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THE ENGINEER AND CIVILIZATION[1]

IF we may accept the estimates of archeologists, it is now some hundred thousand years or more since man began to manifest, in some marked degree, those characteristics which have served as the foundation upon which the superstructure called civilization has been erected.

Throughout this long evolution, three great principles or lines of action have stood out as the determining factors. These are specialization, cooperation and the utilization of the resources of nature. These are, in fact, all interrelated. No one is independent of the other two.

So long as the unit of life is the individual, or at most the family, there can be but small progress toward a state of what we term "civilization." So long as a man or a family must do all the things necessary for his or its life, no one thing can be done with super-skill or super-excellence, and progress must needs be slow. The acquirement of super-skill or of super-excellence means specialization, concentration and the limitation of activity to a relatively narrow line of endeavor. Only by this pathway can progress be made. But if the individual is to limit his own activity to a narrow line of endeavor and give to this field of work his entire time and effort, he will obviously be in no position to provide for himself, at first hand, more than some of the things needful for life, and he must perforce depend on others for those things which he can not supply himself. This means that he must contribute from the results of his own skill to the needs of his neighbors and that he must count on receiving from them, in return, the products of their special skill to supplement his own lack. Thus is born the principle of cooperative effort, and out of this flows, of necessity, the commercial institution of barter and exchange.

THE BEGINNINGS OF MATERIAL CIVILIZATION

If we seek to place a finger upon the very beginnings of what we may term "material civilization," we shall find it at that point where some race or community of men of primordial stamp and character began to realize and enjoy the advantages accruing through the utilization of some combination product of human skill directed upon a raw material of the earth. For, with the growth of such a condition, there would come

[1] Presidential address at the annual meeting, New York, November 30 to December 4, 1925, of the American Society of Mechanical Engineers.

a premium on human skill, and thence an inducement for specialization and concentration on some particular line of human endeavor. And with this must come the whole train of specialized human effort, cooperation and mutual dependence as foundation blocks for the building up of a civilization.

Again, if we seek to place a finger upon the time, place and circumstance when, where and how such a condition first came into evidence as a guiding factor in human evolution, we shall apparently find at least one such point in central and southern Europe during the old stone age, and in connection with the utilization of flint arrow and spear heads for the chase, and of other crude stone implements for the simple and homely arts of that far-away time. Man had placed his foot on one of the first rungs of the ladder of progress toward civilization when he found a way of adapting the crude stone fragments lying about him to the needs of life. Definite and material advantages accrued as a result of the use of such implements fashioned from these resources of nature—certainly among the first of such resources to be utilized for other than direct food purposes.

To take, for a moment, a more narrow view in point of time, consider the culmination of this age in the so-called Solutrian phase of culture, and located, in time, perhaps twenty-five thousand years ago.

In that age there might have been seen, about the wonderful limestone caves of southern France, communities of the people of the age, living in or about the cave and practicing the arts of the time. The food supply came primarily from the chase and the flint arrow head and spear head played here a most important part. In this age the art of fashioning flint arrow and spear heads seems to have reached its culmination. In no age before or since have there been produced their equals in beauty and perfection of form, proportion and finish.

Now there seems to be good evidence that the peculiar skill which was required to shape these beautiful examples of chipped-stone art was by no means the common property of all the men of a community. Rather was it, presumably, the property of a limited few, or perhaps of one, who would thus, by force of circumstance, become the arrow- and spear-head maker for the community. Here then perhaps may we discern the very *first* example, in the development of our civilization, of a clearly defined specialization or differentiation of function in a community of human beings. And with such specialization there must come cooperative relations, barter and exchange, and thus the foundation for a modern state of society.

Is it too forced a use of language to call this ancient arrow-head maker an industrialist, perhaps an inventor, and an engineer?

It is of the essence of the work of the industrialist that he shall organize, plan and carry forward undertakings calculated to provide, often in quantity and through repetition processes, the material things of which civilization has need.

It is of the essence of the work of the inventor that he is able to recognize some need in the arts of civilization and to find a way to supply such lack.

It is of the essence of the work of the engineer that he deals in a large way with the constructive materials of the earth and with the energies of nature—all to the end of useful service in the arts of civilization.

The Arrow-Head Maker the Prototype of the Industrialist and Engineer

Surely we can discern in the work of this ancient arrow-head maker and in his relation to the community life of that day the clear beginnings of those functions which, in more recent times, we designate as those of the industrialist, the inventor and the engineer. Indeed, the distinction between these terms is often arbitrary and the same individual may be, and often is, any one, two or all three of these at one and the same time. If, then, we may designate, in a large way, this field as that of the engineer, we may fairly say that far back in those prehistoric times, easily twenty thousand to thirty thousand years before we have even the beginnings of recorded history, we may clearly discern the germ and the essence of the exercise of that function in society which we, as engineers of a later day, consider our own peculiar responsibility.

But the arrow-head maker of the old stone age by no means stands alone as a prototype of the modern engineer. There is his fellow, perhaps of a somewhat later time, who invented the art of weaving, especially as expressed in crude basketry, and thus gave to man, perhaps, his first container or carrier. And again, not long subsequent, that ceramic engineer who discerned, perhaps first through the burning of a clay-lined wickerwork basket, the influence of fire upon clay, and thus laid the foundation of the great modern ceramic industries which have come to mean so much in our own day, and the development of which can be so clearly traced down through the ages. And again, what of that engineer scientist-inventor of twenty thousand years ago, perhaps, who gave to the world of that day the bow and arrow with its wonderfully effective utilization of the laws of mechanics regarding the transformations of energy? We may, in fact, see in play here the entire sequence of invention and engineering science.

Primitive Utilization of Mechanical Laws

All invention must start with the recognition of a

lack or need, and following this there must be some mental vision of a manner in which this lack or need may be supplied. The invention must be subjective before it can become objective. There must be in the mind of the inventor some mental picture of the means whereby the lack may be filled before it can become clothed in material form. And so some one, in some way, in those remote times caught some realization of a need or insufficiency in the weapons used in the chase, and following upon such recognition he must have gained some mental picture of a way in which the need could be met and the insufficiency supplied. And so was produced the combination of bow and arrow, with its wonderfully effective means for receiving the organic energy of the bowman as he pulls the arrow and flexes the bow, and for storing it in potential form, expressed as the potential energy of a distorted elastic system. And then, at the instant of his choice, with the arrow released by the fingers, this stored energy becomes transformed into kinetic energy expressed in the flight of the arrow toward its mark. Truly a wonderful series of energy transformations, and realized with marvelous efficiency and perfect adaptation to purpose!

THE GREAT ANTIQUITY OF THE ENGINEERING PROFESSION

Do we, as engineers of the present day, stop to remember that whenever, in our modern mechanism, we utilize a spring, no matter of what form or character, we are simply following along the path marked out by this great inventor-engineer of the long ago? Do we not, as did he, simply use the distortion of an elastic system and its release as a means for storing and transforming energy? And again, in this same category of scientist-engineer, there is the inventor of the sling. This ancient military engineer or huntsman found a way of utilizing the kinetic energy of a rapidly rotating material system. We do the same with the flywheel and, so far as basic principle is concerned, we are simply again following along the pathway first worked out by this engineer-inventor of a vanished race and of a departed age.

And again, have there not been naval architects and shipbuilders since the days of the long dugout?—a period of not less than fifteen thousand years; have there not been bridge builders since our ancient forebears—no one can guess how many ages ago—first learned to throw a log across a stream, or to stretch, suspension-wise, cables made of twisted vines or other like material?

And have there not been metallurgists and metallurgical engineers since the days of Tubal Cain who, as we are told in Genesis, was "an instructor of every artificer in brass and iron"? And have there not been great structural engineers and builders who for six thousand years past at least have been enriching the earth with the products of their genius and skill—as witness the wonders of Nineveh, Babylon, Egypt, Greece and Rome, or again the records of the Maya and earlier civilizations on our own continent?

And so, as we follow the sequence of the utilization of the constructive materials of Nature and of her energies down through the ages—from the products of early paleolithic or rough chipped-stone culture to later paleolithic, and then to neolithic or polished stone, horn and bone, and then on to bronze and so finally to iron and steel and thence into the more complex conditions of modern times—we see continuously and clearly the accumulating results of specialization, of cooperative human labor and of the inheritance, by each successive generation, of the accumulated culture of those which have preceded it.

If I have taken this length of time to examine the early beginnings of the art and practice of engineering, it has been to draw attention to the great antiquity of our profession and to justify, in some degree, the claim, which we may make, of belonging to the first group or guild of society which became distinguished in relation to the community at large by reason of some peculiar or special function or service rendered.

We sometimes consider that engineering and the engineer, in the distinctively modern sense of the terms, do not antedate the invention of the steam engine and the beginning of the utilization of the inorganic energies of nature—those developments which have so revolutionized the material content of our civilization during the past two hundred years. The distinction, however, is superficial rather than fundamental; the informing spirit and purpose are the same. The difference results primarily from the enormously increased magnitude and diversity of the material content of our present-day civilization, arising from the utilization of the inorganic energies of nature in lieu of the organic energies of man or domestic animals. It has resulted, naturally, that the engineer of to-day must be a man of far different training and type of activity than his brother of three hundred or five hundred or one thousand or ten thousand years ago. But the point which I make is simply that, in spirit, in purpose and in relation to the civilization of the age, the art and practice of the engineer of the present day have their roots far back before the dawn of written history—back in those first movements in human society which gave

evidence of the working of some leaven of evolution, and which in one hundred thousand years or more have led us from the condition of our paleolithic ancestors up and into the condition and circumstance which we now enjoy.

MODERN MATERIAL CIVILIZATION A PRODUCT OF THE ENGINEERING GUILD

And so, in these latter days, we have come into a state of civilization, so-called, of which the objective content, with its richness and complexity, is the product of this guild of those who work with the materials of the earth and with the energies of nature. But so commonplace has all this become that the world accepts us and we accept ourselves as part of the scheme of things with little thought of the extent to which this work of the engineer, in the broadest sense of the term, permeates our entire community life.

Suppose we take so humble an object as the slice of toast which appears on our breakfast table. Do we stop to consider the extent to which engineering and the engineer have entered into the vast cooperative enterprise necessary to the production of so commonplace a result? Thus we find that the soil on which was grown the wheat was turned up by a gang plow drawn by a tractor. The grain was sown, harvested, winnowed and bagged by machinery driven by power. The bags of grain were transported to a rail shipping point by motor truck and thence by rail to a wheat center. The entire program of milling, transport of flour to bakery, mixing, kneading, baking and delivery at the kitchen door is again realized through the use of power and energy. And finally, its preparation on the electric toaster is an expression of the utilization of power in its very latest and most versatile form.

And again, what of the design and construction of all these mechanisms and agencies—the plow, the reaper, the motor truck, the locomotive and the freight car; the rails on which they run, the bridges, trestles and tunnels over and through which they pass; the flouring mill, the bakery equipment, the auto-delivery wagon, and finally, the long line of electric machinery, apparatus and equipment which takes mechanical energy at a far-distant point, transmutes it into the electrical form and brings it over mountain and valley and across plain to our door, and so to the electric toaster on the breakfast table; there again to be transformed into heat and applied to the bread to render it the more toothsome? And as we thus eat our toast while reading the morning paper, what thought do we give to the manifold energy transformations, the hundreds of mechanisms, devices and appliances and the thousands of individuals whose joint labor and service have made this simple act on our part possible?

Or again, consider the newspaper itself. The happenings of the entire world are brought by telegraph, telephone, radio or mail service, assembled within one room, there by typewriter transformed into copy, thence, by the aid of wonderful type-forming machines and technical processes, expressed in the form of records on cylindrical metal shells, and thence, through one of the marvels of modern inventions the printing press, transformed into the printed page, moved by auto truck, railway train and otherwise, and finally laid on our doorstep ready for consumption with the toast. All these complex operations and processes, as well as the mechanisms and agencies through which they are realized, are again only an outward expression of a combination of the materials of the earth; the energies of nature and the directive agency of man, and therefore fall within the direct and peculiar field of the engineer.

And as with these familiar examples, so with the entire *material* content of our civilization. The food we eat, the houses in which we dwell, the clothes we wear, the facilities we enjoy by way of travel on land, over water or through the air, of trade and commerce with the farthest ends of the earth, of communication with our fellow by written word, telegraph, telephone or radio, the *material* facilities and means through which we maintain an ordered state of society through government and judicial procedure, the *material* means whereby we transmit the culture of our own age to our children through education, and indeed the *material* background of the organization of our society which makes it possible for select spirits to find time for reflection, for study, for things of the mind and of the spirit rather than things of the body—turn which way we may in the tangled maze of our modern life, and we find on every hand dependence, in some degree at least, on that combination of constructive materials, energies of nature and the directive agency of man which constitutes the especial field of activity and service of the engineer.

This enunciation of the place of the engineer in the progress of civilization is uttered in no boastful spirit and with no purpose of exalting his services over those of his brothers in arms. The carrying on of our present-day civilization calls for the exercise of a vast number of diverse though interdependent functions. There is no need of an attempt at enumeration. All are necessary, and no one is independent of the others. Rather all are dependent on each and each is dependent on all. If the tiller of the soil, the herdsman, the merchant, the banker, the doctor, the lawyer,

are all dependent on the engineer, so is he in turn dependent on them. Life is like some intricately woven web of chain mail wherein each link is necessary to and in turn dependent upon all the others. Truly, the ideal of our civilization is that one shall labor for all and all for one.

And so, in the endeavor to mark out the place of the engineer in our modern civilization the purpose has been not to exalt but rather to bring into emphasis the opportunity for service as the measure of the responsibility which attaches to us, both in our individual and collective capacities.

If we, as a guild, stand as the repository of the results of the work of our fellows in bygone ages, even from prehistoric days down to the present time, and as trustees for its useful application to the requirements of our own times, then must we, as a guild, recognize our responsibilities to worthily carry on with this great accumulation which has been placed in our hands. It is only the simple truth to say that the trend of civilization in coming ages—especially as to its material content—will depend in fundamental degree upon the manner in which we discharge our obligations during the short day in which this responsibility and opportunity are placed in our hands. We pass this way but once; the opportunity will not come again. Future ages and future generations are awaiting the enjoyment of a *material* civilization, the character of which is, in some measure at least, in our hands to determine, here and to-day.

How the Engineer may best serve the Cause of Advancing Civilization

If, now, we turn to more practical aspects of the matter and ask how we may so act as to properly discharge these duties and responsibilities, we come fairly face to face with the simple query: What is the duty of the engineer of to-day, and how may he best serve the cause of advancing civilization?

The discharge of a duty is, in large degree, a personal matter; we can not easily lay down directions for the individual, but, in the aggregate, we can perhaps safely venture to indicate what seems to be the line of obligation.

In the first place, it is perfectly clear that each individual owes it as a duty to himself, to his guild and to the world at large that he cultivate to the highest practicable degree the faculties and gifts of which by heredity and environment he has become the living expression.

This is simply an application of the parable of the talents and there is no reason for argument or discussion. Its application and the resultant obligation upon the individual are self-evident.

But individual bricks do not make a building, nor isolated human units a society. If there is any one lesson to be drawn from a study of the evolution of our civilization, it is that of the significance of cooperation. This is the mortar which serves to bind together the individual units and make of them a coherent, enduring and purposeful structure.

And so, binding together the individual units of our society, there must be the spirit of cooperation; and if this is true for society at large, it is doubly so for those of the guild of the engineer. No one is better qualified to realize the basic law of mechanics that mass effect can be realized only by mass action. The time has gone by when man might be measurably sufficient unto himself. This is the age of great undertakings, and these can be realized only through joint and cooperative effort.

The Part Engineering Societies have played in the Developments signalizing the Last Half-Century

And so, in order to further such ends we as engineers have organized ourselves into groups with closely allied interests and purposes, and have thus formed the great engineering societies of the present day.

If we form, as best we may, in mental vision some composite picture of these great organizations the world over, we shall obtain a most impressive realization of the application of this principle of cooperation and mutual helpfulness. And no one who will study this picture will fail to realize the significant part which these societies have played in the great engineering developments which have signalized the last half-century. It is not perhaps too much to say that the organization of these societies, furnishing as they have great centers around which engineering activities have crystallized, has constituted the most important single element in making possible these latter-day achievements in engineering; and that during this time they have played a vitally essential part in this march along the lines of material progress.

And here again, what has been said with regard to the development of the individual will furnish a sure guide when applied to these great organizations as groups of individuals.

The engineering societies, collectively and individually, will best serve the public welfare and best contribute to the progress of civilization by developing, each in its own sphere, to the highest possible degree. The picture of one great engineering society, embracing all who may call themselves engineers and covering the whole field of engineering activity and service, is indeed a beautiful ideal. It seems hardly practicable, however, having in view the great diversity of interest and character of work, and the limitations of the individual regarding the extent of the field which

he himself can cover. Were indeed any such society organized, it would inevitably divide up into subgroups, divisions, sections, and what not, each one corresponding to some one measurably narrow field of interest and activity, even as we note similar centrifugal tendencies in the older and more widely comprehensive societies of the present day. And so we may conclude that intensive development, each within its own boundaries, and assiduous cultivation, each of its own field of activity, will best contribute to swell the grand total of service which the world expects of these great organizations and which they are under obligation to render.

But the parallel between the individual and the society must not stop here. If cooperation is necessary between and among individuals in order to achieve larger ends, so also is it necessary between and among societies in order that *they* may achieve the larger ends which the progress of civilization demands. There are many problems of wide sweep for the solution of which the world is looking to the engineer—or to the engineer in alliance with his brother the scientist—and which touch simultaneously the fields of activity of several of our modern engineering societies. These can not be adequately and properly studied by any one body or group alone. All the mental acumen which can be brought to bear upon these problems will be none too much to light up the pathway toward some solution. Again the lines of demarcation between the fields of activity of our several societies are often vague, and many fields of activity may fairly enough be claimed by more than one of them. All this is of course well known, and is a natural result of the marvelous growth in the activity of the engineer during the past half century and the vast extension in the scope of his work. This situation, however, should lead only to the exhibition of a spirit of kindly cooperation and friendly emulation, motivated throughout by a readiness to unite whole-heartedly in joint undertakings, whenever or wherever such procedure may indicate a more useful result than through individual society effort.

Some Questions for Engineers in their Individual and Collective Capacities

Let us attempt to gather up in a single sweep of vision some concept of the great guild of the engineer with its historic background, tracing far away to the very first impulses toward civilization and with its unique and important place in the fabric of our present-day life; and with this concept in mental vision, will it be amiss if we ask ourselves a few questions?

Do we, either as individuals or as societies, often enough seek out the mountain tops and endeavor, from such vantage point of view, to place ourselves in relation to the great problems and movements of the day and to properly orient our own purposes and aims in relation thereto?

Are we, both as individuals and as societies, too prone to the microscopic view rather than the telescopic?

Are we so occupied with the immediate task, with that which is set before us as the day's work, that we are in danger of failing to appreciate the articulation of our own task with that of our fellow, or to give thought as to how his task and ours may best fit into the great problems which the progress of our civilization presents?

Have we, either as individuals or as societies, sufficiently well-defined goals or purposes in our professional life? Have we definite aims professionally toward which we are working with a conscious purpose, or are we following too much the opportunist policy of dealing as best we may with individual problems as they arise and of doing the day's work as it comes along?

Again, are we, either as individuals or as societies, sufficiently alive to the opportunity and duty of taking constructive and helpful part in the larger life movements about us? Do we sufficiently realize the obligation which lies upon us of contributing, as opportunity may offer, helpfully to the solution of great problems which may seem to lie aside from the normal field of our professional life?

Do we, in short, sufficiently realize the obligation of good citizenship along and paralled with the day's work in our chosen field of activity?

Are we, in brief, both as individuals and as societies, striving to definitely direct our course over the sea of life with a firm hand at the helm, with definite objectives in view, with a long look ahead, with a generous recognition of our duty to the generations coming after, and with an appreciation of the larger duties of life as members of a great social organism? Or, are we looking only at our immediate environment with its professional problems, and allowing ourselves, with reference to the larger aspects of life, to drift, subject to currents and tides of which we take little or no heed?

These are indeed searching questions. You of the profession are as well able to answer them as am I. But it will perhaps be safe to assume that neither as individuals nor as societies is our score in these respects what it should be.

If then we imagine ourselves upon the mountain top, may we spend a few moments in looking a little more closely at some few of the things which we might thus discern, and, seeing, ask ourselves whether

or not we are living up to the full measure of our obligations thereto.

THE DUTY OF THE ENGINEER AS REGARDS CONSERVATION OF NATURAL RESOURCES

Among the many which might thus challenge our attention, none is perhaps of greater importance than that aspect of the duty of the engineer which centers around the general term "conservation of natural resources."

We have already noted the peculiar position in which the engineer stands relative to the constructive materials of the earth and to the inorganic energies of nature. He is their custodian, and charged with the duty and has assumed the responsibility of their development and use to meet the requirements of human progress.

Now the facts are, as engineers well know, that the supplies under these categories are far from unlimited in extent. We know of this fact of limitation and that in some instances it is defined with relative sharpness. Furthermore, we have no assurance of the operation of natural agencies tending toward replacement, at least in any degree commensurate with the rate at which we are carrying on with their exploitation and exhaustion. Future generations may perhaps grow beyond the need of some of the things which we now find necessary. Substitutes may be found in some cases. But we can not be sure of this and in the absence of such assurance it does devolve upon the engineer as a most weighty obligation that he give heed to the means which he employs in the exploitation of these natural resources, and that every possible effort be made to avoid waste and to use them with the highest attainable degree of economy and efficiency. Avoidable waste is a direct theft from generations to be. With the lack of care which has characterized much of the exploitation of the resources of nature, especially during the last half century, have we not wasted, in some measure, the patrimony of our children and grandchildren? Imagine that in some way the progress of civilization had been hastened and that the exploitation of the resources of nature had begun on a grand scale with the Romans, two thousand years ago; and suppose that they and their descendants had carried on, as have we during the last fifty or one hundred years; in what condition should we be to-day? We are not to infer that the sole responsibility in these matters lies with the engineer—he may fairly share it with society as a whole; but after all, his is perhaps the major share because no one is so well qualified as he to see the consequences of the reckless exploitation of nature, and upon no one does the duty lie so clearly to lift up his voice in protest and to direct his professional energies and skill along lines looking toward the reduction of waste and inefficiency to the lowest minimum.

To this latter duty he has, in fact, responded, and in many cases with most gratifying results. But the end is not yet and only by untiring, wholehearted, continuing effort along such lines can the engineer in anticipation look fearlessly in the eye his brothers of the next generation or the next century, and await their estimate of the manner in which he has discharged the duties of his own day and generation.

Again, if from our fancied mountain top we look in another direction, we shall see ourselves as legatees of a hundred thousand years and more of a gradually growing accumulation. Each age and generation has added some quotum to this vast accumulation of which we are the trustees and executives. Can we either as individuals or societies take a just sense of pride in what we are accomplishing from year to year in this respect? And coming closer home, are we as a society discharging our whole duty in the matter of research and its support? With our numbers and our resources, should we not take a more aggressive stand in this matter and devote, year by year, a larger share of our energies and of our resources to the support of research along lines which lie within the field which we consider peculiarly our own?

THE RENEWAL OF PERSONNEL IN THE ENGINEERING PROFESSION THROUGH TECHNICAL EDUCATION

But let us turn again and note another aspect of our place in the present fabric of civilization. Our guild is like a great army, constantly in need of new recruits in the ranks of the younger strata as its numbers become depleted by age and casualty in those of the older. This is, in short, the great problem of the renewal of personnel and translates itself into the problem of education for those who are planning to enter our ranks.

It will probably not be claimed that either as individuals or as societies have we in general shown the degree of interest in this subject of engineering education which its importance requires. The technical schools and colleges are intended to furnish opportunity for the effective training of those of our youth who are to furnish at least a very considerable quota of the new recruits in our ranks. Other things equal, we are more likely to find the leaders of future years among those who have been so trained. Of what vital importance it is, then, that we should cooperate with those whose duty it is to direct these great educational activities, to the end, on the one

hand, that their measures may be taken with full knowledge of the ever-changing requirements on the firing line of the profession, and on the other, that those who are to receive these new recruits and direct them into the active work of their calling may do so with a sympathetic knowledge of the scope, character and necessary limitations of training which can be given in the course of a technical curriculum.

As one with some years of experience as a teacher, I am only too ready to admit the inadequacy, in some respects, of the training which our engineering and technical schools are now giving, and due in large degree, I believe, to the lack of sufficient contact between the schools and the fields of activity in which their output, as an educational product, is expected to take its place. On the other hand, I believe that some, at least, of the criticism which has been directed toward the product of our technical schools and colleges has arisen as a result of asking or expecting the wrong things of the neophyte—as a result of a lack of understanding or appreciation of the limitations with which the new recruit must approach his job. These conditions can certainly be vastly ameliorated by a better understanding on both sides. The schools and colleges are certainly desirous of such a better understanding and to us, as societies, the duty now comes, with a significance and an importance which it would be hard to exaggerate, to arouse ourselves to a more active interest in this subject of the training of the recruits for our guild, and to insure that, as far as may be humanly possible, this training shall be such as to best give a well-rounded development of the mental faculties, stimulate genius—if there be such a spark—and withal awaken and foster those characteristics which will make for accurate thinking, independence, originality, devotion to truth, leadership and high character.

As we know, a splendid beginning has been made toward this closer approximation of the educator and the requirements of the field of active practice, by way of the survey which is now being carried on through the agency of the Society for the Promotion of Engineering Education.

This is a subject of vital importance to the future of our engineering societies and to the whole future trend of progress along engineering lines. It should receive unqualified and wholehearted support from these societies, and nothing less will clear us of the obligation which we are under to prepare, as best we may, for the next generation of leadership in our guild.

THE ENGINEERING METHOD AND ITS APPLICATION TO PUBLIC QUESTIONS

The duties and obligations to which I have directed your attention thus far have lain in close relationship to our work as engineers. But there are wider duties and obligations. We are engineers and as such hold a position of peculiar trust and responsibility in connection with the progress of civilization. But we can not live unto our guild alone. We are citizens of a complex civilization and touch on every hand problems of life and destiny in which we must take some part.

In a sense, life is a complex of problems. The interrogation point presents itself to us on every hand and in regard to every relation in life.

But the solving of problems in his own field is, in a peculiar sense, the meat and drink of the engineer. His professional work is, in very large part, concerned with just this form of activity, and he has developed and used, consciously or unconsciously, a form of grand strategy which he has found absolutely essential for the effective study of these situations in life.

Thus he knows that a problem presents in general a complex of factors, and that as the first step such factors must be recognized and listed; and furthermore that such a census must be exhaustive—that no factor must be omitted. Again, he knows that such factors must be evaluated in one form or another, that their interactions must be studied—all with a view to their relations to the particular character of the conclusion which it is desired to draw.

And then with all this material in hand it must be subjected to some logical process—formal or informal—and a conclusion drawn. Often, in fact as a rule, the material resulting from the census and evaluation of factors is of necessity incomplete. In many cases the logical process must be informal rather than formal. In all such cases judgment must supply the missing elements if a solution is to be reached. However, no one knows better than the engineer the need of discrimination between the sure ground of known data and formal logic, on the one hand—as exemplified, say, by mathematical operations—and acts of judgment on the other; and no one has learned through wider experience than the engineer the need of applying his conclusions in the light of that component part which, of necessity, has been dependent on estimate and judgment.

But if such, in broad outline, are the characteristics of the grand strategy which the engineer is accustomed to apply in a study of problems in his own field, how or where could we find a better mode of approach for the study of all problems in life, whether of economics, diplomacy, international affairs, problems of the nation, of the state, of the municipality, of the school district, of trade and commerce, of finance, of education—in a word, of all relations in

life which go to make up the complex of our modern civilization?

This does not mean of course that the engineer as such can pose as an expert in the study of problems in these varied fields remote from his own normal activity. It does mean that his own general grand strategy is equally applicable in such fields as in his own, and therefore to that extent is he qualified to serve effectively with others who may be able to supply the more narrowly technical details, in the study of a wide variety of problems in life and lying outside his own special field. It means, in particular, when such problems involve questions of engineering or when they have an engineering background, as is so frequently the case, that he is especially well qualified to take an important and helpful part in the broad and thorough study of such matters, and that in general, aside from narrow technicalities, he may helpfully join with his fellows from various walks of life in the effective study of a wide and important range of problems which lie outside the immediate limits of his own chosen field.

It is, in fact, perhaps not too much to say that as the engineering method, if we may so term it, is the more applied in our study of public questions, and broadly in that of the problems of life generally, so shall we be able to reach more sure and safe conclusions, and so will the engineer the more fully realize the degree of service which he may render to the cause of human progress.

CONCLUSION

To sum up the whole matter, the engineer, either as an individual or as a collective type, is simply a link in the chain of human progress—a chain the links of which, in one form or another, run back into a past removed from our own time by tens of thousands of years, to go to no higher figures. With the trend of human progress as it now is, he seems, moreover, to be a very necessary link. He has taken upon himself the peculiar function of developing and translating into use for the needs of civilization the constructive materials of the earth and the inorganic energies of nature, and in connection with the exercise of such function he has acquired peculiar and weighty duties and responsibilities.

There are naturally the duties of self-development and improvement, both individually and collectively, as organizations such as our own. This is the duty so well inculcated by the scriptural parable of the talents. Likewise there are the duties of friendship and of cooperation for the realization of larger ends, and again, both individually and collectively as organizations.

And then it is peculiarly the duty of the engineer to see that, so far as in him may lie, these stores of nature, of which he is the custodian, are used frugally, with due regard to their limited supply, and having in mind the needs of future generations. Again, it is his duty to leave behind him some definite increment to that great store of knowledge through which we are able to enter into partnership with nature, and only by means of which we may hope to more effectively align ourselves with her laws and thus maintain an ever-ascending gradient of human progress.

Again we must individually as we may, and collectively with definite purpose, endeavor to cooperate helpfully with agencies charged with the training of recruits for our ranks, to the end that there may be a continued and adequate supply to the younger strata in our guild, whence we may hopefully look for leadership and guidance in the future.

And finally, since in the exercise of his functions as an engineer he must of necessity develop and employ habits of mind and methods of study which may be usefully employed in dealing with problems as they arise in all activities in life, therefore should the engineer stand ready to serve, not only in his chosen sphere, but wherever and whenever his habit of mind, his training and his experience may enable him to contribute a helpful element in this great cooperative enterprise which we call civilization.

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BIOLOGICAL ABSTRACTS

BECAUSE of numerous inquiries concerning the status of plans for *Biological Abstracts*, the following brief statement is presented:

Historical.—It will be recalled that in 1923 the joint publications committee of the Union of American Biological Societies, the division of biology and agriculture of the National Research Council and the American Association for the Advancement of Science made a report[1] on the general status of literature aids in biology and tentatively outlined a project for the establishment of an inclusive abstracting and indexing service for the entire field of theoretical and applied biology. The secretary of the union submitted this report to members of the larger research biological societies with a request that the individual biologists examine the proposal and express themselves frankly concerning it. The joint publications committee has reported[2] on the 4,500 replies received in this "referendum," about 85 per cent. of which favored the project and 65 per cent. expressed tenta-

[1] SCIENCE, September 28, 1923, pp. 236–239.

[2] SCIENCE, November 28, 1924, pp. 485–489.