of scientific knowledge accumulated and printed by the West, and as part of their training program require scientific students to become proficient in the use and knowledge of the English language.

A Russian engineering student, as described by Dr. John T. Rettaliata, president of the Illinois Institute of Technology,[9] is more intensively trained in his field than his American counterpart. Most of the program of 5½ years' duration is devoted to narrow specialization at the expense of the humanities. In major subject matter, Dr. Rettaliata expresses the opinion that their education goes beyond the master's degree level here, but does little to prepare the scientist and engineer for civic responsibilities, as does such professional training in the United States.

Russia is emphasizing graduate study, particularly in engineering and science, according to Dr. Rettaliata. These subjects account for nearly one-third of all advanced degrees. In the United States, where local draft board policies discourage retention of students, Dr. Ret-

[8] Tensions Within the Soviet Captive Countries—Hungary, S. Doc. No. 70, pt. 7, 83d Cong., 1st sess., p. 194–5.

[9] New York Times, November 7, 1954, IV, p. 11:7.

taliata finds it "disturbing when students who have ability and desire to pursue advanced study are prevented from doing so." He urges more liberal selective-service deferments.

Added to the incentive of deferment or possible exemption from military service, Demitri B. Shimkin points out that the material rewards of the engineer or scientist in Soviet society may become very large, with handsome salaries being supplemented by prizes and bonuses.

> Direct allotments of extreme Soviet scarcities such as apartments, summer cottages, automobiles, and other consumer durables are customary. Professional earnings are lightly taxed, a minimum of 13 percent; inheritance taxes, too, are moderate.[10]

Dr. DeWitt points out that in certain fields Soviet students, unlike their counterparts in other parts of the world, are not subject to military service or to the disturbances incident to military mobilization. This applies even though universal military training has been the law since the early days of the Soviet Union's existence.

Since about 1930, all students in the technicums and other higher educational establishments have been deferred from military draft long enough to complete their course. This does not extend after the age of 28, however, As presently interpreted, successful secondary school graduates can enter higher education unperturbed by draft law at age 17. After that they can probably get deferment until completion of their education.

Since scholastic failure automatically deprives a student of the protective provisions, he has a special incentive to maintain his academic record. It follows that smart, ambitious, career-minded students make great efforts and sacrifices to maintain their privileged status. Dr. DeWitt describes this as fostering selection among those who enter higher education.

Dr. DeWitt believes that only with reservations could it be said that a Soviet certificate of graduation from a higher educational establishment is equivalent to a particular degree in our educational system.

Another observer came away with a "tremendous respect for Russian engineering capabilities in the field of aviation." He claims Russian engineers know 10 times as much material by heart as the average German engineer. He qualifies this with an observation that the Russians are fairly low on what the West would call technical imagination.

Apparently, he writes—

> they don't play around with ideas the way western engineers would. Real inventiveness on the model of Edison or Diesel does not exist in Russia. Russian engineers become somewhat scared when they have to enter any real new ground.

He warns, however—

> that the Western World should realize and appreciate the complete religious devotion to his job on the part of the Russian engineer. The Russian engineer has tremendous ability to soak up knowledge and to learn by rote. This is aided by the fact that textbooks are extremely cheap. He also has a very real sense for practical, simple solutions. On the other side of the coin, there is a certain born disregard for basic values, and machine tools fall apart under their hands.[11]

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[10] Russians Fear Their Own Engineers, by Demitri B. Shimkin, U. S. News and World Report, June 17, 1955, p. 114-116.

[11] How Russian Engineering Looked to a Captured German Scientist, Aviation Week, May 9, 1955, pp. 31-32.

According to this same observer—

Education on the lower level—on the high school and undergraduate level—is bound very tightly by Marxist doctrine. But at the higher seats of learning, such as the Universities of Moscow and Leningrad, this curricular limit does not hold true.

Natural science faculties at Moscow and Leningrad Universities are completely and thoroughly trained in the traditions of European research and scientific work. They are not only well trained but cultured on western standards as well.

This same unnamed German expresses the opinion that—

While the Russians probably educate lots of mediocre scientists, the Western World should never forget that they do turn out some really top-flight people. What probably sets a top-flight Russian scientist apart from his western counterpart is the fact that he is even more highly specialized than his colleague in the West. When the Russians train a really good physicist, they don't allow him to spend much time on subjects such as chemistry and mathematics, for example. A high degree of overspecialization is the result.

The competence of Russian work in the physical sciences and mathematics is distinctly better than in the biological sciences.

This agrees with the opinion of Dr. Alan T. Waterman, Director of the National Science Foundation, whose final judgement is on the basis of results.

We know, he said—

they have been able to construct nuclear weapons, achieve vast engineering developments such as the Gorki Dam, the Volga-Don Canal, construct a jet engine that in 1951 was superior to any we had, and build tractors comparable to our own.[12]

Dr. DeWitt concludes that Soviet training appears well suited to Soviet conditions. He sees this as particularly true in an economy where technological expansion in various industries is primarily dependent upon the application of technology already discovered and tested. This is not to deny that in some fields of industrial technology and applied science original research has been and is being done. He points out, however, that on the whole, Soviet industry of the past 25 years has been built on adaptations, modifications, and occasional improvements of industrial techniques, models, types, and practices developed elsewhere.

F. HIGH SCHOOLS AND SECONDARY SCHOOLS

The U. S. S. R. provides free education for all children, with attendance described as compulsory for ages 7 to 15. This order appears to be universally enforced, however, only for ages 7 to 12. From 12 to 15 years about one-third of the children, largely those in the rural districts, remain away from school.

The complete secondary school has 10 or 11 classes. Those who complete only the first seven classes are entitled to enter the technicums or teachers' institutes. These are specialized secondary schools and continue for 3 or 4 years. Graduates are between 18 and 20 years of age. The technicians train technicians, lower medical personnel, and teachers of primary grades. Not more than the top 5 percent of technicum graduates may continue their education in universities or in higher institutes, and usually they are required to continue in the field of former specialization.[13]

There are three levels of Soviet secondary school instruction: Elementary, intermediate, and upper. The system is centrally

[12] Nation's Business, September 1954, p. 44.
[13] Soviet Professional Manpower, p. 86.

administered, and the scope of instruction centrally prescribed and regulated. It is therefore justifiable to say that uniformity of curricula and scope of instruction exists on all three levels in the U. S. S. R.

The Soviet secondary school curricula is based on a 6-day week and 33 weeks of instruction.

The following is a generalized summary of the curricula of Soviet primary and secondary schools:

Group of subjects	Allocation in percent of class instruction time by levels of grades			
	Elementary grades 1–4	Intermediate grades 5–7	Upper grades 8–10	All grades 1–10
1. General education	57.5	54.2	50.0	53.9
2. Mathematics and science	28.5	36.3	40.8	35.2
3. Other	14.0	9.5	9.2	10.9
Total number of class instruction hours	3,300	3,135	3,234	9,699

Source: Soviet Professional Manpower, p. 38.

Enrollment in primary and secondary schools in 1950 reached a total of 33 million pupils. A drop which followed promises to be restored from heavy enrollments in the intermediate and upper grades. Recent reports indicate the surplus of secondary-school graduates are a serious burden on the technicums and other higher educational establishments. DeWitt thinks this situation implies that the expansion of professional training in higher establishments is not now and will not be handicapped in the future by any lack of secondary-school graduates.[14]

During 1953–54 the upper grade enrollment in Soviet secondary schools was 4,500,000, as against the highest prewar figures of 1,800,000 in 1939–40. During the earlier period, the 16 Union Republics of the U. S. S. R., were reported as having 11,753 rural schools and 8,263 of somewhat higher standards in the urban districts.

Mathematics and science are of paramount importance, especially in the upper grades, where instruction in these subjects occupies almost 41 percent of the time. Soviet schools offer no optional or elective courses.

All Soviet secondary school textbooks are prepared, approved, printed and distributed through central organs of administration.

The curriculum is heavy, examinations rigid, and promotions are based on required passing grades in all subjects, resulting in a pace of schoolwork described as "far more rigorous than any encountered in the United States." [15]

Tuition fees, introduced in 1940, are believed to have been selective as well as incentive. Scholarship funds provided by the specialized secondary schools, or technicums, are sufficient to offset the tuition charges and provide supplemental income. Their introduction offers a process of selection, and serves to channel individuals into other than the regular upper-grade secondary schools.

Over the past 2 or 3 decades the Russians have stressed the building up of their general educational system. This has broadened the base from which they can draw talented youth for advanced training in science and engineering. The most promising youngsters receive state support for continuing their education.

[14] Ibid., p. 66.
[15] Ibid., p. 47.

According to available information, the liberal arts education which is a fundamental part of our educational system is practically nonexistent in Russia. After a student enters the higher educational system and selects the field in which he intends to specialize, his educational program is almost completely prescribed. After graduation he is obligated to work in that field for a specified number of years.[16]

According to Demitri B. Shimkin:

The base of selection is relatively narrow, with all higher education contingent upon fluency in Russian. Other political, economic, and cultural factors strongly favor the children of urban, white-collar workers. Thus, an analysis of official Soviet data reveals that, in 1940, such children enjoyed 5 times as great a probability of completing a professional education as did the children of blue-collar operatives, and 11 times as great a probability as peasant's children.[17]

During 1945–48, Efron [18] described the upper classes of the secondary schools as having required 2 hours a week of arithmetic, 5 and 6 hours per week of algebra, trigonometry, and geometry, 2 and 3 hours of general science, 3 hours during the last year of chemistry, and 2 hours in the 6th year and 3 hours in the 7th of physics.

Six hours per week were allocated to algebra, geometry, and trigonometry, usually split in each year. Algebra was taught in grades 6–7 for 5 hours per week, and 2 hours in grades 8–10. Trigonometry was given for 2 hours a week in grades 9–10. Geometry was introduced in the seventh grade for 1 hour a week, stressed in the eighth grade with 4 hours a week, and continued for 2 hours a week in grades 9–10. Coverages in these subjects coincided closely with the entrance requirements for higher educational establishments.

General science consisted of a descriptive introductory survey of nature (grade 4), botany (grades 5–6), zoology (grades 6–7), and human anatomy and physiology (grade 8). Principles of Darwinian theory and Soviet contribution to it was part of Soviet genetics. (grade 9).

Introductory chemistry was taught in grade 7. Systematic inorganic chemistry was taught in grades 8 to 10, and introductory organic chemistry in grade 10. Coverage in chemistry was about the same as required from entrants into higher educational establishments.

Physics was introduced in grades 6 and 7, and direction given its systematic branches in grades 8 to 10. Coverage of physics was about the same as required from entrants to higher educational establishments.

A brief introductory survey course in astronomy was given only in grade 10.

Izvestia for July 16 and 20, 1954, reports an increase in instruction time devoted to physics, chemistry, and technical drafting at the expense of general science (biology) and other general subjects. Included in this are an increased and strengthened program in grade 7, and similar action with regard to physics in grade 8.

The 10-year secondary school system of Soviet Russia assigns a definite and important place to physical sciences. Physics and chemistry are required of all pupils regardless of destination. The aim, according to Dr. Efron, is to provide a grasp of fundamentals, fuse theory and practice, and encourage an appreciation of the materialistic philosophy that underlies Soviet thought. Classroom procedure is enriched by a wealth of after-school experiences.

[16] Nation's Business, September 1954, pp. 46 and 50.
[17] Op. cit., Shimkin, pp. 114–116.
[18] Op. cit., Efron, pp. 257–281.

Dr. DeWitt points out that the Soviet curriculum is heavily packed with science and mathematics. Save perhaps for the teaching of biology, there is little room for the free application of ideological tendencies among these subjects. Progressions, complex numbers, Ohm's law, or the second law of thermodynamics remain the same whether they are put to application by a Soviet industrial manager or by the contemptiously depicted capitalist.

Dr. DeWitt's observations lead him to the conclusion that:

> Soviet secondary education does not produce robots. In fact, despite various shortcomings in teaching, Soviet secondary graduates seem to acquire sufficient knowledge to embark upon further training in higher educational establishments. In most instances they are better prepared to enter scientific and professional training than our own high school graduates, but their quality admittedly suffers from a certain amount of ideological interference and from lack of broad liberal education. Today there are enough secondary school graduates to permit a wide selection for further training.
>
> Assuming that the Soviet population is today above 200 million * * * nevertheless secondary school enrollment has remained at about 30 million. Assuming that there are between 45 and 50 million persons in the age group between 5 and 15, it appears that less than two-thirds of the school-age children attend school. While the Soviet secondary school provides training for many, there are undoubtedly a substantial number who remain outside and for whom even a secondary education remains inaccessible.[19]

G. SUMMARY AS APPLIED TO SOVIET RUSSIA

The present estimated backlog of about 540,000 engineers and 190,000 scientists in Soviet Russia is the result of a tremendous national effort to provide well-trained technical leadership for its changing economy. In 1930, the records showed about 41,000 engineers. Since then, the numbers in this one field have multipled about tenfold. A feature of this expansion of technical manpower is the extent to which it is shared by women. About 20 percent of all engineers are now women, perhaps 50 percent of all professionals.

In 1954 Russia had some 890 universities and institutions of higher education, with an enrollment of 1,732,000 students. Many of these, as well as of the less demanding technical institutions, are concentrated in three large cities: Moscow, Leningrad, and Kharkov.

The university graduating classes of 1954 included about 53,000 with a first professional, or bachelor's degree in engineering, about 18,000 in agriculture, which includes agronomy, animal husbandry, forestry, and veterinary medicine, and 24,000 in the health and medical sciences. In addition, about 70,000 graduated in education, and 8,000 in several socioeconomic subjects such as the physical and biological sciences, and mathematics.

Engineers and scientists trained in Soviet institutions have many virtues, and except in detail, the education preparatory to granting the degrees is in no way inferior to that of holders of degrees from American universities and colleges. In the several fields of engineering and in chemistry, Soviet training is generally based on a larger number of instruction hours. Moreover, there is higher concentration on the major subject of study. This is accompanied by a reduced opportunity to select other subjects of a cultural or humanitarian nature. As a result, competent observers have expressed the opinion that Soviet engineers and scientists suffer a degree of overspecialization in comparison with those trained in the United States or in many of the European institutions.

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[19] Op. cit., Dr. Nicholas DeWitt.

All observers agree that Soviet textbooks are little more than compilations or manuals, and too frequently they fail to reflect recent scientific theories and discoveries. They are generally accepted by western educators as inferior to American university textbooks. On the other hand there is a growing tendency to release many textbooks and much of the teaching from the incubus of Marxist theories.

The Soviet student, like his counterpart in the United States, is subject to military service. However, deferments are general. As now administered, they serve as an effective means of allowing university entrance to only the most capable candidates. At the same time, the ever-present threat of possible military service provides a strong incentive for continued high standards of scholastic work.

Secondary education is free, generally compulsory, and of a uniform character. School enrollment of about 30 million out of a total population of close to 200 million, has led to an estimate that attendance is available to no more than two-thirds of the children of school age. Country children are frequently at a disadvantage to those of urban white-collar workers. Their school instruction is generally less effective, and after the age of 12, attendance is less rigidly enforced.

Mathematics, science, and the Russian language have top priority in all Russian secondary schools. General science has a lower place in requirements for advancement, and, generally speaking, is more subject to the influence of Marxian philosophy.

Tuition fees were instituted in 1940. These are offset in part by scholarship funds. Like military service, these provide a means of selecting students for the higher grades, and also prove an incentive to encourage the pupils to maintain standards of scholarship. Failure to maintain high classroom standards can result in withdrawal of the scholarship fund.

V. GENERAL SURVEY

Any superiority in numbers of engineers and scientists which the United States now has over the Soviet Union is negligible. Even the combined advantage which the United States and the countries of Western Europe now hold is being threatened.

Graduate engineers in the United States now number between 500,000 and 535,000, and about 250,000 more are in the countries of Western Europe. The United States also has 210,000 to 225,000 graduate scientists, while Western Europe has about 175,000. The United States and Western Europe, together, can therefore be credited with 1,135,000 to 1,195,000 engineers and scientists. Current estimates give Soviet Russia about 730,000 engineers and agricultural specialists—540,000 engineers and 190,000 agriculturists. In addition, 160,000 scientists were attached to higher educational establishments and research institutions. This total of 890,000 engineers and scientists exceeds the number in the United States, and is more than three-fourths the number available in the free countries of Europe and the United States.

To replace the normal losses, provide for research and expected technical advantages, and maintain a state of partial mobilization for defense in the United States, the current need of 30,000 to 35,000 new engineers each year may be increased by 3,000 to 4,000 a year for some time to come. The aggregate number needed for the countries of Western Europe is probably about the same, and will also grow. Latest available graduation figures indicate that nowhere in the free world are these needs being met. More than that, they have not been met at any time during the past 4 or 5 years. In 1954 the 218 accredited engineering colleges and institutions of higher education in the United States and outlying parts conferred 22,329 first or bachelor's degrees in engineering. That same year, 27,933 comparable degrees were conferred by 344 institutions in 15 countries in Western Europe. This made a combined class of 51,262 new engineers for the United States and Western Europe, as against a need for the 2 areas of 65,000 to 75,000 new engineers. The 22,589 first degrees in engineering conferred in 1955 by the 218 establishments in the United States show no major change in the established trend.

As against this, 177 Soviet universities and institutions of higher education granted first degrees in 1954 to 53,000 new engineers and estimates gave them 63,000 in 1955.

In the United States, 1,324 institutions of higher education granted 31,178 first or bachelor's degrees in science in 1954. The degrees granted are distinct from those in engineering, but many of the institutions include engineering colleges. Establishments in Western Europe granted similar science degrees to 14,324. This makes a total of 45,502 new scientists who were prepared to enter the reservoirs of skilled manpower of the United States and Western Europe in 1954. Most of them entered the field of their original choice, but as is characteristic of a free economy, some were diverted to other fields, and some used their training as a steppingstone from which to enter advanced studies.

Engineering and science graduates from institutions of higher learning in the United States and Western Europe, totaled 96,764 in 1954.

Meanwhile, Soviet institutions graduated 26,000 with a first degree in agriculture and socioeconomic subjects, and 24,000 in the health and medical sciences. This totals 50,000 Russian men and women whose training was designed for specific jobs in engineering and science. The comination of these 2 groups gives 104,000 new Russian engineers and scientists, a figure greater by about 7,000 graduates than those from institutions in the United States and the free countries of Europe. That the Russian figure includes several thousand graduates trained in social sciences not included in American statistics may bring the figures in closer balance, but give small ground for satisfaction.

Numbers graduating from the universities of Western Europe are expected to increase. The same is true of engineering and scientific graduates in the United States, but long before an increase is achieved comparable to the spurt that climaxed with the outbreak of hostilities in Korea, the record of the past two and a half decades points to the conclusion that there will be further increases in the number of Soviet graduates. As a result, concludes Nicholas DeWitt, the Soviet Union—

> has reached a position of close equivalence with or even slight numerical supremacy over the United States as far as the supply of trained manpower in specialized professional fields is concerned. The Soviet effort continues. Our own policies in the field of education and in regard to specialized manpower resources will decide whether within the next decade or so the scales will be tipped off balance.[1]

DeWitt offers scant encouragement with the reminder that the present numbers of engineers and agricultural specialists in Soviet Russia—

> must be viewed in relation to the size of the population and the nonagricultural labor force. While the Soviet population is about one-quarter larger than that of the United States, the Soviet nonagricultural labor force is still about one-third smaller than that of the United States. Thus, the proportionate share of trained professionals employed in the Soviet Union is lower with respect to the population at large, but obviously somewhat higher in relation to the nonagricultural labor force.[2]

Allen W. Dulles, Director of the Central Intelligence Agency, summed up the situation with a prophecy for the years 1950–60. The Soviets will graduate 1,200,000 in the sciences, while the United States will graduate 900,000 he said.

> Unless we quickly take new measures to increase our facilities for scientific education, he continued, Soviet scientific manpower in key areas may well outnumber ours in the next decade.[3]

The future of modern nations rests largely upon their educational equipment for engineering and scientific training and the extent to which it is used. In short, it depends upon the number of educational institutions, their teaching staffs, their student enrollment, and their financial support. In 1954 the Office of Education reported that 1,324 institutions of higher education in the United States and outlying parts had granted degrees of the bachelor's level or above. The 1952 enrollment in these institutions was 2,150,000. Included were 150,000 in engineering. This last figure compares with the engineers in the graduating class of 1954 about as 7 to 1. In 1949, 15 of the countries of Western Europe with 354 universities and

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[1] Op. cit., Soviet Professional Manpower, p. 257.
[2] Ibid., p. 255.
[3] 53d annual commencement, Columbia University, June 1, 1955. New York Times, June 5, 1955, p. E-11

institutions of higher education, with enrollments of 644,708, granted bachelor degrees in engineering to 27,938. Of the total enrollment 33,321 were in engineering, 84,908 in pure science, and 11,078 in agricultural sciences. This total of 129,307 students in engineering and science is about 20 percent of the Western European student body. For general comparison, therefore, the 2 areas of free countries may be credited with 2,794,708 students, including about 185,000 engineers, enrolled in 1,678 universities and comparable institutions of higher education.

Descriptions of educational institutions in Soviet Russia are difficult to interpret. They include about 890 universities and comparable institutions with a 1951–52 enrollment of some 1,400,000. Among these are 177 establishments with 266,000 enrolled in engineering. This is 80,000 more than are enrolled in the United States and Western Europe. Another group of 4,000 institutions, whose scholastic requirements rank between high school and college, report enrollments of about 1,790,000 students. Without attempting to weigh the abilities of the latter group, these figures combine to indicate about 3,190,000 students enrolled in some 4,900 Soviet universities and institutions of higher education, as contrasted with 2,794,708 students enrolled in 1,678 educational establishments in the United States and Western Europe.

The 266,000 engineering students enrolled in Soviet institutions of higher education are in sharp contrast to the 156,000 in the United States.

This deficit is not due to lack of physical facilities or opportunities for enrollment in the United States. In 1952–53, the United States had 27,873 secondary schools, generally recognized as high schools. Their enrollment totaled 6,600,000. In the period 1947–50, the countries of Western Europe reported 16,429 secondary schools, more or less comparable with our high schools. They had an enrollment of 4,173,838 pupils. Together, these 2 areas of free governments had 44,302 secondary schools and a total enrollment of 10,773,838 pupils.

In 1939, primary and secondary schools in the U. S. S. R. totaled 171,800, of which 12,500 schools contained 10 grades and may be compared with American high schools. The reported enrollment of 32,900,000 pupils and students included 1,800,000 in grades 8 to 10.[4]

In Western Europe 24,284,922 pupils were reported in primary and secondary schools during the years 1947–50, and in 1954 about 29 million were credited to the same groups of schools in Russia. Enrollment in higher secondary schools reached 5,380,000 students in 1954,[5] in an estimated 16,000 schools.

These figures indicate that the pupil backlog in the United States is more than a million greater than that of Soviet Russia, and considerably larger than that of the countries in the Western bloc of Europe. In terms of those who carry on to complete a college course in engineering, however, the United States lags behind both areas.

With 1952 populations of 152 million in the United States, 134 million in the countries of Western Europe, and 193 million in Soviet Russia, the United States leads in the proportion of children in primary and secondary schools, but lags in the numbers who complete courses for a first degree in engineering. On the basis of the latest available engineering enrollments, the United States has 1 engineering student

[4] Op. cit., Soviet Professional Manpower, pp. 264 and 279.
[5] Ibid.

for every 974,000 of its total population, the countries of Western Europe have 1 to every 700,000 and Soviet Russia has 1 to every 725,000.

The training given Soviet engineers and scientists is of a high order and compares favorably with the best in the United States and Europe. Soviet universities, colleges, and technical institutes have achieved a helpful combination of formal education with guided industrial practice and research. As against this, doctrinal domination of technical education appears as a serious weakness. Notable also is the absence of elective courses, with consequent rigidity and compartmentation of subject matter. American observers view this as capable of stultifying imagination and individual initiative. Textbooks are another source of weakness in the Soviet system. Generally speaking, they fail to reflect modern thinking and are described as little more than compilations of facts and theories on a given subject. A result is for teaching methods to be stereotyped and empirical.

Regardless of such criticisms, however, Soviet engineers and scientists are frequently so independent in their thinking as to prove a problem to Communist leaders. Demitri B. Shimkin, economic analyst with the United States Department of Commerce, credits Soviet party leaders with having deep suspicions of many graduates. Writing of the Soviet engineer he says his—

> vital technical skills give him a power potentially challenging the party's absolutism. To do his job, he must maintain contact with both the prerevolutionary past and with the West. And the logic of his work drives him into repeated conflict, open or hidden, with party dogmatism and favoritism.

Thus far, concludes Mr. Shimkin, who would test the system by available results, its effectiveness—

> in scientific innovation and application is far lower than might be indicated by the large numbers of its physical scientists and engineers, and by the immense Soviet efforts in training and research.[6]

The training available in Soviet secondary schools is also disciplined but tends to be rigid. This applies also to the secondary-school training in many countries of Western Europe. The Soviet curricula, and that of most of the countries of Western Europe, generally require pupils to devote more time to mathematics and physical science than is the case in many American high schools.

The senior high schools of the United States, those of the second level in France, as well as in many countries of Western Europe, and the 6-year secondary schools of the Soviet Union are sufficiently similar to permit many comparisons. School standards are subject, however, to a number of variables which tend to prevent actual comparisons. These include methods of student selection, character of the home and school environment, social and intellectual maturity, and less evident ones.

As of 1936, the American secondary-school system was characterized as yielding to no other in the broadness of its democratic pattern, the high proportion of adolescent population enrolled, the richness and variety of the curricular and extracurricular offerings, the dynamic responsiveness to changing social, economic, and political thought, and adaptation to the needs of a heterogeneous clientele. The conclusion

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[6] Shimkin, Demitri B., Russians Fear Their Engineers. U. S. News & World Report, June 17, 1955, pp. 114–115.

was reached that "American methods of teaching science on the secondary-school level, are, on the whole, more original, varied, and skillful than those in vogue" in either France or Soviet Russia.[7]

The present-day American school system enrolls more than 90 percent of the children from 7 to 16 years of age—a figure exceeding that attained in any other country. Nevertheless, during the years since 1936, and before, the teaching of the physical sciences in the American secondary schools has suffered a steady decline. Physics and chemistry are now frequently elective 1-year laboratory courses, and stress is laid on physical rather than on mathematical thinking. Whether as a corollary or as a cause, the teaching of mathematics at the secondary-school level has also declined. To meet this situation many colleges have adjusted their science courses to meet the high-school offerings.

Not less significant in any appraisal of the American secondary-school system is the severe loss of enrollment between high school and college. Of all high-school graduates whose qualifications are such as to warrant them in striving to become engineers and scientists, about half drop out of school and enter activities necessary to a livelihood for themselves and a growing family. Equally important is the continued attrition after college entrance. Of the half who enter college, scarcely 40 percent graduate. Thus, of every 10 high-school pupils with potential capacities for careers in a technical field, only 2 graduate from college. From then on the survivors for advanced education are even fewer, for of all college graduates only about 3 percent continue to study for a doctor of philosophy degree. In comparison with this, according to recent studies, of the students who enter Soviet higher educational institutions over three-fourths complete their courses.[8]

It is increasingly evident that the lead long held by the United States in numbers of effectively trained engineers and scientists is threatened. Our universities and colleges are turning out fewer graduates in these fields than are similar establishments in Soviet Russia, or in the so-called western bloc of Europe. Moreover, the future seems to hold no truly adequate increase. No person in authority sees an early possibility of our colleges repeating the rise in engineering graduates that preceeded the conflict in Korea. During the 4 years from 1946 to 1950, engineering graduates from American universities and colleges stepped from 7,000 to 52,000. Thereafter, largely under the impact of manpower demands in Korea, the numbers dropped until no more than 22,329 received first degrees in engineering in 1954. This appears to be the low point; yet, despite an awareness of current shortages and inadequacies no one attempts to prophecy a repetition of the 1950 class of 52,000. The most optimistic is the prospect of 38,000 graduates in 1960.

Why is this happening to a country which has a traditional respect for education, which takes pride in the universality of a high-school education, and which boasts of its facilities for higher education?

Much of the responsibility for the present situation and the immediate prospects, according to President Retalliata, of the Illinois Institute of Technology, at Chicago, arises out of inadequate train-

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[7] Efron, Alexander, The Teaching of Physical Science in the Secondary Schools of the United States, France, and Soviet Russia. New York, Teachers College, Columbia University, 1937.

[8] Status and Trends in Soviet Scientific and Technical Manpower Resources, p. 15.

ing and discipline in high schools, a failure of colleges to expand the use of their facilities and to encourage students to complete their courses, and to deficiencies in the military draft policies as they affect college students.[9]

He cites "a pronounced trend in the high schools toward a more general education, at the expense of mathematics and science, the prerequisites for engineering and science studies in the colleges." His remedy is a high-school program which would prescribe courses in English, mathematics, science, and history, sufficient to meet the requirements of accredited colleges of engineering or science. He would support this with more effective counseling on the advantages of a college education, and constructive efforts to increase the numbers who would enter fields of teaching.

He urges more scholarships for worthy students to help relieve the financial strain which is a principle cause of the heavy dropout after entering college. He suggests, however, that the scholarships be financed by industry and the State and not by the Federal Government. In this regard, he writes:

> Federally sponsored veterans' aid education programs have been satisfactory, but outright Federal subsidy of scholarships, with its attendant possibility of interference, is not to be desired.

He would also place responsibility on the technological educational institutions to recruit more students and maintain a larger portion of them. He urges also that their facilities be more effectively used for night school and summer classes.

Finally, he urges a reappraisal of our military draft policies as they affect higher education. "Selective Service deferments should not be regarded as granting privileges to a few," he writes, "but as a means of enhancing the security of the many. Engineers and scientists constitute less than one-half of 1 percent of the population. Yet, this limited group is relied upon to advance the standards of living, to create new and ever more powerful military equipment, and, in general, to be responsible for our national security.

"The task before us is to apply broad, positive remedial action as soon as possible to assure continuance of the technological competence upon which our future progress and, in fact, our very survival depend."

[9] Retalliata, John T., the Scientific Manpower Shortage—A Peril to America School and Society, July 23, 1955. Pp. 17-20.

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