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Milo S. Ketchum

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ENGINEERING AS A PROFESSION

By Milo S. Ketchum

ENGINEERING

LIVRE DE LYON
Lyon 2020

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INTRODUCTION

With the advance in science and in the arts our life and the things we do are becoming more and more complex. With the changes that will occur after the close of the war the demands will be much greater and new opportunities will open. To be able to meet the competition in business and industrial life, the young man of the future will need a much better preparation than can be obtained by a high-school course.

In a recent article in the Independent, Judge Elbert H. Gary, Chairman of the United States Steel Corporation, makes the following comment on the value of the work of high grade technical and engineering schools:

"Their graduates have a highly specialized knowledge that is immediately saleable, and if a young man can by any means obtain such a technical education I should say that he would be well-advised to do so. In fact, I believe that this kind of specialized training will in increasing measure become the quickest road to success

in practical business of the future."

The papers in this collection were first published in the Colorado Engineers' Magazine, the quarterly publication of the engineering students of the University of Colorado. The aim in writing these articles was to give high-school students and college students an appreciation of the advantages to be gained from a college training, and to impress them with their responsibilities in life. The papers were written at different times and there is therefore some duplication of ideas. That the reading of these articles may give young men the courage to get an adequate preparation for life is the hope of the author.

WHY GO TO COLLEGE?*

Last year nearly 400,000 young men and young women were in attendance at institutions of higher learning in North America. Many of these students found it possible to go to college only by the sacrifice of their parents and by the strictest economy. Several years ago a wealthy business man published several pamphlets in which he criticized the colleges very severely and endeavored to show that it was a waste of time for any young man to go to college. It is said that Horace Greeley had a sign in his office which read: "No College Graduates or other horned cattle need apply."

If a millionaire business man and one of our greatest editors had no use for a college graduate it is certainly proper for you to ask the question, "Why Go To College?"

Before considering the advantages of a college education it will be well to consider very briefly the progress of civilization during the last few decades. Before the days of electricity, of modern methods of transportation and production, of the telephone and the telegraph and the application of scientific achievement, the opportunities of any one man lay in a very narrow field, and it was possible for him to enter business or a profession and reach a position of prominence with a limited educational equipment. In those days the curricula of Harvard and Yale were more limited and very much less efficient than the present curricula of our best high schools. With the exception of the three learned professions of Law, Ministry, and Medicine there were very few college trained men. In addition there were no large cities and conditions of life were relatively simple. Today we find the conditions of business and social life very complex. The advance in educational standards and ideals has been fully as rapid as the advance in material things. In addition to

* Extracts from a Chapel Address.

the classical college we now have technical and professional schools giving training for the professions, and universities in which students may obtain both liberal and vocational training. Today the college graduate is found occupying positions of leadership in all lines of activity. Not only are college graduates found in the President's chair, in the cabinet and in Congress, but they are occupying positions as presidents and managers of railroads, editors of magazines, presidents and managers of great business and manufacturing concerns. While there is still more or less criticism of the recent college graduate, his position has materially changed in the last few years, and in place of the sign of Horace Greeley, "No College Graduates or other horned cattle need apply," in many lines of work no one not a college graduate is even given an opportunity to show his worth. As an example of the attitude of a great corporation it may be interesting to know that the Pennsylvania Railroad will no longer take into its employ in line for promotion anyone who is not a college or technical graduate. The same thing is true of most of the large industrial and manufacturing concerns.

With the changes in business and in the industries have come many changes in government until special training is as necessary to hold a government position as it is to hold a position with a private concern. Our larger cities now furnish the people with water, with light, with transportation, with sanitary surroundings in addition to the police protection which was formerly sufficient. To govern a city now requires a highly specialized training in law, in business and in engineering. Corporations have grown to be so rich and powerful that they must come under government control. The national government has recently undertaken the task of making a physical valuation of all the railroads in the United States. This work will require the services of several thousand trained engineers for many years.

One reason for going to college then is that the training that you get in college will give you a chance to take part in the world's work as a leader. It also increases your opportunities for service and for personal pleasure and profit. In addition to the mental training and discipline that will prepare the college graduate to live with the world, he should also learn to live with himself. He should get a taste for good literature, he

should lay the foundation of life-long friendships and should get that breadth of view and finesse of intellect that distinguishes the cultured man. "A graduate who studies to be a specialist in any line needs also the education which will give him depth, background and the historical significance of civilization and life in general."

The contribution of the college to individual leadership is well expressed by President Hadley of Yale:

"If a college man has used the opportunities offered by the faculty, he has acquired a wide knowledge of history and a broad view of public affairs. If he has utilized the opportunities offered by his fellow students, he has acquired the democratic spirit, has gotten a grip upon the public opinion, and has had a considerable experience in dealing with a large variety of men. All these things give him an advantage in the race, and statistics show that he has made good use of this advantage."

If you are to go to college what college should you select? Should you select a small college or a large one? Is it better for you to come to the University of Colorado or should you have gone to the large middle west or eastern schools? The libraries and laboratories of the smaller schools are entirely adequate for your undergraduate work. While the large university has some advantages, the smaller schools have a decided advantage for undergraduate students in that they have an opportunity to take much of their work under experienced and mature teachers, in classes small enough so that they may come directly in contact with the teacher, a privilege not possible in the larger universities.

It is as important that the student should choose instructors quite as carefully as institutions. What a man selects when he gets to college—his studies, his teacher and his friends—will prove far more vital to him than the institution he happens to choose.

After all the greatest privilege given to the college student is the opportunity to come in direct personal contact with -men and women who have given their lives to literature, science, or engineering, who live in their work, and to whom the greatest joy is in assisting students to unlock the storehouse of knowledge.

In the preface of a recent book on "Why Go to College?" the author, Clayton Sedgwick Cooper, who has spent more than ten years in visiting

educational institutions in the United States and Canada, pays this tribute to the great teacher:

"The characteristics of a college course demanded by our American undergraduates is determined by two things; first, by the character of the man who is to be educated, and second, by the kind of world in which the man is to live and work. Without these two factors vividly and practically in mind, all plans for courses of study, recreation, teaching, or methods of social and religious betterment are theoretical and uncertain.

"After ten years of travel among American college men, studying educational tendencies in not less than seven hundred diverse institutions in various parts of the United States and Canada, it is my deep conviction that the chief need of our North American educational system is to focus attention upon the individual student rather than upon his environment, either in the curriculum or in the college buildings.

"A few great teachers in every worthy North American institution who know and love the boys, have always been and doubtless will continue to be the secret of the power of our schools and colleges. There are indications that our present educational system involving vast endowments will be increasingly directed to the end of engaging as teachers the greatest men of the time, men of great heart as well as of great brain, who will live with students, truly caring for them as well as teaching them. We shall thus come nearer to solving the problem of preparing young men for leadership and useful citizenship.

"That this is the sensible and general demand of graduates is easily discovered by asking any college alumnus to state the strongest and most abiding impression left by his college training. Of one hundred graduates whom I asked the concrete question, 'What do you consider to be the most valuable thing in your college course?' eighty-six said, substantially, 'Personal contact with a great teacher.'"

I have said nothing about the money value of a college education. I cannot do better than to quote from an address that I delivered to the engineering students a couple of years ago oh the Value of a Technical Education.

"If it is your ambition to get so many dollars a day or so many dollars a month; if all work is something which is distasteful to you; if you are

willing to be a plodder, to be handicapped in the race for life; it will not pay you to make the necessary effort to get a technical education. But if you are ambitious to do and to serve, to enter a profession that will occupy all of your energy, and one in which honesty, integrity, constructive imagination, clear thinking, painstaking, careful work counts; where you have to deal not only with the forces of nature, but with men, it will pay you to get a technical education. The measure of success in life is not measured by the money accumulated, but in a good work well done. A large part of the compensation in any profession must be found in the doing of the day's work, in the joy that comes from work well done. The beginning may be slow, but success will come sooner or later, and with it sufficient emoluments for your needs, together with the satisfaction of a life well spent."

To sum up you should go to college for the reasons that it gives you:

Special Training
Liberal Training;
A Taste for Good Literature;
Ideals of Life;
A Knowledge of Public Affairs;
The Ability to Think Clearly;
An Acquaintance With a Few Leaders in Science and Literature.

This training makes it possible for you to be of greater service to the world and to get more out of life for yourself in the way of satisfaction and appreciation.

I cannot bring my remarks to a close in a more fitting manner than by quoting the last paragraph from this most interesting book, "Why Go to College?" which you will enjoy reading:

"After we have said much concerning the life and the work of the American undergraduate, there is still a valuable thing which the college should impart to him, and through which he should become enabled to present with greater charm and with greater force the message which is in his soul. This valuable thing, at once both idealism and incentive, is the undergraduate's individual message to the world. It may be composed of knowledge, the ability to think, the faculty of relaxation, and the power to

do faithfully and successfully some given task. These things, however, are all dependent upon the spirit of the actor, upon his vision, his determination, his ambitious and unflagging attempts. The true modern university contributes to the world a great-minded and a greathearted man, to whom college life has been a soul's birth as well as a mind's awakening. It gives to its youth that peculiar but indispensable thing which burned in the heart of the young art student who stood before the masterpiece and said, 'I, too, am a painter.'"

THE VALUE OF A TECHNICAL EDUCATION*

You are here at the University of Colorado to get a technical education. This will mean an expenditure of four years in a high school and four years in the University, together with a considerable sum of money. In addition to the direct expenditure of money your earning capacity in the doing of those things which require manual dexterity and skill has not increased in the proportion that it would had you been engaged in this class of work for the eight years that it will take you to get an education. It has been made possible for many of you to be here by the sacrifice of your parents and friends and by the strictest economy. In view of the above considerations it is proper that you should know something about the value of a technical education. In order that you may have a better appreciation of a technical education and be better prepared to view the matter from all sides it will be well to consider briefly the essentials of such an education.

The present technical course in engineering is built on four years' work in a first-class high school, and gives the graduate a thorough foundation in science, mathematics, mechanics and English. The principal object in a technical education is to train the man for efficiency, to give him power to think for himself, to develop his imagination in order that he may be able to plan work so that the finished structure will serve the purpose intended, in the best possible way. In order to make the most of his opportunities as an engineer the student must have a training for life.

A relatively small percentage of ambitious young men have an opportunity to complete a high school course and a course in a high grade technical school. The trade school offers an opportunity for these boys to get sufficient training in order that they may become expert mechanics,

* Extracts from an address at an Engineering Convocation.

superintendents, etc. The object and aim of a trade school is to make a high grade mechanic. The object and aim of a technical school is to make a high grade engineer; a man who shall be a leader among men, a man who shall deal not only with things, but with men; a man to whom the joy of doing the thing means more than the compensation received for the doing. The trade school course is to prepare for a trade; the technical college course is a preparation for a profession.

Before going into the detail of making a product it is well to have a definite idea of what the finished product should be Engineering, especially in America, has always differed and is now radically different from all other professions, in that they are professions of conservatism, while engineering is one of action. In the best and broadest sense an engineer is one who creates, one who designs material things and by applying the laws and forces of nature causes to be brought into being those things which are of service to man. Probably the best definition of engineering is that given by the late A. M. Wellington. "Engineering is the art of doing well with one dollar what a bungler can do with two, after a fashion, or in special cases cannot do at all." The man who builds a railroad from anywhere to anywhere, who designs a bridge, or who designs a power plant is not necessarily an engineer. He, only, is an engineer who designs economically after having carefully studied existing and future conditions of topography, revenue and finance.

It may be assumed that an engineering student comes to college to prepare himself for real success in his chosen profession. This being true, it may be of assistance to the future engineers and to others of the student body to know what have been the difficulties of those who have gone Before, and how one might best avoid the mistakes that he might otherwise make.

On graduation you will enter the employ of some firm or man, and you should be interested in knowing what an employer is looking for in an employee. While I might state definitely what I have looked for in selecting an employee, I prefer to give the specifications of a prominent consulting engineer who is now president of a technical school, Alexander C. Humphreys of Stevens Institute. He says, "I would select, first, for honesty, then for thoroughness and then for energy and earnestness.

First of all, I do not want any man in my employ unless he is honest in his intention to work wholly in my interest. Secondly, I do not want him unless he will do the work assigned to him thoroughly, even if the quantity of work is not large. Lastly, if I can get a man who is honest and thorough, and also is endowed with energy and earnestness, in other words, has a large capacity for work, I know then that I have a man that will meet all reasonable requirements. The man who performs any duty, no matter how humble, anything less than thoroughly has no right to expect promotion. The employer who would promote such an employee does not deserve loyal service."

To repeat what President Humphreys has so well said; if you expect promotion you must be honest, you must be loyal to your employer, you must be competent, you must be thorough, you must be industrious, you must be energetic. Employers today say that it is quite as difficult to secure competent employees, as men out of positions find it difficult to secure satisfactory employment. Wideawake employers are constantly on the watch to find whether or not young men in their employ have the ability for higher positions.

If, then, these are the essentials for success, how may you best prepare yourselves to meet the demands when you have graduated? I cannot map out a definite line of action for each one, but I can call your attention to certain things to which you should give more or less attention, depending upon your needs and your environment.

Begin by getting a right idea of work. Genius is all right in its way, but it will not do your work. Your first duty is always that which is immediately before you. Remember that your opportunity is the small one that lies directly before you, and not the large one that you hope to get next week. The only step that you can take in advance is the next one. Cultivate singleness of purpose. We are often surprised at the efficiency of the uneducated, but we find that they have given their work so much attention that they are able to excel those that have had better opportunities. The broadening power of education and training increases one's range of vision, but unless the power of concentration is likewise cultivated there is a tendency to scatter instead of doing effective work. David Starr Jordan has said: "The purpose of knowledge is action. But to refuse action is to secure time

for thé acquisition of more knowledge. It is written in every structure of the brain that each impression of the senses must bring with it the impulse to act. To resist this impulse is to destroy it. This lack of balance between knowledge and achievement is the main element in a form of ineffectiveness which, with various others, has been uncritically called degeneration."

Be diligent. Get what you go after and do not easily be turned aside. When you go after anything, get it all. Do not be satisfied with anything less than full competency in everything, from essentials to details. Some can use what they have with great effect, while others appear to have a faculty for obtaining a vast amount of misinformation. To be right you must be 100 per cent right; almost but not quite never won a race. You are deserving of no particular credit for doing a thing right the second or third time you have tried it; real power is characterized by the ability to do a thing right the first time.

Think clearly. Many minds are overwhelmed with a flood of ideas, but are not able to systematize and arrange their thoughts.

Train your reasoning and intuition. The reasonableness of each result should be inquired into. Be frank in admitting your mistakes and profit by them.

Perhaps no one thing will be of more service to you in college and in after life than a cheerful and optimistic attitude. Not only will this make you agreeable and better understood, but it will exert an influence on all your associates.

In brief then, remember that whatever success you have in life is going to come out of yourself. You cannot borrow success, the University will not give it to you as it does your diploma. It is the inherent capacity to perform with your brain that will make you what you become, and not the education you receive. Your education will therefore be of little service to you in reaching success unless you are honest, unless you are loyal, unless you are diligent, unless you are willing to work hard and long. If you have these then your education will assist you and will make it possible for you to reach real success; a life well spent in your chosen profession and service to others.

I cannot give you a better idea of the type of man that is needed for complete success in the engineering profession than by quoting to you

an extract from the report of Chief Engineer Starling of the Mississippi River Levee Commissioners: "A good engineer must be of inflexible integrity, sober, truthful, accurate, resolute, discreet, of cool and sound judgment, must have command of his temper, must have courage to resist and repel attempts at intimidation, a firmness that is proof against solicitation, flattery or improper bias of any kind, must take an interest in his work, must be energetic, quick to decide, prompt to act, must be as fair and impartial as a judge on the bench, must have experience in his work and in dealing with men, which implies some maturity of years, must have business habits and a knowledge of accounts. Men who combine these qualities are not to be picked up every day. Still they can be found. But they are greatly in demand, and when found they are worth their price; rather, they are beyond price, and their value cannot be estimated by dollars."

Graduates from technical schools are excellent material out of which, with a few years' experience, may come engineers of the first order. They have been given the knowledge and the training to think, they know how to attack a problem, but they lack in skill. In accepting a position preferably choose that which will best, prepare you for advancement. As a rule the higher up one begins the earlier promotion stops, and the lower down one begins the higher will he ultimately climb. The man at the top should know in a practical way all the work over which he is called upon to preside. With your college training you should master details rapidly and in a few years you will outstrip the practical man or the man who has an indifferent preparation. Be careful not to accept a position in which you have no opportunity to rise, or where the experience will not be valuable. One of the greatest opportunities that you have in college is to come in contact with men who are devoting their lives to science, mathematics and engineering, and who live in their work. When you get out in the world, if possible get an opportunity to work under the leaders in your profession. Their example will be an inspiration and their friendship will be invaluable.

If it is your ambition only to get so many dollars a day or so many dollars a month; if all work is something which is distasteful to you; if you are willing to be a plodder, to be handicapped in the race for life; it

will not pay you to make the necessary effort to get a technical education. But if you are ambitious to do and to serve, to enter a profession that will occupy all of your energy, and one in which honesty, integrity, constructive imagination, clear thinking, painstaking, careful work counts; where you have to deal not only with the forces of nature, but with men, it will pay you to get a technical education. The measure of success in life is not measured by the money accumulated, but in a good work well done. A large part of the compensation in any profession must be found in the doing of the day's work, in the joy that comes from work well done. The beginning may be slow, but success will come sooner or later and with it sufficient emoluments for your needs, together with the satisfaction of a life well spent.

The technical school is the poor man's opportunity, for there it is the man that counts; wealth, influence and birth count for naught.

If you are to get a technical training, you should get the best education possible. You should get your degree, for your diploma will be to you what the stamp is to the gold dollar. Before and after graduation you should do everything you possibly can to raise the standard of the institution. For it is your institution; its success is your success, its failure is your failure. The graduates from our College of Engineering in the early days received very indifferent instruction, but by its growth and increase in reputation their diplomas have become as valuable as those from any other institution in the country. They should feel a pride in our work and should support us.

THE MAKING OF AN ENGINEER

Engineering may be defined as "The art and science of directing the great sources of power in nature for the use and convenience of man." The art of engineering is very old, dating back to the dawn of civilization, while the science of engineering is of recent date and is now in a development stage.

Scientific knowledge may be of three kinds; purely scientific knowledge, purely practical knowledge, and that intermediate knowledge which relates to the application of scientific principles to practical purposes and which arises from understanding the harmony of theory and practice.

The object in giving instruction in the first or pure science is to cultivate the mind of the student and to qualify him, if possible, to become a scientific discoverer. In pure science exactness is an essential feature and mathematical difficulties must be overcome whenever they appear. The main objects are to determine truths without reference to their utility.

The object in giving instruction in practical knowledge or the trade or art of engineering is to acquaint the student with the present state of the art, to give him such training that he may inspect materials and workmanship, and may be able to direct the operations of workmen and transact commercial business that is connected with engineering work.

The object in giving instruction in the science of engineering, applied science, is to enable the student to apply scientific principles to practical purposes. It enables the student to plan a machine or a structure for a particular purpose without copying an existing machine or structure, or to improve an existing machine or structure without recourse to a cut and try method. The engineer should also be so well trained in mathematics and science that he may undertake investigations in pure science, when such investigations are required to be made.

The distinction between pure and applied science is one, not of method, but of aim. The methods employed by the physicist or the

chemist are to a very great extent the same as those used by the engineer in the higher branches of engineering. The physicist endeavors to discover new properties of matter and new laws for the sake of extending his knowledge and without any thought as to their utility or possibility of their application to the service of man. While the worker in pure science is not necessarily interested in the utility* of his discoveries, it is a striking feature of the history of science that nearly every discovery in pure science has been turned to account by the engineer or doctor.

It is the province of engineering or applied science to select those facts known to science and to apply them to the solution of industrial problems. To make the application of scientific facts and discoveries may require additional experiments on a commercial scale, which has led to the creation of large experimental laboratories in our universities and by industrial concerns.

While practical application may lag behind theory, not infrequently theory lags behind practice. In pure science when a doubtful point arises, for the solution of which either experimental data are wanting or mathematical methods are not sufficiently advanced, the worker must either supply the necessary experimental data or develop new methods, or await patiently the time when the necessary data and methods will be furnished by others.

In engineering, in doubtful cases, our machine or structure must be designed and constructed with the experimental data and mathematical methods available. If existing data are insufficient to give an exact solution of the problem, that approximate solution must be chosen which is the most probable. The engineer therefore must not only have training in pure science, but must have prompt and sound judgment.

While the aims and purposes of the workers in pure science and in applied science are not the same, the same qualities of mind and the same sort of training are required by an engineer as by a worker in pure science. Though the scale of experiments may be different, the general method of attack must be the same in both cases. The object of applied science is to keep the applications of science abreast of the advance of pure science and to keep pure science abreast of the applications. The engineer is interested not only in the application of the facts of pure science that

have already been discovered and formulated, but is equally interested in extending the domain of pure science in fields where the practical applications have outstripped the theory.

The engineer must have training in mathematics and the sciences, so that he can use them with the confidence and certainty that a good workman uses his tools. The engineer's training in mathematics and sciences should be given with the idea of clearness of thinking, and should include not only those parts of the science that will be directly useful, but also those parts of the science that will give general training and will inspire the student in a love for the science for science's sake. The training in pure mathematics is not less rigorous or scientific because the student knows that he must obtain such a definite grasp of the subject that he may be able to use it as a tool, or because certain parts of algebra and trigonometry are omitted in preliminary courses, to be taken up later or in connection with the applications. It is of the greatest importance that the engineering student shall be trained in the scientific habit. The training should be such as to enable the student to see a problem not only in detail, but in its entirety, to enable him to select the pertinent data and premises and to reason logically from these to the final conclusion.

The engineer must work with approximate data and measurements, and the results that he obtains are therefore subject to the same approximations and limitations as are the data. The worker in pure mathematics carries all his indetermined constants along to the end, and obtains equations containing constants which must be supplied and assumptions which must be approximated before the result is of any practical use. The engineer makes his approximations and assumptions in the beginning, and the resulting equations are immediately of service. The mathematical theory of the engineer is as rigorous as that of the pure mathematician, the difference being in the aim.

Mathematics as taught to engineers should include both algebraic analysis and graphic analysis. Algebraic analysis alone, especially when taught by a in an who has had no experience in the practical applications, is very liable to become merely a matter of juggling with symbols with an entire failure to develop the ability of the student to reduce observed data and facts to mathematical language. First and most important of all,

mathematics must be taught concretely and not abstractly. The student should be taught that general mathematical formulas are necessary when developing general cases or when writing a book, but when studying a particular special problem the student should be taught to reason in particular language at once. There is too much of a tendency for the student to memorize formulas instead of grasping and seeing principles.

While mathematics and sciences are absolutely essential for the engineer, a knowledge of one's mother tongue is even more essential. The object of an engineering course is to prepare the student to enter the profession of engineering as an apprentice so that he may develop into an engineer. The engineer not only designs and directs engineering operations, but he must prepare reports of proposed projects and write specifications for carrying out work. He must have command of language so that he can use exactly the proper word or expression; he must be able to use words not only with scientific exactness, but with historical correctness as well. The engineer must acquire a large vocabulary if he is to make the best use of his scientific training. After a training in science and mathematics the most important thing for the engineering student is training in language. In fact, the training in language is necessary to properly understand a scientific principle or a mathematical proposition. One cannot have ideas without language to express the ideas.

In discussing engineering education it has been customary to refer to courses such as philosophy, logic and language and other courses such as are given in Arts Colleges as the humanities, and many assume that these particular courses are more humanistic and liberalizing than are courses in physics, applied mechanics, thermodynamics or the theory of alternating currents. This conception is entirely wrong, for the liberalizing and humanizing value lies not in the subject matter, but in the teacher.

The engineering teacher should be a man who has had a liberal education as well as thorough training in mathematics and the sciences, and in addition he should have had an extensive engineering and business experience. Much of the training in business, law, ethics, logic and morals must be given incidentally; in fact, the humanities can best be given incidentally in connection with the strictly engineering courses if the teachers are men of the proper training and have the right point of view.

No engineer or worker in pure or applied science can be successful unless he is honest, unless he is moral, unless he has a proper conception of his duties toward society and toward his God; and no man is qualified to be a teacher unless he has a proper appreciation of these elements and of his responsibility for inculcating these proper standards in the minds of his students.

FIELD OF THE ENGINEER

Many do not have a clear idea of the meaning of the term "engineer" as used in the profession of engineering. An engineer is a man that uses and directs the forces of nature for the benefit of man. He designs, constructs and operates.

The civil engineer designs and superintends the erection of bridges, buildings, industrial plants, mine buildings and similar structures which are built of timber, steel and reinforced concrete; tests engineering materials; designs and constructs railroads; designs and constructs and operates waterworks, power plants and sewerage systems; designs, constructs and operates irrigation systems. The civil engineer also makes valuation estimates of existing structures and plants and acts as a valuation engineer and arbitrator. The future development of Colorado depends largely on the conserving and proper use of the water and other natural resources. One of the most important fields for the civil engineer will be the development of the state by the design, construction and operation of efficient irrigation systems. The construction of highways will call for many civil engineers.

The electrical engineer designs and constructs electrical machinery such as motors, dynamos, transformers, etc.; makes tests of the efficiency of electrical machines and apparatus; designs and constructs power plants and lighting plants; designs, constructs and operates electric railways; designs, constructs and operates the electric signal systems for railroads; designs, constructs and operates electrical equipment for mines and for irrigation systems; designs, constructs and operates telephone and telegraph systems; is developing and perfecting wireless telegraphy. The electrical engineer also makes valuation estimates of existing electrical plants and acts as a valuation engineer and arbitrator.

The mechanical engineer designs, constructs and erects steam engines and boilers; designs, constructs and erects gas engines; designs

and constructs locomotives and railway rolling stock; designs, constructs and erects the power plants and mechanical equipment of mines; designs, constructs and erects pumps and pumping engines; designs, constructs and erects the machines and other equipment for railroad shops, machine shops and factories for the manufacture of machines, steel bridges, rolled steel and all manufactured products; designs and constructs automobiles; designs, constructs and operates the signal department of railroads; designs, constructs and erects heating, ventilating and refrigeration plants; tests fuels and oils; makes tests to determine the efficiency of steam engines, gas engines, boilers and mechanical equipment. The mechanical engineer also makes valuation estimates of existing plants and acts as a valuation engineer and arbitrator.

The chemical engineer is a mechanical engineer with a thorough training in theoretical and industrial chemistry. The chemical engineer designs, constructs, erects and operates sugar factories and chemical works; designs, erects and operates gas plants. The chemical engineer also finds employment in smelters and mills, with mines and factories in which it is essential that the engineer be a chemist with an engineering training or a mechanical, engineer with a thorough knowledge of chemistry. The chemical engineer is prepared to enter practically all lines of work open to the mechanical engineer. The chemical engineer also makes valuation estimates of existing plants and acts as a valuation engineer and arbitrator.

Formerly engineering was divided into two branches, civil engineering and military engineering. The term "civil engineer" was used in a broad sense and covered all engineering except military engineering. The field was too broad and after a time the field of the civil engineer was limited by the recognition of the profession of mechanical engineering, electrical engineering and chemical engineering. Civil engineering is still very broad and includes not only the design, construction and operation of engineering works, but also the problem of the sanitation and public health of towns and cities.

The government of towns and cities has been notoriously inadequate. Men who had failed in business or who had no training or experience in business were considered competent to conduct the affairs of

our towns and cities. Election to the board of aldermen was considered as qualifying a man in business administration and as making him an expert in sanitation and matters of public health. The city manager plan, which has been successfully carried on in several large cities, substitutes a trained expert for the inefficient city official, and substitutes sound business management of the city's business in the place of inefficiency or graft, or in place of both. The city manager must be a man of some maturity who has had business experience and experience in the design, construction and operation of waterworks and sewerage systems, and the design and maintenance of highways and pavements. The civil engineer is the only man whose training and experience qualify him for the position, and it is interesting to note that the city managers have thus far all been civil engineers. The government of cities offers a field of' unlimited possibilities to the civil engineer; offering not only a commensurate remuneration, but an opportunity to take part in the working out of the problems of living and the government of cities, two great problems now pressing for solution.

The trend of the time is toward the control of the great corporations. To adjust rates it is necessary first to have a physical valuation. The physical valuation of railroads and other public service corporations offers opportunities for almost an unlimited number of engineers. With government control will come government ownership, and a demand for engineers to control and operate the public utilities.

Engineering is technical training plus experience. The technical training you can get in a satisfactory manner only in a high grade technical school. The only experience that is of value comes to the man who has had an adequate technical training. For a few years after graduation the engineering graduate must be willing to serve in subordinate positions in order to get the necessary experience to qualify him for the higher positions. If you desire to be a factor in the world's work, to occupy a position of responsibility, you must obtain the necessary technical training and after that an adequate experience. The minimum technical training is a four-year course in engineering in a high grade technical school. You cannot afford to be handicapped in your life's work, but should get the best preparation possible at the earliest possible moment.

OPPORTUNITIES OF THE ENGINEER

During the past twenty years there has been a remarkable development along the line of technical education in America. The engineering schools during this time have graduated many thousands of young men who have been given a training preparatory to entering the profession of engineering. For the young man who is about to graduate from the high school or is a student in college it is worth while to analyze the problem to see what has become of these men and to try to determine what are the opportunities of a man with an engineering training.

The aim in an engineering course is to give the student a well- balanced training in mathematics, mechanics, the sciences, and language; and in addition to give him a knowledge of economics and of business affairs. The idea is to produce a well-rounded and well-balanced man; to develop not only the engineering and constructive ability of the student, but to develop his business ability and his knowledge of men and affairs. In brief "the aim of an engineering training is to make a man out of a boy."

If an engineering training accomplishes what I have just outlined it should not only be an excellent preparation for the profession of engineering, but should be an excellent preparation to enter business, contracting and manufacturing, as well as an excellent preparation for law. That many engineers have made a notable success in the above lines is shown by a study of the alumni directories of the University of Colorado and of other technical schools. In this article I will outline and briefly discuss the different lines of work in which engineers are making notable records, and in which engineering graduates will find ample opportunities for a successful career.

ENGINEERING.—Engineering has been defined as the "Art and science of directing the great sources of power in nature for the use and convenience of man." It will be seen that engineering includes in

its sphere nearly everything that makes for progress and that adds to the material comfort of man. The engineer has been the pioneer who has blazed the way, who has built roads, railroads and bridges; who has developed the water power; who has mined the coal and the metals; who has developed the steam engine, and who has developed electricity and all the modern methods of transportation and communication that make modern civilization possible. Engineering has to do with construction, with production, with transportation and with distribution. The opportunities for the engineer in engineering are increasing with every advance in the complexity of our civilization. The present demand in engineering is for men who have had the theoretical and technical training to enable them to solve problems under the direction of experienced engineers, and who have the training that will enable them to hold responsible positions when they have sufficient experience. For young men who have graduated from high grade technical schools there are excellent opportunities in engineering lines, and with the commercial development which must soon come the opportunities will multiply.

MANUFACTURING AND ALLIED INDUSTRIES—Many manufactured products, such as cement, sugar, chemicals, machinery, the manufacture of gas and electric power, require engineers for their efficient production. With the closing of European markets it has been necessary to manufacture many products, such as chemicals and dye stuffs, in this country that had formerly been imported. The manufacture of these articles require? men with engineering training and a high grade of technical skill, and offers exceptional opportunities for engineering graduates.

CONTRACTING.—The engineering graduate with his training in engineering and in the law of contracts has had an excellent training to enter the field of contracting. Many contractors have a large staff of engineers, so that the young engineer has an opportunity to obtain experience not only in business methods, but in engineering proper. Many kinds of contracting are carried on almost exclusively by engineers, which has given rise to the term "Engineering-Contractor." For a young man who has business tact and the ability to meet men contracting offers a profitable and an attractive field. Engineering is an excellent training for contracting.

LAW.—A considerable part of the practice of a lawyer has to do with construction, with production, or with transportation in which an engineering training is very valuable. Attorneys engaged in patent litigation and judges who hear patent suits need an engineering training. Many engineers have found very unusual opportunities in the law, and the increasing complexity of civilization will make additional opportunities in the future. There is no better preliminary training for the law than engineering.

BUSINESS AND COMMERCIAL LIFE.—Many engineers have found their engineering college training of great use in business life. The training in accurate reasoning and in doing things in a methodical way are invaluable for the man in business.

In addition to the fields of endeavor that are commonly classed - as engineering, the engineer has been recently put in charge of valuation work of public utilities and has taken a leading part in the city government as city manager.

VALUATION OF UTILITIES.—There has recently been a demand for the valuation of railroads, street railways, waterworks and other utilities, either to determine fair and equitable rates or for purchase. This valuation work must be made, by engineers and the positions of responsibility can best be filled by engineers. At present the demand for engineers on the valuation of railroads now being carried on by the Interstate Commerce Commission is greater than the supply. This work alone will require many years to complete and will require the continued services of a very large number of engineers. Railroad valuation work offers an unusual opportunity for engineering graduates.

CITY MANAGER.—Many cities have adopted the city manager form of government. Engineers are the only men qualified for the position of city manager, and almost without exception civil engineers have been appointed to the position of city manager. An engineering training, together with additional training in public health work and in accounting, are the requirements for a city manager.

PUBLIC HEALTH WORK.—With the increased responsibility for the health of the public has come a demand for men who have been trained in sanitation and in public health problems. The engineering

graduate is better prepared than the graduates of any other department to take up work in public health.

In connection with the opportunities for the engineering graduate in engineering work it should be remembered that we are on the eve of wonderful commercial and industrial changes which will require more engineers than are available. The great war will not only greatly diminish the number of engineers in Europe, but will practically all European engineers from Mexico, South and other sections. This will result in a great demand ican engineers abroad as well as at home. In addition to unusual opportunities open for engineering graduates it ot be forgotten that the work of the engineer is con- and there comes to him the added pleasure of being of the development of society and the advance of civilization outlook for engineers was never better and wonderful unities await the young men in engineering who are just g or who will graduate from engineering schools within few years.