The Economic Status of the Engineer

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Data gathered by the Bureau of Labor Statistics are used by the author in this article to support his statement that "the economic status of the engineer is largely a matter determined by each individual engineer according to his particular personal qualifications and the relations these bear to the work he does and to the personalities of those persons with whom and by whom he is employed."

THE ECONOMIC status of the engineer is bifunctional in its scope—one part deals with the value of the integrated work which all engineers have contributed to the progress and welfare of mankind; the other part has to do with economic recognition in the way of social position and salary which engineers and their families receive in return for service rendered.

The study on which this article is based shows conclusions which may be briefed as follows:

Engineers, though suffering considerable loss of income and employment during the recent years of business depression, on the whole have fared much better than most classification groups, be they government, capital, profession, or labor.

Preceding the depression, there was no lack of employment for engineers and their compensation for the most part was equitable in comparison with the pay for other types of service.

The verdict of users of engineering service regarding the reasons why engineers who have not made satisfactory progress professionally or in their economic status is almost unanimous that such failures are due to deficiencies in personality, general culture, tact, industry, and so forth, rather than the result of lack of technical training.

Graduation from college is prerequisite to success in engineering, but per se does not guarantee an engineer.

The education obtained by taking engineering courses and engaging in the practice of engineering for most of those who have chosen the routes thereof has led to "the more abundant life" and a better economic status than the lots of the families from which engineers have come.

In the September 1932 issue, ELECTRICAL ENGINEERING announced for the first time the appointment of a committee to be known as the "Committee on the Economic Status of the Engineer." The function of the committee is set forth in Institute by-laws, article III, section 83, which says this committee "shall consist of five members, and shall consider matters relating to the position, function, and responsibility of the engineer in the development of human welfare, and make reports and recommendations to the board of directors thereupon. The committee shall co-operate with similar committees of other engineering societies, and shall also consider and report upon all matters referred to it by the board of directors, the president, and the national secretary." The language of this article shows wisdom in its formulation and clearly charges the committee with the duty of keeping informed and advising the members of the Institute, through its board of directors, of ways and means whereby they may be of service to mankind. Such responsibility would be overwhelming, were it not for the fact that all engineering aims at exactly the goal specified.

The world's economic evolution has resulted in much classification of the workers responsible for changing the habits of its citizens from those of the jungle to our present complex but regal standard of living, though jumbled be its attendant economic program under which we are muddling along.

One group of these workers is known as the professional men's group. Professional men are, perhaps, best defined by saying they are men who have professional education; that is, "the training that fits men for special vocations in which science is applied to the practical purposes of life. It supposes, as its basis, the knowledge and discipline which general culture affords."

Defining the Engineer

Many attempts have been made to write an all-inclusive definition for the engineer, but the rapid march of time has made each effort obsolete, even as the progressive science of engineering rather than the wearing out of machines has relegated many engineering products to the oblivion of the obsolete.

Engineers qualify as professional men by having professional education. Government research as to the "Educational Qualifications in the Engineering Profession" shows:[1]

"A first degree in engineering is now almost a prerequisite in order to obtain professional status and a position. Postgraduate work, however, is important only in a few of the professional classes. The tendency of engineers to transfer from the course of college specialization to other classes of work is negligible. These are a few of the facts developed in the survey of the engineering profession, which was undertaken by the Bureau of Labor Statistics in May 1935, at the request of the American Engineering Council."

Figures on which the above statements are based show that only 1.52 per cent of the engineers who began practice between 1930 and 1934 were not graduates. For all years up to 1929, 27.6 per cent of all engineers were not gradu-

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1. For all numbered references, see list at end of paper.

ates. For all years up to 1935, 17.7 per cent of all engineers were not graduates. For all years up to 1935, 13.3 per cent of all electrical engineers were not graduates. Also the number of engineering graduates with more than one degree is very small, namely, one-half per cent and one-tenth per cent only having, respectively, masters and doctorate degrees.

The doubt expressed as to the importance of postgraduate work is challenged, because graduate work in engineering colleges is too new to provide enough statistical data to draw conclusions as to its value. There is strong evidence, however, that men who are qualified for and have completed graduate courses which are provided in properly manned and well equipped colleges for the study of modern science and mathematics as applied to engineering, have, for the most part, advanced in professional status at rates which show justification for graduate work. In the author's opinion, the limited number of men who have the special scientific and mathematical ability to warrant the continuation of postgraduate work unto the earning of a doctorate degree (and no others) should be encouraged toward that end.

A poet scanning these data and writing in Biblical language might well say, "It is easier for a camel to go through the eye of a needle than for a man to become an engineer without the advantage of graduation from an engineering college," or expressed in current language of the street, it may be said, "The odds are better than 98 to 1 you cannot be an engineer without graduation."

In fact the engineer finds that graduation does not end study, but that he must supplement his practice by continued study else he will lag behind just in proportion as his interest in research and study wanes. Perhaps, therefore, it will be easier to determine who are engineers by the manner in which they do their work rather than to judge by graduation, license to practice, or by passing examinations, often irrelevant to the kind of engineering done.

The law says a boy becomes a man the day he is 21 years old, but, except for legal privileges and voting, no change takes place on the 21st birthday, but rather a boy becomes a man when he puts away childish things and meets his problems in a manly way.

So it is with becoming an engineer. A man does not become an engineer because he graduates, or because he completes a test course and becomes a good draughtsman, mechanic, calculator, designer, or professor of electrical engineering. He becomes an engineer when he diligently and intelligently uses his God-given and hereditary talents, his education, his environment, his background, and his personality to produce new ideas and, through the medium of the crafts mentioned, finds ways and means for putting these ideas to work and makes a scientific analysis of his procedure in order that he may proceed by the engineering method rather than by cut-and-try or empirical methods.

Engineers, perforce, must at once be very co-operative and very individualistic. The co-operative characteristic is necessary because engineering problems of today are too large for one man to solve, and must be worked out by groups of men working in such close relationship as often to make practically impossible any acknowledgment as to the source of key ideas which unlock the problem solutions. Engineers must be individualists in order that each may contribute his share to the profession, by discovering in the daily tasks performed, new problems and their solutions. As illustrative of the latter point, consider the 27 Edison Medalists, beginning with Elihu Thompson and including the most recent one, Gano Dunn. No two of the entire 27 have traveled even similar paths to success. In fact, in all engineering history there are probably no case records which show that two engineers have done identical work, even in instances where promotions and other causes have made vacancies in organizations that result in succession appointments.

Thus we see that engineers in their relations with their work and fellow men have true professional status in that the particular contributions of each engineer to society are unique.

Economic Recognition

The other phase of the economic status of engineers, bluntly stated, is to what extent does all this work enable them to provide themselves and their families with good social positions and the use of the facilities for human betterment which engineers have made available. This part of the question, while not specifically mentioned in the Institute by-laws, is implied by the name of the committee, and committee consideration thereof is expected by the Institute members.

Statistical data regarding employment and income are now available in bulletins published by the United States Department of Labor, Bureau of Labor Statistics. Parts of the data in these bulletins have been published in ELECTRICAL ENGINEERING.

Table I. Comparison of Five Levels of Annual Earnings for All Professional Engineers Reporting in 1929, 1932, and 1934

Figures derived from adjusted data as explained on page 4 of bulletin, and without regard to employment status reported or type of education

Per Cent at Specified Income Level	Annual Earnings of More Than Specified Amount		
	1929	1932	1934
10	$7,466	$5,605	$5,138
25	5,012	3,827	3,429
50	3,412	2,574	2,286
75	2,509	1,698	1,473
90	1,878	889	872

A study of these data and much other information obtained from the printed page, by discussion with others, and by experience on the part of the author, seems to warrant the conclusion that the economic status of engineers in comparison to that of other citizens is for the most part reasonably equitable, though many engineers are of the opinion that the members of the engineering

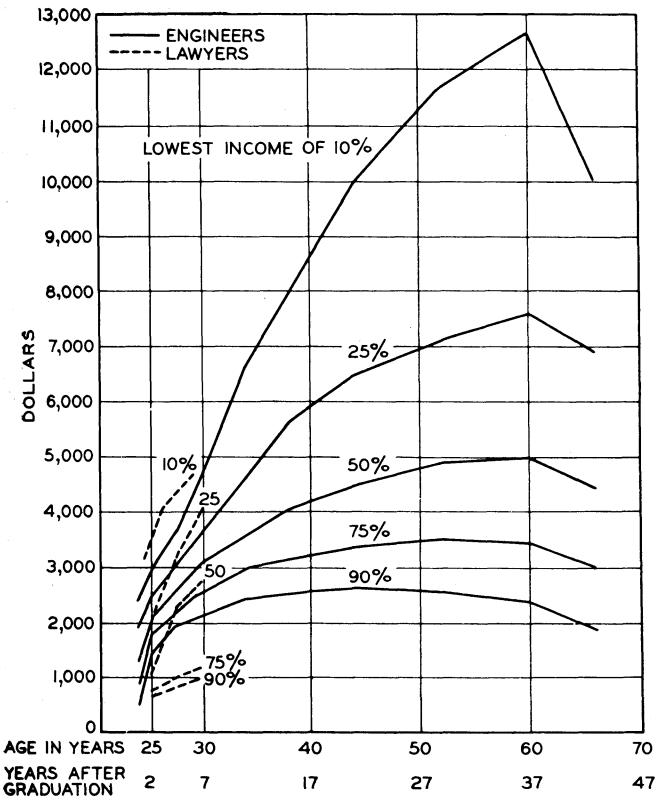

Figure 1. Earned annual income of engineers and lawyers according to age

Curves for engineers represent the findings for all the engineers of the United States; curves for lawyers represent the findings for California lawyers admitted to the bar in 1931

profession have received less reward than their work warrants.

Bulletin No. *R.* 497[2] opens with the sentence: "As far as is known, the recent depression was unique in its disastrous repercussions upon professional groups." This, after all, is just another way of saying the depression was terribly severe, extending even into the professional groups to such an extent as to show a simultaneous unemployment of about 11 per cent of all engineers, all of the several engineering classifications suffering to about the same degree, as might be expected, there was a greater percentage of unemployment for engineers over 53 or under 27 years of age. Summary analysis number 9 of this bulletin says:

"9. The type of education the professional engineer had received did effect variations in both the incidence and severity of unemployment. These factors were very much less for postgraduates than for engineers with other types of education. But as between engineers with first degrees in engineering and those whose college course was incomplete or who had attended noncollegiate technical schools, the differentials were very slight."

Other information shows less than three per cent of the graduates of some engineering colleges unemployed at any one time during the depression years 1930–35. No comparable data being available for the other professions, it is difficult to know just what a reasonable standard of depression unemployment should be, but there is every reason to believe that lawyers, physicians, and dentists, though busy, did not fare any better than engineers in regard to net income received for service rendered. It is also very certain that engineers, in that respect, fared better than skilled mechanics and other craftsmen who constitute much of our working citizenry.

Bulletin No. *R.* 543[3] shows among other things that during the five-year period of rampant unemployment, the number of engineers graduating into the profession was 25.3 per cent the number engaged in engineering in 1929. Since the nation-wide unemployment of engineers at any one time reached a maximum of 17.7 per cent, there was, even during unemployment times, a considerable amount of employment for the beginner in engineering. The number of engineering graduates, therefore, probably was not too high for normal times and the indication is that all should be needed by industry, if only persons well qualified for engineering work choose to enter the profession.

Bulletin No. *R.* 588[4] presents much very interesting data. The accompanying table I is part of table III of this bulletin. The table shows that in 1929 all but ten per cent of the engineers received wages equal to or better than the wages of skilled mechanics, as published in Bulletin No. 616, "Wages and Hours of Labor," which lists the pay for skilled and unskilled labor in many industries and shows mechanics' wages are $25 to $35 per week with occasional skilled occupations paying larger amounts.

Opportunity Outweighs Pay

First-degree engineering graduates start work at about $25 or $30 per week. Graduates with master's and doctorate degrees start at from $30 to $50 per week, the latter amount being reserved for men of special ability. These rates of pay appear just—the mechanic or skilled laborer being paid a premium over the common labor wage in recognition of his skill and the cost of its acquirement. The wage premium for neophite engineers is a recognition of the fact that time and money have been required for college training which will enable them to become engineers, rapidly, rather than as recognition of acquired proficiency as in the case of mechanics. The pay received by men just out of college, provided it keeps them from want, is relatively unimportant, as compared to opportunity for advancement in responsibility and salary. Salary advances for engineers of the United States and for lawyers of California, so far as the latter information is available, are compared in figure 1. The curves applying to engineers are taken from figure 1 of reference 4. The data pertaining to the lawyers of California is from an unpublished "Digest of a Survey of the Economic and Professional Status of California Lawyers During the First Five Years of Practice," prepared in 1937 by the committee for cooperation between the law schools and the state bar.

The curves for the engineers show favorable advancement in salary with age and experience for the upper half of those in the profession, as also does the rather limited data for the lawyers. It is interesting to note the long rise in earning capacity extending unto a man's 60th year of age and 37th year of practice. Observation, without confirming data, creates the opinion that lawyers and physicians follow the same laws in this respect. No actual

data have been made available for physicians, but an oral check with a number of them brought forth statements, all in agreement, to the effect that in the opinions of those interviewed, the curves for the engineers were, on the whole, indicative of the net salaries for physicians—the average for the physicians being perhaps a little better than the average for engineers; but less than ten per cent of the physicians have net incomes above the ten per cent curve for engineers.

All this information seems to indicate equity in the income of engineers as compared to skilled laborers, lawyers, and physicians.

The professional men are indeed fortunate in having occupations which provide for increasing service to fellow men as years add to skill and experience, and also in having at the same time increasing incomes which grow apace with the family expenses and often continue to grow beyond the period required to get the children established in their own homes and occupations.

Those of our profession who disagree with these findings, particularly as they apply to engineers, have two arguments against them—one the apparent greater expenditure of money by lawyers and physicians as compared to that of the engineers, which they have witnessed. It must be borne in mind that some of the expenditure made by physicians and lawyers is for office equipment and automobiles that must be used in connection with the practice of these professions. Also it is worthy of note that the expenditures which attract attention are usually those made by the more prosperous, rather than by the representative members of the profession.

Moreover, comparisons which men make purely by observation, rather than on the basis of exact data, between the spheres of their own activity and those of others, generally result in optimistic interpretations regarding the outside spheres, with a simultaneous pessimistic appraisal of their own. "The grass on the other side of the fence is always greener."

The second objection has to do with the exactness of the data obtained from returned questionnaires as compared to that which would have been available, had every engineer in the land returned a complete questionnaire. A complete report, would, of course, be impossible except by absolute governmental decree ordering a census of all engineers, but the data available which came from the 52,589 engineers who properly filled out and returned the questionnaire should give a fair cross section of the 167,268 engineers who received them.

Assuming the data used to be representative, the analysis has narrowed to two questions: (1) Why is there such great spread in income for men in the same profession who have gone through the same training courses, been subject to the same tests as to ability, and have survived the same processes of selection? (2) What are we going to do about it?

Many educators and others have often asked these questions and made surveys of industry, hoping thereby to find the answer, but all have ended with only a variety of general but authoritative statements by those who employ engineers. Some of these statements are:

Graduates of engineering colleges fail to reach expected goals not because of lack of technical education but rather because of deficiencies in those qualities described by such terms as:

Personality	Aptitude
Loyalty	Promptness
Patience	Accuracy
Humility	Judgment
Breadth of interest	Proper estimate of own value
Business ability	Executive ability
Leadership	

with sometimes the comment that there is lack of education in basic science and mathematics. All of which takes us back to a part of the definition with which we started, "it supposes as its basis the knowledge and discipline which general culture affords."

Only the last of these objections; namely, the lack of education in basic science and mathematics, will, at first thought, be charged to weakness in engineering college curricula and training, but there is a four fold responsibility involved in the making of an engineer which must be assumed jointly by the young man, his family, the college, and industry.

Engineering Offers High Living Standards

America, the land of opportunity, provides many avenues for rendering service and at the same time improving standards of living. Not the least of these are the engineering professions. Via engineering and the education provided by the engineering colleges, many men have reached social positions and attained economic rewards far better than those of the families from which they came. In fact, there are so few exceptions to this order of things, even among the poorer paid engineers, as to make perfectly valid some such declaration as: "Engineering is a profession through which the sons of small merchants, farmers, and laborers, as well as those of professional men and the prosperous in industry find golden opportunities to high living standards."

A large portion of the enrolled students in engineering colleges in part or entirely "work their way through." The author has, for more than a quarter of a century, cooperated with these men to make work, college courses, family budgets, and loan funds blend to the best advantage of all concerned. This blending process is not always easy, nor, though a certain amount of labor experience is desirable, is it advantageous for a student to be compelled to allot a very large part of his college time to earning money. In one college where the tuition is $300 per year and there are relatively few scholarships, one-sixth of the undergraduate student body and one-tenth of the graduate students are using National Youth Administration assistance. Nearly all the families to which these young men belong have incomes of $1,200 per year or less. According to the catalogue of the college in question, the minimum estimated cost per student for board and room, books, tuition, and so forth, but with no allowance for enentertainment and clothing, is:

Students taking 21 meals in student houses per week. . . $840 per year

Students taking 15 meals (going home weekends)..... 740 per year
Nonresident students..... 390 per year

The cost per student in many free-tuition colleges, when all factors are considered is practically the same. If a family with an income of $1,200 per year (and there are those with less) must, with the aid of the student, apportion an amount equal to two-thirds the family income for the bare essentials of being in college, it is obvious there is little money available for travel, hotel life, theater, dances, and other social functions, or even for church activities, all of which have great bearing upon the phases of life which employers have declared are deficient in engineers to an extent which impairs engineering careers.

These deficiencies fortunately can all be remedied by any normal young man with capacity to complete an engineering course, if he is made aware of them, and will make an honest effort to know himself and apply the needed corrections. Keeping well is always simpler and better than curing illness, but continuing in illness is infinitely worse and sometimes inexcusable.

Being born and nurtured in an atmosphere of culture where all the graces of life are daily habits which can be acquired with little conscious effort has its advantages. When this experience has been denied the engineering students, colleges should provide clinics for correcting the deficiencies. Some of the more progressive engineering colleges have made progress in the right direction by having in their curricula a goodly proportion of cultural courses with the consequent necessity for postponement of the more special technical courses to graduate years.• Industry also should not limit all its training courses for young engineers to the technique of the business, but should provide opportunity for them to learn of and correct faults which impair the rendering of the highest possible type of engineering service. College and industry together must show interest in our educational program from kindergarten on and co-operate with our engineering societies and the Engineers Council for Professional Development in extending their program for educating the public as to the requirements for being an engineer.

Industry should see to it that all who qualify as engineers be paid all the work done will warrant, and should not designate as engineering, work which is not engineering, but is only high-class clerical calculating, draughting, or skilled machine operation.

Engineers should make themselves thoroughly conversant and be sympathetic with all the problems of labor, skilled and unskilled, preferably through having had actual experience as workers in both classifications. They should not make entangling commitments to either capital or labor which may interfere with their great opportunities to correlate these two great industrial factors into teams that, working together at the business of applying engineering methods, cannot be defeated.

Fortunate indeed are the youths who find their talents and choices leading them into engineering; they can have a lot of fun following one of the many paths leading to enjoyable service for their fellow men, and at the same time providing so well a means of livelihood for themselves and their families.

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2. Unemployment in the Engineering Profession, United States Department of Labor, Bureau of Labor Statistics, Bulletin No. *R.* 497; essential substance appeared also under the same title in Electrical Engineering (AIEE Transactions), volume 56, February 1937, pages 216–23.

3. Employment in the Engineering Profession, 1929 to 1934, United States Department of Labor, Bureau of Labor Statistics, Bulletin No. *R.* 543; also Employment in the Engineering Profession, Electrical Engineering (AIEE Transactions), volume 56, May 1937, pages 524–31.

4. Income and Earnings in the Engineering Profession, 1929 to 1934, United States Department of Labor, Bureau of Labor Statistics, Bulletin No. *R.* 558; also Engineering Income and Earnings, 1929–34, Electrical Engineering (AIEE Transactions), volume 56, September 1937, pages 1089–1104.

Other articles in this series appearing in Electrical Engineering (AIEE Transactions) were: Security of Engineering Employment, volume 56, June 1937, pages 655–61; Sources of Engineering Income, 1929–34, volume 56, November 1937, pages 1353–8; and Monthly Earnings of Engineers; 1929–34, volume 56, December 1937, pages 1450–60.

Voltage Distribution in the Welding Arc

A PAPER by H. von Conrady entitled "Investigation of the Voltage Distribution in the Welding Arc," which was published in *Elektroschweissung* (volume 8, June 1937, pages 101–06; July 1937, pages 125–28) recently has been translated by Herman J. Munz and is being distributed by the welding research committee of The Engineering Foundation. The author (1) describes apparatus devised as a part of a research subject under investigation at the experimental station for welding technique of the Technical University of Berlin, Germany, for measuring the voltage drop in welding arcs carrying currents as large as 1,000 amperes; and (2) presents results of tests made with that apparatus.

Electrodes made of iron, copper, and aluminum, all having diameters of 40 millimeters, were employed in the investigation. Test results showed that the arc characteristic for currents used in welding has a slowly increasing slope; in other words, the voltage increases with increasing current, assuming the length of the arc to be constant. Both the cathode voltage drop and the anode voltage drop are said to vary with the arc current.

The author found also that the voltage drop on the cathode is always larger than that on the anode, as should be expected in considering the energy regained on the anode. The magnitudes of the voltage drops, however, depend on the material used. For iron the voltage drop on the cathode is somewhat larger than that on the anode. The external shape of the unobstructed arc between iron electrodes was observed to be different from the shape of arcs between carbon, copper, or aluminum electrodes. Arcs between these latter materials graduate from a narrow limited point at the cathode in a cone-like shape to a wide base at the anode; however, the shape of the arc between iron electrodes is exactly reversed.

A few mimeographed copies of this translation are available from the Welding Research Committee, Engineering Foundation, 29 West 39th Street, New York, N. Y.