# "PUBLISH OR PERISH": THE SURVIVAL OF CIVIL ENGINEERING AS A LEARNED PROFESSION

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*"I hold every man a debtor to his profession; from which as men of course do seek to receive the countenance and profit, so ought they of duty to endeavor themselves by way of amends to be a help and ornament thereunto."*—SIR FRANCIS BACON.

THE slogan "publish or perish" that introduces this address is often voiced in the academic community as a warning to young teachers who have not yet attained a permanency in their university. Implied is the threat that they must either give evidence of possessing the drive and ability to advance their field of learning through creative scholarship, or fail of promotion. It is in this sense of professional responsibility and competence that I have employed my catchwords.

From meetings of our profession, enquiries of committees, and publications of our societies, it seems that the civil engineer's lot is no longer a happy one; that his services are poorly compensated; that he feels insecure in his work, inadequately appreciated by his public, and dissatisfied with his education; that recruitment to his banner is lagging behind that of other branches of engineering and that those enlisting in his ranks are of inferior quality; that in a world of change he has failed to move forward; and that the present generation no longer sees intellectual challenge in bridging great rivers or arms of the sea, harnessing the floods, slaking the thirst of communities and industry, expediting physical communication, or having any part, for that matter, in creating the seven times seventy wonders of the modern world.

Exercised equally and perhaps more immediately—and certainly more vociferously—about the present status of our profession seem to be the teachers, deans, and presidents of our institutions of higher learning, and it is, indeed, impossible to separate a discussion of the profession from that of education for the profession. My address,

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therefore, falls naturally into two parts: (1) the status of civil engineering as a learned profession, and (2) the status of education for civil engineering. To these must be added, as a matter of compassion, some assurance of the probability of survival.

## The Status of Civil Engineering as a Profession

*Origins of our Profession.* To measure the present condition of our profession, let us quickly turn back the pages of history to the origins of civil engineering and thence forward to the more recent past. Accordingly, I shall call on S. E. Finer, Professor of Political Institutions at the University College of North Staffordshire to have the first say (1). "The engineers," to quote from his study of Sir Edwin Chadwick, social reformer and leading spirit in the Sanitary Awakening of Great Britain in the mid-nineteenth century, "particularly the railway engineers, were the folk-heroes of mid-Victorian England. The railway—the most revolutionizing technical invention of the whole century—struck the imagination of the nation like nothing else. Composers wrote ballads like *The Railway Bell(e) and the Railway Guard, Excursion Train Gallops,* and *Railway Overtures. Tracts for the Times* were parodied in *Tracts for the Trains.* Newspapers broke into a rash of 'Murders on the line,' or 'Melancholy accidents.' . . . In that lusty infancy of civil engineering there were no specialisms: every man was expected to ply all branches of the mystery. The railway constructors drove tunnels, made cuttings, built locks, and drained marshes. They built undreamed-of bridges of steel, like the Britannia and the Saltash, and reared splendid and graceful viaducts, like those at Dutton and Llangolen, Monsal and Wharnecliffe.

"These engineers were a peculiar social phenomenon. Most of them were of the humblest origin . . . . Robert Rawlinson's father was a builder, Rendel and Hawkshaw were farmers' sons, Stephenson was the son of a collier. They rose to fame and influence by their native ability and their gusty energies. By consequence they were intensely individualistic even for an individualistic age. It was they who invented the term 'private enterprise.' They obstructed the Railway department of the Board of Trade, the Harbour Commissions of the Admiralty, and the Board of Health, protesting against the 'mischievous flourishing of the functionary weed,' and the 'difficulties thrown in the way of the rising generation of engineers by the governing classes of the country.' They would not, in their own words, be 'interfered with, restricted, and controlled.' . . . In their ruthless eruptive animal energy, the engineers showed a swashbuckling disdain for the social evils around them. 'Railways were meat and drink.' Nearly all of them were Tories and Protectionists in an era when Torying was just beginning to become synonymous with a tenderness to vested interests and with Herbert Spencer's version of *laisser-faire*. Indeed, Spencer's *Man versus the State*, written when he had just ceased to practise as an engineer, may be taken as the social philosophy of the whole profession—civil engineering and social buccaneering.

"The engineers were an 'order,' a freemasonry, whose centre and sounding-board was the Institute of Civil Engineers. By mid-century this had transcended its original purpose. It was no more a simple self-improvement society, but a social club, a clearing-house for information, a bureau for employment. It aspired even to be a Senate. But one cannot read its 'Minutes' without being struck by its self-complacency and its professional bigotry. The whole Institute had a chip on its shoulder. Its emblem should have been the thistle, and its motto *Noli me tangere*."

That is not a very encouraging beginning, but we may excuse it by assuming that Finer, within the context of this biography, may have given us a somewhat partisan account of our origins. Nevertheless, there are at least two observations that we should take to heart from the passages that I have cited and from Finer's later discussion of the battle between the civil engineers and the men agreeing with what was called the "dilettante engineering" of Sir Edwin's aids in the substitution of small-bore clay pipe sanitary sewers for brick combined sewers of large dimension.

The first observation supports a criticism often voiced against civil engineers in our day, as it was a hundred years ago, namely, that civil engineers have shown little leadership in and understanding of public affairs and, like their forbears, suicidally, have obstructed progress in the very field of which they are the masters. The social philosophy of encouraging public services as well as private goods and services has, indeed, come to the fore once again in our times. Economists and political scientists point in mounting measure to the imbalance between the two types of services, although not often in words as provocative as those of Kenneth Galbraith (2) in his "Affluent

Society." There, his evaluation of our present society is epitomized in his description of "The family which takes its mauve and cerise, air-conditioned, power-steered, and power-braked automobile for a tour through cities that are badly paved, made hideous by litter, blighted buildings, billboards, and posts for wires that should long since have been put underground. They pass into a countryside that has been rendered largely invisible by commercial art. They picnic on exquisitely packaged food from a portable icebox by a polluted stream and go on to spend the night at a park which is a menace to public health and morals. Just before dozing off on an air mattress, beneath a nylon tent, amid a stench of decaying refuse, they may reflect vaguely on the curious unevenness of their blessings. Is this indeed American genius?" Galbraith's conclusions, therefore, are that:

"The line which divides our area of wealth from our area of poverty is roughly that which divides privately produced and marketed goods and services from publicly rendered services" and "The disparity between our private and public goods and services is no matter for subjective judgments."

The second observation supports another criticism of civil engineers in the present, as it did when Sir Edwin Chadwick conducted his great crusade for clean water and good drainage, namely, a tendency to overvalue experience and to undervalue experimentation, as well as research and education. Here may I quote a paragraph or more from the presidential address of A. J. S. Pippard to the Institution of Civil Engineers (3). Shown, in addition, will be that the questions we are discussing are not unique to America.

"The most important function of practical training is the amplification of theory by experience and it is one of the most urgent and responsible professional duties of the established engineer to deal faithfully with the young men who will ultimately succeed him and who must rely on him for the widening of outlook which will make possible the full use of the scientific education they have received.

"The civil engineer can no longer afford to hold, or even pretend to hold, theoretical knowledge in contempt. Let us accept the position that the future of the profession depends upon sound practice based on a solid foundation of science and show this faith in the education and training of our young men; then we need have no misgivings about the security of their position in the world of tomorrow.

"Engineering being the application of natural laws in the service of man, it should be clear without laboured argument that the study of those laws, and appreciation of the consequences flowing from them, are matters of supreme importance and interest to the practitioner. One can go further and assert that in the absence of such study and appreciation, the profession of engineering must languish and ultimately die. True, even in such a disastrous event, there would remain the need for routine construction and maintenance, but the living spirit would vanish and the engineer would rightly cease to rank as a creator and would sink to the level of a hack.

"The real life-blood of the profession must therefore be research, but in saying this I do not want to be misunderstood. Research is not only, or even mainly, the prerogative of a few selected workers in universities and in official and private research establishments; the spirit and practice of research should inspire every member of the profession. The opportunities are greater today than ever before for the practitioner to add something to the general store of knowledge, and we shall be judged by our successors not only by the engineering works produced in our generation but by our contributions to that body of knowledge which will provide them with the means to exceed our achievements. I would emphasize this point for it must never be forgotten that research in engineering must be directed to the main function of the art, which is construction, and only to the extent to which it ultimately advances the practical ends of the engineer can it properly be considered to add to the science.

"This, however, is a broad generalization, and much that may appear to be excluded as legitimate engineering research by contemporary thought will surely in a few years, or maybe generations, prove of practical value in the hands of those who will follow us."

I cannot forgo introducing a puckish note at this point by quoting, as did Pippard, the contrasting opinion of the great 19th century engineer Smeaton: "In my intercourse with mankind," he said, "I have always found those who would thrust theory into practical matters to be, at bottom, men of no judgment and pure quacks."

A brief and final quotation from Sutton Pippard's address will lead me to an analysis of our professional publications.

"It has been said that every man has at least one book in him. Whether this is true I do not know but every civil engineer should have at least one or two ideas which would be of value to his fellows, and I suggest that as a matter of professional duty such ideas, whenever possible, ought to be placed on record for the common good."

It has seemed to me for some time that our professional publications are not quite as representative of the profession as once they were. I have noted among other things (1) a progressive reduction in important communications by engineering consultants and industrial agencies; (2) a progressive increase in mathematical papers by teachers and university research groups; (3) a progressive decrease in the discussions of all types of papers; (4) a progressive abridgement of accounts of important new works; and (5) a progressive falling-off of analytical papers by all but university groups.

Some of these statements are supported by my analysis of the principal publications of the American civil engineering profession recorded in Figs. 1 and 2. There I have shown the four major sources and subjects of the papers published in the Transactions of the American Society of Civil Engineers for the triennia 1957-59 and 1922-24. To these I have added a source and subject analysis of the communications that appeared during 1959 in the Proceedings of the Institution of Civil Engineers of Great Britain and in the Transactions of the American Society of Civil Engineers *cum* Civil Engineering. My statistical sample, I grant you, is small, and evaluation of the publications by others might not reproduce my results exactly. Hence I leave the interpretation of these summaries to the reader along with an examination of the changes that are not analyzed in these figures. Of special interest to me has been the confirmation of the drop off in analytical papers in the U.S. shown by the combined percentage values for Transactions and Civil Engineering in Fig. 2.

*Towards Professional Responsibility.* Among the learned professions, medicine is about as closely an applied science as is engineering and, most particularly, civil engineering. Although medicine has, notably during the year just past, experienced a decline in highly qualified applicants for medical education, I do not believe that the decline has been so sharp as that in civil engineering. In my opinion, therefore, we can still learn much from the organization of medicine for professional responsibility. This is shown in Table 1, taken from a study by D. H. Pletta (4). The organization of Law is added for good measure. In his discussion of this table, Pletta has stressed the time lag between the organizational activities of engineers and members of other professions. However, this aspect of professional coordination is not so deeply worrisome to me as is the failure of civil engineering to identify itself anywhere nearly as much with professional education as has medicine. I question even whether there ever has been in

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                         SOURCE OF PAPERS

                            University

ASCE 1922-24   xxxxxxxxxxxxxxx 14.6%
ASCE 1957-59   xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 48.4%
ICE 1959       xxxxxxxxxxxxxxxxxxx 19.0%
ASCE 1959*     xxxxxxxxxxxxxxxxxxxxxxxxx 25.0%

                            Government

ASCE 1922-24   xxxxxxxxxxxxxxxxxxxxxxxxx 25.0%
ASCE 1957-59   xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 33.1%
ICE 1959       xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 34.5%
ASCE 1959*     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 32.0%

                            Consulting

ASCE 1922-24   xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 43.7%
ASCE 1957-59   xxxxxxxxxxx 11.4%
ICE 1959       xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 31.0%
ASCE 1959*     xxxxxxxxxxxxxxxxxxxx 17.6%

                             Industry

ASCE 1922-24   xxxxxxxxxxxxxxxxx 16.7%
ASCE 1957-59   xxxxxxx  7.1%
ICE 1959       xxxxxxxxxxxxxxxx 15.5%
ASCE 1959*     xxxxxxxxxxxxxxxxxxxxxxx  23.4%

*Transactions plus Civil Engineering

Source Analysis of Transactions, A.S.C.E.; Proceedings, I.C.E.;
and Transactions plus Civil Engineering, A.S.C.E.  (Percentages)
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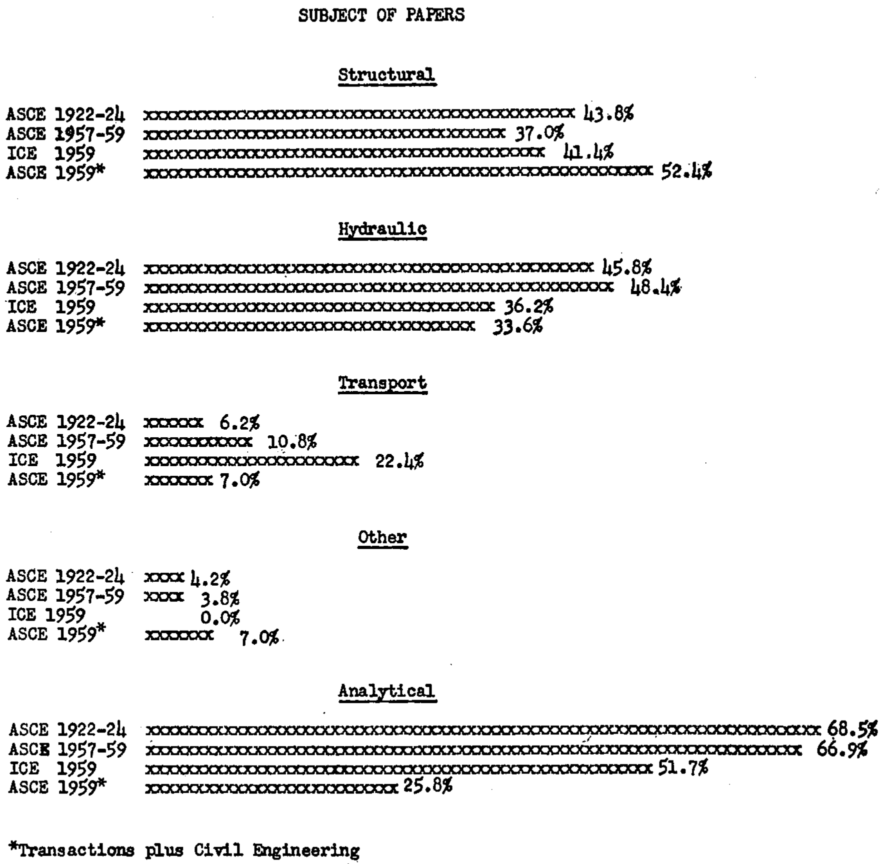
FIGURE 1.

America a professional school for engineers in the same sense as a professional school for physicians. Accordingly, I have outlined in Fig. 3 the very considerable involvement of medical practice with medical schools. On the left of my composition is the contribution to




Subject Analysis of Transactions, A.S.C.E.; Proceedings, I.C.E.; and Transactions plus Civil Engineering, A.S.C.E. (Percentages)

FIGURE 2.

professional education by medical science and its self-perpetuation and growth through study and research; on the right is the bifurcate contribution of medical practice (1) by the attachment of medical practitioners to medical school staffs and (2) by the students "walking" the hospitals; at the bottom is the opportunity for medical graduates to choose, if they wish, a career in public administration through schools of public health. Not shown, because it is numerically unimportant, is the opportunity for hospital administration and other activities close to private management.

TABLE I.

A Study in Comparative Professional Organization

| | Medicine | Law | Engineering |
|---|---|---|---|
| First Licensing Law | 1760 | 1890 | 1907 |
| First College Course | 1765 (U.Pa.) | 1799 (W.+M.) | 1819 (Norwich) |
| 2-4 Plan Adopted+ | 1918 | 1921 | 19?? |
| Prof. Society Accreditation | 1907 | 1921 | 1936 |
| National Board of Examiners | 1892 | 1931 | 1920 |
| Founding of Professional Society | 1847 (AMA) | 1878 (ABA) | 1934 (NSPE) |
| Licensed Individuals | 239500 | 262300 | 260000 |
| Practicing Individuals | 207240 | 254700 | 500000* |
| Membership in Professional Society++ | 180700 | 97000 | 53000 |

+2 Yr. Pre-Professional followed by a 4 Yr. Professional Program.
++Membership restricted to legally qualified individuals.
* Estimated number eligible for licensing.
Statistical data presented above represent the best available information and cover the period 1959-60.

If engineering education were to be supported in similar measure by the engineering profession, the organization of its professional schools would have to take the form shown in Fig. 4. At first glance, the reader may conclude that we possess some such organization; but this is not so. As yet, the lines have not been drawn so sharply, the functions not defined so clearly. We have been content with "practising professors" instead of engaging "professorial practitioners." To be sure, we have introduced students to practice through cooperative education; but have we ever made the office, works, or department in which the cooperative student is placed, an arm of his education in the sense that the teaching hospital is an arm of the medical school? We have produced the cooperative student; but have we developed the cooperative practitioner? Did we ever see that it is essential to the full

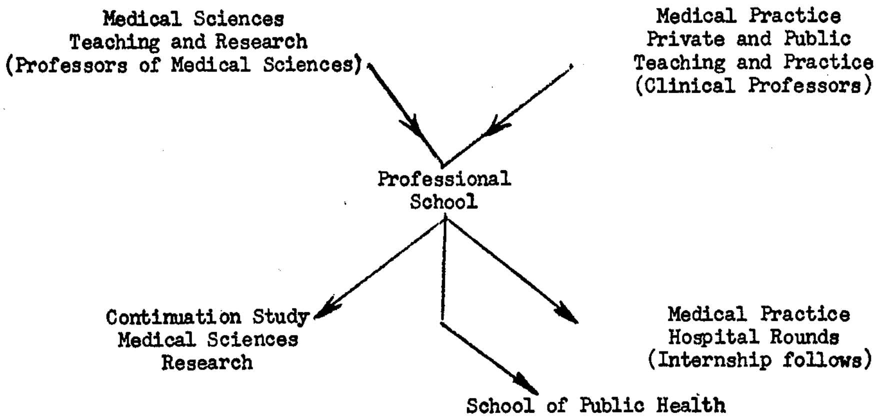



FIGURE 3.—INVOLVEMENT OF MEDICAL PRACTICE IN MEDICAL TEACHING.

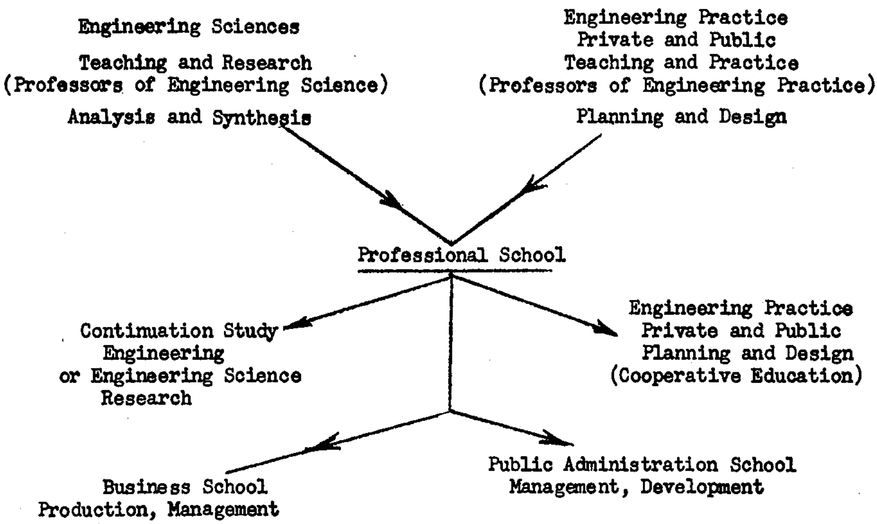



FIGURE 4.—REQUIRED INVOLVEMENT OF ENGINEERING PRACTICE IN ENGINEERING TEACHING FOR MEDICAL EQUIVALENCE.

success of this venture to enlist the supervisor of the student as a member of the faculty of our professional schools in the varying ranks of the academy in the way this has been done in medical schools?

Obviously, the creation of an engineering school in the image of a medical school is not all beer and skittles. The Harvard Medical

School, for example, has a student body of about 500,* a teaching staff in the medical sciences close to 200,† and in clinical work of nearly 1,150‡ within 16 hospitals. The involvement of medical practice with the medical school is indeed fantastic, and has mounted ever higher from year to year in spite of a stationary student population. Thus the total number of teachers of faculty rank is now over 450, with a supporting group of about 900. I, for one, would like to see at least one equivalent U.S. school of civil engineering. In my opinion, it would be swamped with superior applicants.

Looking abroad, it seems to me that both United Kingdom and Continental European civil engineers, in spite of shortcomings and worries of their own, have been more responsive to the educational needs of their profession than have American engineers. In Britain, the Institution of Civil Engineers is an examining body, and the Chartered Civil Engineer a teacher as well as a practitioner. On the Continent, some of the best engineers in government and industry (there is almost no private practice) are anxious and proud to be teachers in the important professional schools of their country, and there exists in Germany, at least, a two-year rotating internship for graduates who wish to enter the civil service at the municipal, state, or federal level.

## The Status of Education for Civil Engineering

*Origins of our Education.* Speaking to the National Convention of Tau Beta Pi in 1950, I introduced the following note about the origins of education in the U.S.A. (5).

"In the early years of this country, Thomas Jefferson advocated two educational measures for the ultimate benefit and safety of the republic: first, mass education at the elementary level and, second, selective education of the most brilliant minds for leadership in the professions and in the affairs of state. Both of these educational efforts were to be supported from public funds. In accordance with the French system of higher education, which was greatly admired by the small group of American intellectuals to which men such as Franklin and Jefferson belonged, admission to higher education was to be open, irrespective of wealth and social standing, to all those who could qualify

* Not including almost 600 postgraduates in short-term specialties.
† Of whom 130 are full-time appointees, research and teaching fellows not being counted at all.
‡ Of whom more than 400 are full-time appointees, research and teaching fellows again not being counted at all.

for it in competitive examinations or *concours,* as they are called in France.

"In the middle years of this country, by contrast, there was introduced, in the era that had felt the levelling influence of Andrew Jackson, a new concept: that of raising the average standards of education for all young people. A democratic people that thad just conquered a vast continent responded quickly to the Jacksonian ideal. In the days of Emerson and transcendentalism, all things seemed possible, and the country was joyfully ready to hitch its wagon to the star of Jacksonian equality.

"In the fast-expanding American community, which often received as many as a million adventurous immigrants in a year, the problem of free public education was tackled with superb energy and zest. In a period covering the biblical life span of man, the enrollment in secondary schools multiplied about thirty times as fast as the population, and the enrollment in colleges about ten times as fast. Among the men who were responsible for this great undertaking were the prophets of universal education Horace Mann and Henry Barnard, who had taken their cue from the great Swiss emancipator of school children, Johann Heinrich Pestalozzi. Among the measures that advanced higher education was the Morrill Land Grant Act of 1862 which created the great state universities of this country. This act has been rightfully referred to by President James B. Conant of Harvard University as the one great contribution to political thinking in America after 1776.

"Viewed on the basis of numbers, a truly magnificent job was done. Yet, today, doubts are being raised on many sides about the adequacy of the Jacksonian principle. We are told by the more critical that we have turned out a first-rate group of second-rate capacity. Even the less critical are in general agreement that the Jacksonian principle has failed to give us the leadership that we need if we are to remain a great people. A high average standard of education is not enough. It must be supplemented and supported at the highest level by greater opportunity for the most gifted minds and an adequate response to this opportunity by the possessors of these minds. Only then will the democracy develop and enjoy to the full its greatest asset: the total capacity of its people. We have come to understand, in the words of the Harvard Report on General Education in a Free Society, that democracy is based upon 'the interworking of two complementary forces, the Jeffersonian and the Jacksonian, the one valuing opportunity as the nurse of excellence, the other as the guard of equity.' In line with the criticism of the Jacksonian principle, furthermore, the Harvard report goes on to say that 'much of our future will be written in answer to the question whether Jeffersonianism and Jacksonianism are in fact complementary or whether they struggle against each other.' "

As yet, the doubt raised in the Harvard report has not been resolved. Nevertheless, there is today a great and growing awareness of the compelling necessity of "greater opportunity for the most gifted minds" at all levels of education. That consciousness of our need for more and better education should be greater among the practicing members of the profession than among the teaching members is, however, sad. For we read in the Report of the Task Committee on Professional Education of the A.S.C.E. that only 22 per cent of the heads of civil engineering departments in our engineering schools thought that undergraduate study in their departments should be extended to five years, whereas 66 per cent of the members of A.S.C.E. opted for this increase (6). Unfortunately, this complacency in high places appears to be continuing to this very day. To quote the words of the Task Committee: "With notably few exceptions the general program for engineering education has been limited to four years. During the period of tremendous expansion in the field of higher education, and in the face of the growth in the art and science of all professions, it is significant that the schools of engineering have generally retained the four-year curriculum, while the medical, architectural and legal professions have extended their educational programs."

Shown in Table 2 are the present time requirements in our country

TABLE II.

Present Requirements for Professional Education, U.S.A.

| | Minimum years or equivalent | | | | | | |
|---|---|---|---|---|---|---|---|
| | Medicine | Law | Business | Engineering | | | Planning |
| Preprofessional college education | 3-4 | 4 | 4 | 1 | | | 3-4 |
| Professional education | 4 | 3 | 2 | 3 | | | 2 |
| Post-professional training | 1 | - | - | - | | | - |
| Degree | M.D. | L.L.B. | M.B.A. | S.B. | | | Master |
| Post-graduate study | - | 2+ | 2+ | 1 | 2 | 3 | 2 |
| Degree | - | S.J.D. | D.B.A. | S.M. | E.M. | Ph.D. or D.Eng. | Ph.D. |

for professional education in medicine, law, business, engineering, and planning (city and regional planning being implied). A further study in which the focus is on the two fields of applied science (medicine and engineering) by themselves is presented in Table 3. Once again, the

TABLE III.

A Study in Comparative Professional Education
in Medicine and Engineering

| | Minimum years | | | |
|---|---|---|---|---|
| | Medicine | Medical Sciences | Engineering | Engineering Sciences |
| Preprofessional college education | 3-4 | 4 | 2-4 | 4 |
| Degree | - AB | AB | SB | SB |
| Professional education | 4 | 1 | 3-2 | 1 |
| Professional Degree | M.D. | M.A. | M.Eng. | S.M. |
| | | 3 | 5-4 | 3 |
| | | Ph.D. | D.Eng. | Ph.D. |
| Years to Doctorate | 7-8 | 8 | 7-8 | 7 |

reader should note the differentiation between education in the medical and engineering sciences from education in medicine and engineering. As time moves on, we may expect that some educational institutions will confine their instruction and research to the engineering or medical sciences respectively, whereas others will continue to provide integrated programs of scientific and professional education.

*Towards Educational Responsibility.* That we may not view engineering in an educational vacuum, the place of the technologies in a university is shown in Figs. 5 and 6, Fig. 5 being the equatorial belt of the sphere in Fig. 6. It goes without saying that engineering is one of the suggested technologies. Harold Cassidy, Yale chemist, who has elaborated this symbolic structure of the university describes his globe as follows: (7)

"In all disciplines of the university which have intellectual content there are practiced three kinds of activities: analysis, synthesis, and reduction to practice. *Analysis* is the activity of gathering data, describing things as they are, collecting and recording instances, making lists, and so on. Now an intelligent person cannot go very far in this kind of activity before he begins to see patterns in his data, likenesses in his descriptions, similarities among the separate instances. As this occurs, the essentially analytical activity goes over into a synthetic one. *Synthesis* is the activity of finding connections between the data made available by the analytical activity, making hypotheses and theories, and developing laws. In short, synthetic activity is a generalizing activity. It involves abstraction, for the general statement is at a higher level of abstraction than the many single instances in which it is based. But the hypothesis, theory or law must be reduced to practice. *Reduction to practice* is the activity through which a return is made from the general principle to the single instance. It may be carried out to see if a predicted fit is obtained. It is then the experiment designed to test a theory. It may be the examination of a document to see whether it meets some critical test. It is also the creative activity by which the work of art or science is produced.

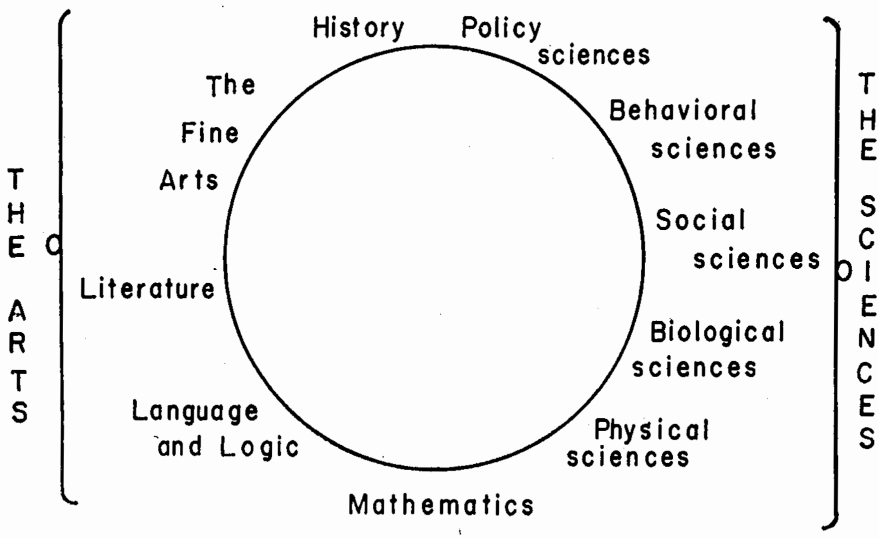



FIGURE 5.—DEFINITION OF THE ARTS (THE HUMANITIES) AND THE SCIENCES. *After H. G. Cassidy.*

"The technologies we define as disciplines wherein reduction to practice is emphasized. But we must insist that, like any other university discipline with intellectual content, the technologies comprise analysis and synthesis, and as a part of the university they comprise the heuristic activity . . . (of) the analysis and generalization at higher levels, of the technology. If pure reduction to practice were involved, we would not have a technology, but a craft. In this definition we do not derogate the craft, but distinguish it clearly from the technology.

"Every discipline in the Arts and Sciences has its conjugate technology. In the sciences these are often called engineering; in the arts they have special names. And it is a characteristic of the technology that it often calls upon many disciplines, which it then fruitfully com-

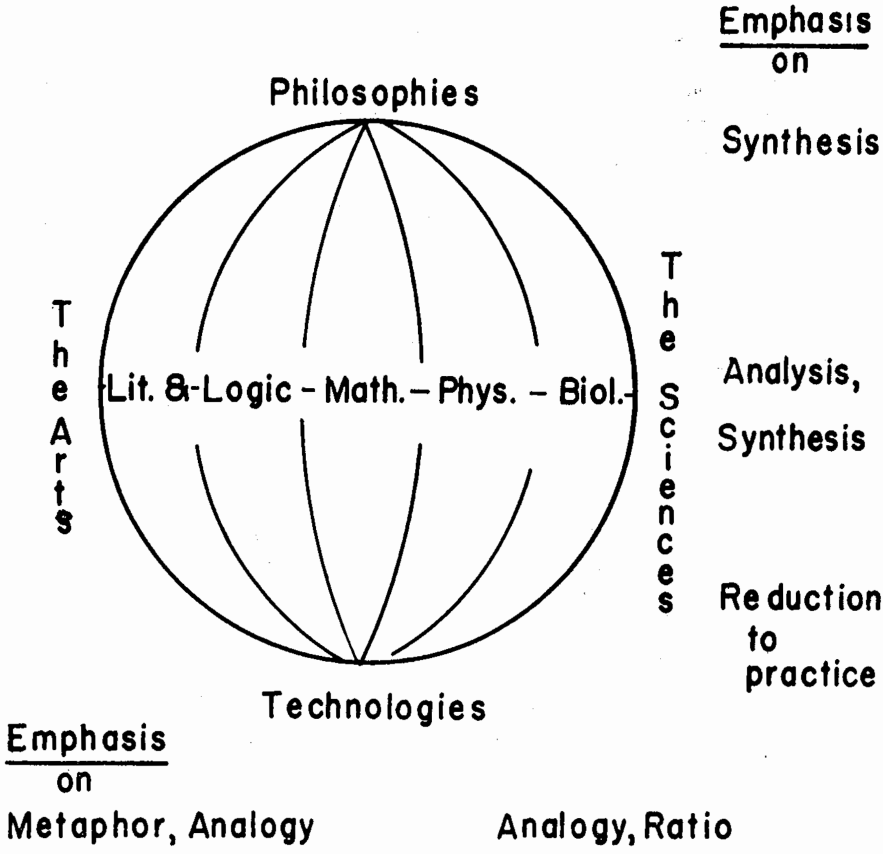



FIGURE 6.—CONCEPTUAL ANALYSIS OF THE STRUCTURE OF THE UNIVERSITY. THE EQUATORIAL BAND OF DISCIPLINES, SHOWN IN PART, IS TAKEN FROM FIGURE 5 AND EXTENDS AROUND THE SPHERE. *After H. G. Cassidy.*

bines. Thus medicine is the technology of a whole constellation of disciplines, ranging from physics and chemistry to literature and drama. Most kinds of engineering include mathematics, physics, and a number of other sciences. Law is the technology of jurisprudence, and calls upon anthropology, psychology, and much more. The technological disciplines of literature and the fine arts—the 'commercial' disciplines—as also drama, call upon many kinds of knowledge and experience."

In their response to the so-called crisis in civil engineering, some of our teachers have concluded that only analysis and synthesis deserve to be included in the engineering curriculum, that there should be no "reduction to practice" and, therefore, I presume, no development of "technologies." Eliminated from engineering curricula, among other material, would be all instruction in engineering design. To be sure, the profession could use a philosopher or two, and engineering scientists should examine this area of uncertainty, but I am convinced that all engineers need the intellectual stimulus and discipline of design. However, instruction in design need not be the routine and unimaginative grind that some of us remember. Since engineering, in my judgment, finds fulfillment in design, I hold that engineering students should not be denied the satisfaction of their creative instincts, sharpening of their imagination, and contact with the imponderables that intrude in all engineering situations. Also, design should be guided by great and active designers. It is these men who should be the professors of engineering practice.

A discussion of program structure and course content I leave to the committees of E.C.P.D.* and A.S.E.E.† It does not lie within the frame of reference of our discussion. Obviously, however, there should be rich sequences of mathematics, physics, chemistry and other sciences—both pure and applied—and equally demanding sequences in structural mechanics and structures; soil mechanics and foundations; fluid mechanics and hydrology and hydraulics. At the professional level, these should be capped by instruction in structural engineering, foundation engineering, and hydraulics (including sanitary) engineering, as well as planning, systems analysis, and other integrating offerings that will provide the public services and goods for both underdeveloped and highly-developed countries. Familiarity with statistical processes, computer techniques, and econometrics as well as comparative government is as essential to the modern engineer as are the languages of mathematics and graphics that he made his own many years ago.

There are other good reasons why I shall not detail course pro-

* Engineers' Council for Professional Development.
† American Society for Engineering Education.

grams. One is contained in Professor George F. Swain's suggestion that when a physician makes a mistake, he buries it; when a lawyer does, he appeals the case; and when an engineer does, he excuses himself by saying that this material was not covered in the course he took in school. A second reason is expressed, more charitably, by Dean Gildersleeve of Barnard College when she says: "That Great American superstition that the only way you can learn anything is having a course in it, has, of course, been a dreadful blight and handicap in our American education." Her statement, incidentally, is reinforced by the judgment of President Lowell of Harvard that "all true education is self-education."

Neither shall I speak of the cultural and socio-economic courses "that every engineer should have." Professor Lewis Jerome Johnson reacted to course prescription that *nolens volens* was to convert its taker into an educated man by saying that "Culture absorbed for culture's sake is self-defeating." Yet I do want to add the opinion of Sir Walter Scott (substituting for the word lawyer used by him the word engineer): "An engineer without history or literature is a mechanic, a mere working mason; if he possesses some knowledge of these, he may venture to call himself an architect." Within my own experience, indeed, I have never met a truly outstanding engineer who had not made of himself a cultured human being, no matter what his origins and his education.

*Towards Research Responsibility.* From what has been said so far, it should be clear that the responsibility of our profession for advancing the frontiers of knowledge is shared jointly by the world of learning and the world of practice. The underlying reasons are especially cogent in an era when what was once a trickle of scientific discovery has swelled into a mighty flood and the pressures for industrial and community growth are forcing a shortening of the time lead between discovery and use. So great has become the impact of an advancing science upon engineering in our time that the interpretation of new developments in science to the using community of government or industry has become a key responsibility of the engineer. This is the meaning of "reduction to practice" and the creation of "new technologies." This is the strongest bulwark of engineering against becoming merely "a craft."

The accelerating pace of technology is depicted in Fig. 7 by Ladis

Kovach after Karl McEachron (8). As suggested there, the basic laws of motor and generator behavior were enunciated by Michael Faraday in 1830, but half a century went by before Thomas A. Edison, in order to build a power station for supplying energy to his newly invented electric light, reduced Faraday's analysis and synthesis to practice.

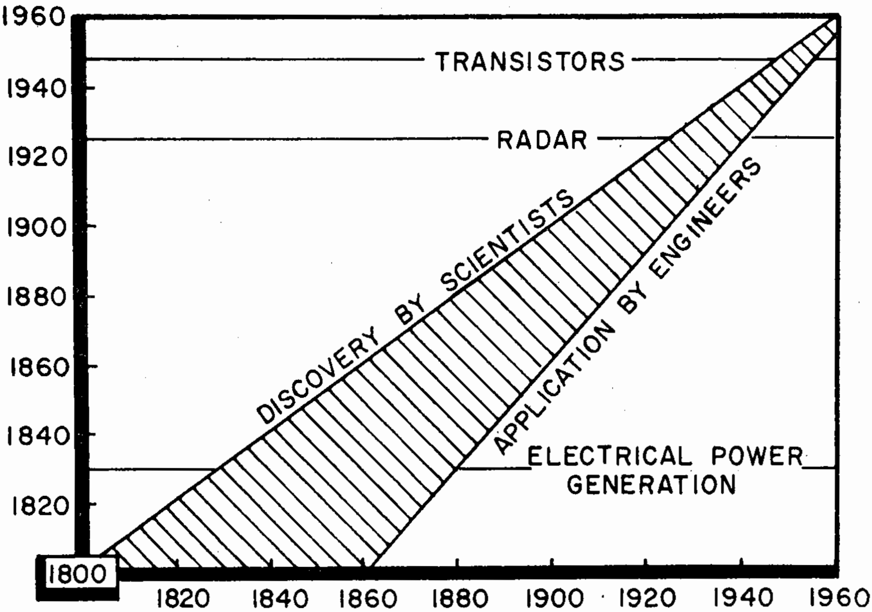



FIGURE 7.—THE CLOSING GAP BETWEEN SCIENTIFIC DISCOVERY AND ENGINEERING APPLICATION. *After K. B. McEachron.*

Radar was discovered in the 1920's. Fifteen years later it was put to use under the pressures of threatening war. Transistors were developed by the Bell Laboratories in 1947. Lead time was here reduced to just a few years. Artificial diamonds, finally, became a commercial product within two years after they had been synthesized by the General Electric Company.

It would hardly be possible to exaggerate the importance of this aspect of engineering research. Nevertheless, a more liberal consideration of the engineer's responsibility must lead to the conclusion that the engineer could build his interpretive function into a Maginot Line of the mind. This he should avoid at all costs. By accepting responsibility for analysis and synthesis as well as for the development of technologies, he will leave his imagination free to reach the frontiers of science as well as those of technology. We should realize in this connection that technology has become part of the armamentarium of the pure scientist and that there is no reason why pure science should not be introduced more effectively and in greater measure, also, into the weapons system of the engineer.

Let me point out in passing Kovach's conclusion that, in contrast to physical science, the lead time of mathematical theories, as shown in Fig. 8, still remains to be foreshortened. Included in Fig. 8 by

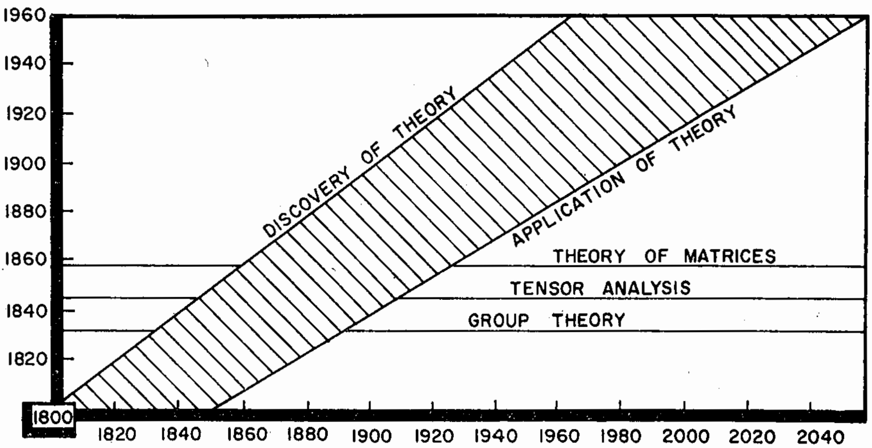



FIGURE 8.—THE WIDENING GAP BETWEEN MATHEMATICAL THEORY AND ITS APPLICATION. *After L. D. Kovach.*

Kovach is the time spread between the development of group theory by Evaniste Galois in 1832 and its application to crystallography simultaneously and independently by Fedorov, Schoenflies, and Barlow in 1890; Grossman's tensor analysis of 1844 which had to wait until 1905 when it was introduced into the Einstein theory of special relativity; and Cayley's theory of matrices of 1858 which finally found use in Heisenberg's quantum mechanics in 1925. This, too, is an area for more intensive exploration by engineers.

Addressing himself to civil engineering research and funds for it, Lee DuBridge, President of California Institute of Technology, has given sound advice as follows: (9)

"It can be stated with some certainty that funds for research will not come in ample amounts unless people are available to do the research and unless they are qualified and anxious to do it and have ideas about what they want to do.

"This suggests that possibly the next research funds you can lay your hands on should go toward the establishment of a couple of hundred predoctoral and postdoctoral fellowships in the leading civil engineering departments in the universities and engineering schools of the country. That would cost between a quarter and a half million dollars a year after the program was well under way. It would be a tremendously profitable investment. That is precisely the way physics research got its start in this country in the days after World War I, with the establishment of the National Research Council fellowships, financed by the Rockefeller Foundation. Civil engineering research is far more advanced now than physics was in 1920, of course. But there are more competitors for the services of young people, too. And bright young potential research people are not choosing civil engineering in large enough numbers. Here is a good place to start putting on the heat."

## The Outlook for Survival

Since, in the engineering world, analysis and synthesis must be followed by reduction to practice, I should, at this point, foretell under what circumstances civil engineering may be expected to survive as a learned discipline. The essential parts of my answer have, however, already been stated in the preceding arguments of this paper. By way of summary, therefore, I have prepared Fig. 9 which, I shall suggest, is a model of the organic unity of civil engineering education and practice. Structurally, this model is symbolized by the human hand. The five fingers point to the five common functions of civil engineers: (1) *teaching and research,* like the thumb apposable to the four fingers —because learning and discovery must touch upon every decision of the profession; (2) consulting practice in *engineering science,* the youngest and as yet not fully acknowledged new dimension of the profession, pointing (as the index finger) to an ever-deepening concern of mathematically and scientifically talented members of our profession with the solution of present and future analytical problems in civil engineering; (3) *independent consulting practice,* the oldest and (like the middle finger) most central responsibility of the profession to be exercised with wisdom founded on experience, judicial restraint nurtured by independence, and broad knowledge stored up through many years of continuing study and response to our calling; (4) *public engineering practice* encircling (as suggested by the ring finger) the public services that measure the social capital of a given country and that demand efficient management and imaginative development; and (5) *supporting private enterprise* in its many forms (and by no means small, although symbolized by the little finger) through which the plans and conceptions of the profession are translated into physical realities.

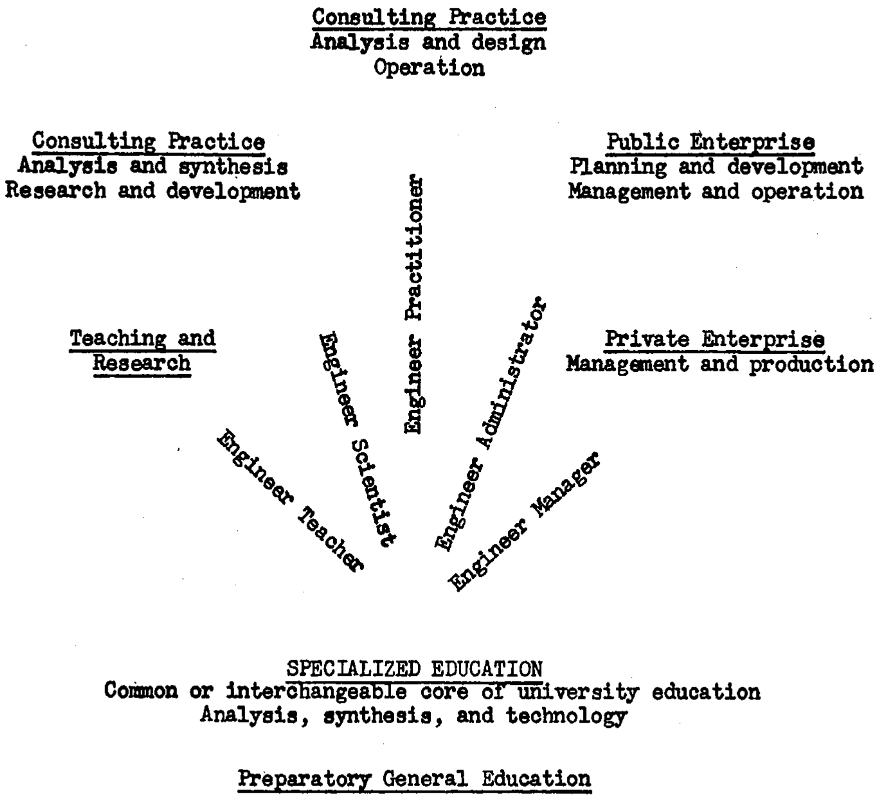



FIGURE 9.—THE ORGANIC UNITY OF CIVIL ENGINEERING AND PRACTICE.

The substance within the palm of the hand is the needed specialized learning, superposed on the common or interchangeable core of university education. Both practical and theoretical considerations lead to the conclusion that this specialized learning and research, too, must issue from the profession as much as from the universities; that the practicing professor must eventually be displaced by the professorial practitioner; and that the cooperative student or, for that matter, the beginner in practice must receive the benefit of supervised, progressive education under a master committed to the advancement of his profession and attached to a professional school as a matter of duty and satisfaction.

Supporting the hand from below in flexible wrist is the preparatory general education within the secondary schools. If it remains inadequate, higher education will continue to carry an unwanted and unnecessary burden of elementary instruction. Of this the universities of older lands have long been relieved.

There are within the life of every profession moments of decision in which the future must be weighed against the past and a new purpose wrought for its practitioners. This is the reason for our present crisis. The fact that it is considered a crisis, I am convinced, offers the best assurance of the survival of civil engineering as a learned profession.

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