from them by controlled removal of the water content, represents another avenue of approach to the problems of large molecules employing the technique of the colloidal chemist. Here also x-ray investigations are an invaluable supplement to the physico-chemical studies of such structures. They reveal the structure or its absence in the aggregates obtained. Completely amorphous, crystalline and half-crystalline structures have been observed. The physical characteristics of the jelly undoubtedly depend on the same type of orienting forces, if quantitatively less strong, as are involved in the building up of the more robust structures. The zeolites may be thought of as a half-way house between the jelly and the large-molecule crystal.

The techniques of colloid-chemistry are invaluable also in the determination of the distribution of sizes amongst the polymer aggregates. In this regard, mainly due to the brilliant leadership of Svedberg, our knowledge is rapidly growing. By measurements of the rate of settling of the particles dispersed in a suitable liquid medium, either under the action of gravity or under the influence of centrifugal forces which may rise to many tens of thousands of times the force of gravity, we can learn whether the individual particles of a product, natural or synthetic, are uniform or non-uniform. If uniform, the rate of settling will be uniform and reveal itself as sharp-edged sedimentation. If the material be non-uniform, the lighter particles settle more slowly and a blurred boundary is obtained in the process. Size-classifications can be obtained in the latter case. The outstanding results of such studies by Svedberg and his collaborators lie, however, in the observations made with naturally occurring proteins, many of which, after suitable purification and under stable conditions, are found to be remarkably uniform in size. This implies that the units are identical chemically, are, indeed, single macromolecules. Svedberg's researches reveal, moreover, that the molecular weights of different proteins show a surprisingly simple relationship with one another. One series of proteins have a molecular weight of about 34,500. Another group have a value of about 68,000; a third averages 104,000, another group 208,000. Some have molecular weights of as high as 5,000,000.

In the general field of the large molecules, included under the term protein, the greatest scientific activity now obtains. Here, at its best, is exemplified, at the moment, that cooperative international effort in science in such marked contrast to the divisive, competitive struggles that separate nations in other fields. A great concentration of skills is being brought to bear upon the problem. The shapes and sizes and surface properties are being studied by observations of insoluble protein films on water. The velocities of protein reactions are being followed, practically and theoretically, in an effort to elucidate the mechanisms of interaction. Stanley's studies of the crystalline tobacco leaf virus are revealing the conditions necessary to the multiplication of protein material. Crystalline pepsin and trypsin, typical protein enzymes are steadily compelled to reveal the complexities of their structure and behavior. More recently still, from the ranks of the mathematician, from a topographical approach, Dr. Wrinch is discussing the pattern of protein structure, two-dimensional cyclol layers capable of extension in three dimensions by linkage front to front and back to back by side chains and hydroxyls, respectively, in a manner made familiar by the study of Langmuir and Miss Blodgett with oil films on saturated barium carbonate solutions. The pattern of the protein surface is being linked with the structure of the physiologically active substances, such as the carcinogens, sterols, sex hormones, as the substrate on which these latter may be superposed. Finally, the same protein pattern may be built up into closed globular structures which would define the uniformity of molecular weight determined by Svedberg in his studies and the particular magnitudes for these weights which the measurements reveal. All these varying techniques are available to assist the synthetic organic chemist in the development of his own rich efforts, so well exemplified in the person of him who to-day we have come from near and far to honor.

ENGINEERING IN AN AMERICAN PROGRAM FOR SOCIAL PROGRESS.[1] II

By Dr. KARL T. COMPTON
PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

CONSERVATION OF NATURAL RESOURCES

We turn now to the third great feature of the American program for social progress, which is the conservation of our natural resources. To this end the Federal Administration has maintained a National Resources Committee which has made an extensive survey into every aspect of national resources, including soil, water, minerals, timber, waterways and even manpower. There can be nothing but approval of this

[1] Address on Commemoration Day at the Johns Hopkins University, February 22, 1937, celebrating the twenty-fifth anniversary of the founding of the School of Engineering at the Johns Hopkins University.

crystallization of effort to survey our situation with regard to natural resources for the purpose of developing a program which will conserve and use them for the best ultimate public interest. It is another step in that succession of moves in the same direction which have occurred since the time when this country first realized that its natural resources were not unlimited and must, therefore, be husbanded and used with wisdom.

Among the specific activities which have been undertaken under this general heading and which are in various stages of completion are the large number of construction projects under the Public Works Administration and related agencies, together with some special services in other bureaus. They range all the way from the St. Lawrence Waterway Project, which has not been authorized and remains in the controversial stage as to its economic desirability, to the work of the Tennessee Valley Authority, which is in an advanced stage of operation. Other such activities are the Soil Erosion Service, the Shelter Belt, the Mississippi Valley Commission, the Passamaquoddy Tidal Project, Grand Coulee and Bonneville Dams, oil production control, and so forth.

As scientists and engineers, our reactions to these various projects are probably diverse. At the bottom of the list in merit I would place the Shelter Belt, which was a grand emotional gesture, but whose conception in large part neglected essential scientific facts both of ecology and of aerodynamics. Somewhat higher in the list would be the Passamaquoddy Project, of undoubted engineering interest but economically unjustified. The Tennessee Valley Authority Project is undoubtedly accomplishing much of public value and will be a useful experiment, provided its results will be interpreted in accordance with the facts, as the engineer would objectively analyze them, and are not misrepresented for the political purposes of justifying past actions or of promoting future policies. Unfortunately, the records already contain some evidence that such abuse of the truth for ulterior purposes has already been practiced in this otherwise great engineering venture. Of highest value in the list I should place the Soil Erosion Service and the Oil Production Control, since a wise prosecution of the former will undoubtedly be of enormous ultimate benefit to our agriculture, and the administration of the latter is in aid of conservation of our oil reserves through elimination of some of the economic pressure to wasteful production.

Note the significant fact that nearly every aspect of this program of conservation of natural resources is an engineering job. I venture to suggest that the country may soon be in a position to draw a very important lesson in regard to the projects of the type which I have mentioned. Every one of them is interesting and is aimed at some valuable goal. From all the work which will be done on them, there will undoubtedly emerge much constructive improvement of the physical plant of our country. The great question to be answered, however, is whether the economic and social results of this great program have justified the expense; or, in other words, has the program been efficiently conceived and carried through? When these questions are examined, the criterion will be the analysis of the engineer; and I suspect that the answer will contain the conclusion that it will always be very much to the best interests of the country to have the decisions as to such programs made with more attention to the judgment of the engineer than has in the past been true.

Another important aspect of the rôle of the engineer in the conservation of our natural resources is well illustrated in the case of petroleum. For years there have been various estimates of the time in which our oil reserves will be exhausted. With every passing year we know more about the amount of oil which is still in the ground because of the continual surveys by improved methods to locate new oil fields. Consequently, it is safe to say that the present estimates are the most accurate which we have ever had.

In the recent annual report to the stockholders of one of the great oil companies, a company whose traditional policy has been to deprecate fear of early oil exhaustion, it was stated that the oil in sight in this country is sufficient to supply the present rate of demand for a little over twelve years. How much new oil may be discovered before this twelve years are past no one can foretell, but I believe that all experts now agree that the oil supply in the United States will begin to show shortage well within our lifetime.

Oil has become so important in the economy of the country that it is of tremendous importance to find some substitute fuel before oil becomes scarce. What the best substitute fuel will be is a question for the scientist and the research engineer to answer. Perhaps the two most promising fuels in sight are alcohol from agricultural products or hydrocarbons produced by hydrogenation of coal. For the public interest it is very important for the engineer to develop such fuels and to design engines adaptable to these different fuels in order that this important problem of fuels for automotive engines may be well solved by the time the need is pressing.

So we see that the engineer is involved in important ways both in the direct conservation of natural resources and also in the provision for the country's needs when these resources shall have been exhausted.

Housing

There seems to be general agreement that a notable improvement in the social conditions of the country will come through a great housing program. Statistics show a real pressure for new homes. Sociologists and economists can easily demonstrate the great advantages in moral, spiritual and physical welfare which would follow a housing program wisely administered. There is no other work project which would give such a good distribution of employment and stimulation of industry, since it includes the heavy industries, equipment industries, transportation, skilled labor in the building trade and unskilled labor. The Federal Government, through its Federal Housing Administration, has exerted strong efforts to get a large housing program under way. Something has been accomplished, but on the whole the program has been disappointingly slow and ineffective. Nevertheless, I think there are few people who have studied the situation who do not believe firmly in the social advantage and the inevitable approach of a great program along these lines.

Fundamentally there are two aspects to the housing program on which its success will depend. The one involves the town or city planner and the other involves the engineer, although these two functions can not be entirely separated. The city planner must view with the eyes of a sociologist, a welfare worker, an economist, an engineer, a politician and a prophet those circumstances which determine where people should live, where people can live and what will be the future trends. He must consider such trends as the exodus of industry from the north to the south, or the east to the west, or the crowded city to the suburban community; he must make a practical estimate of how much the community will be willing to pay in the form of subsidy in rebuilding a slum district because of civic pride or humanitarian instincts, combined with the saving which will be secured in the administration of public health and law. This relatively new profession of the city planner is one in which the engineer, the architect and the sociologist all play cooperating rôles.

But in the last analysis the question of building houses or not building houses is an economic one and depends on the answer to the question: Can the houses be built of such a type and for such a price that they can be sold or rented at a reasonable profit? The answer to this question is definitely in the hands of the engineer, for it is the success of his work which determines the materials which will be used for construction, the methods employed in erection and the nature of the supplementary services of heating, ventilating, gas, electricity and plumbing. In private home construction there has been surprisingly little change in fundamental materials or methods since the earliest days, and there is strong reason for believing that ways will be developed for introducing into home construction some of the features which have made it possible for the ordinary man to buy, for $500 or $600, an automobile which, according to ordinary standards of excellence, ought to sell for several thousand dollars. If the engineer can make progress along these lines in the field of housing, then there is no doubt but that the flood gates will be opened and this country will see a tremendous boom in building construction.

This program is not an easy one, for there are many difficulties to be overcome. One is the inertia of habit and tradition which holds us to a certain notion of how and where people should live, even though this notion is indefensible by the logic of the present situation. Another difficulty may be with organized labor, which is so strongly entrenched in the building trades as perhaps to form a powerful obstacle to the introduction of any method of building construction which would partake more of the nature of erection than of traditional building. But most important of all is the fact that satisfactory success has not yet been attained in the search for materials and methods which will provide an entirely satisfactory house, one which does not look cheap, which will actually stand the wear and tear, which is solid enough to give the desirable feeling of security and privacy and which can be built more conveniently than the present home but at a notably lower cost. Here is undoubtedly a great challenge for the engineer.

DISTRIBUTION

Another element in the American program for social progress is the search for more efficient methods of distribution of the products of agriculture and industry. This is not a problem which has been notably stressed during the emergencies of the late depression, but it is one of which the American people have been conscious for many years. Its significance is brought out by a comparison of the price paid by the consumer for his foodstuffs or home equipment or clothing as over against the price which is received by the farmer or the manufacturer who produces these articles. Such comparisons show that the cost of distribution is generally a major portion of the price which we pay.

The answer to this problem has not been found, although progress has been made. For example, the federal coordinator of transportation has urged increased efficiency in distribution over the railroads through consolidation and better planning of terminal facilities. The great increase in number and popularity of chain stores for distribution of household necessities and the success of the large mail-order houses are due to their contribution toward the solution of this great problem. Perhaps the most basic feature for securing the best possible solution to this problem is the maintenance of free competition, so that the man or the company who can discover a method of cutting the costs of distribution will be financially rewarded for his efforts. Government assumption of the rôle of distributor would probably be the worst solution. If industrial codes should ever again be established, one important consideration is that they should leave the way open for the stimulation and encouragement to increased efficiency through some financial advantage to any organization which can find a means of reducing the cost of products to the consuming public.

There are many ways in which the engineer can contribute to this problem. One of these, of course, is through increasing the efficiency of the means of transportation by rail, highway and air. Another is through improvement in the methods of packaging and the discovery of large-scale methods for preserving perishable goods. Still another is in the development of methods for easy storage and for quick handling of goods. Thus there is scope not only for the "Simon pure" engineer, mechanical and electrical, for example, but also for the so-called efficiency engineer who operates by somewhat the same methods of logic.

Higher Standards of Living

And now I come to the last feature which I will discuss in the American program for social progress, and it is the one which is probably most prominently now in the minds of the American public. It is the effort to secure higher wages, shorter hours of labor and a generally higher standard of living.

When we consider wages, hours and standard of living, we find on analysis that there are two approaches to the desired objective in these matters. The one approach is through distribution and the other through creation. The former is a matter of legislation and negotiation, while the latter is primarily the responsibility of the engineer.

Let me illustrate this analysis by considering wages. Every worker desires the highest possible wage which he can secure. This is perfectly natural. The easiest and most direct way for him to get this is to try to take it away from some one else. This is the traditional method, which goes back to the dawn of history and has been the basic philosophy of wars, conquests, strikes and demagoguery in politics. On humanitarian grounds there has been much to defend this philosophy, because, also from time immemorial, we have had the picture of the strong oppressing the weak and the rich becoming richer at the expense of the poor. It is undoubtedly good and proper social philosophy and for the ultimate best interests of the human race that profit and wealth be distributed more evenly than has been the general tendency of the past.

A closer analysis of the situation, however, discloses the fact that there are definite limits and decided dangers in carrying this policy too far. The limits are disclosed by a survey of the amount of wealth or the amount of profit which is available for distribution. Thus it is found that the total amount of wealth or the total amount of profit, if distributed uniformly over the population, would raise the wealth or the income of the mass of workers by a disappointingly small amount. Furthermore, there would be a great danger in carrying this tendency too far, because to do so would dry up those sources of financial support which have proved to be the most potent means of creating new industry, providing new jobs and new profit. An extreme state of socialization involving more or less uniform distribution of wealth would certainly become very rapidly a state of stagnation in so far as progress is concerned and might very well become a state of retrogression.

This tendency of a movement toward a desired objective to set in motion forces which tend to counteract that objective is a social analogy of a well-known law of thermodynamics (Clapeyron) according to which any action sets up forces which tend to counteract it.

Therefore, while we can say that while a certain degree of distribution of wealth and profit is in the best public interest and is proper on ethical, economic and humanitarian grounds, nevertheless this approach to higher wages has its definite limitations and, if carried too far, brings serious dangers. Consider, therefore, the alternative of creating higher wages through the creation of new wealth by engineering methods.

Engineering methods in industry tend to raise wages by creation of new wealth in two different ways. One of these, which is the most direct and easily understood, is the development of new industries which directly provide new products, new employment and new profits. These industries depend upon inventive and engineering skill of a creative type. The other method is less direct and is sometimes misunderstood, as it was in the discussions of technocracy a few years ago. This indirect method operates as follows.

One function of the engineer is to discover the most convenient and economical method of doing the things which are desired to be done. Thus he creates labor-saving and quantity production devices whose first effect may be to throw people out of work through producing a given amount of goods with less labor. It is general experience, however, that this method of production so lowers the cost of goods that the market for the goods is enormously increased and the net result is far more labor at higher wages and with more profit than would have been possible without the introduction of the labor-saving and quantity production machinery. The assembly line in the automobile factory has not only made the automobile available to every class of person in the country, but it has resulted in creating one of the two or three largest lines of employment in the country at next to the highest wage paid in any large industry. Similarly, it was the introduction of machine methods of building incandescent lamps that made these lamps so cheap that they have become universal lighting fixtures, providing again large employment in manufacture and distribution at a relatively high wage-scale.

Along with these higher wages there have come shorter hours of labor, which would never in the world have been possible except by the development of quantity producing machinery, which has enabled the human race to supply its necessities and its luxuries in a sufficiently short working day to leave time for education, recreation, old-age pensions and other advantages which are only possible to the extent that engineering developments increase productive power.

The ideal community, therefore, which we might call the "analogue of Plato's republic" expressed in terms of modern technique, would be a community in which all work is performed as easily and quickly as possible, and in which there are enough things to contribute to desires beyond the bare necessities of life to provide a proper amount of general employment. In this ideal community the increased profits due to engineering efficiency would be split three ways: between the wage-earner, the owner and the consumer.

In these days of agitation for higher wages and shorter hours and a higher standard of living, it is important to remember the fundamental fact that it is only efficiency of production through engineering methods which makes general improvement in these lines possible.

Having thus discussed the rôle of the engineer with reference to some of the best recognized elements in the American program for social progress, let me turn briefly to the consideration of another problem which is fundamentally related to these and to all activities in our national life. I refer to the problem of leadership.

It is a rather discouraging and frequently startling situation in which we so often have to admit that proper leadership is lacking and is apparently unavailable. One could very well take the ground, therefore, that in all the elements of the American program for social progress there is fundamentally involved the problem of developing leaders. What contribution does the field of engineering make to the solution of this human problem?

I can suggest an answer to this question quite briefly and very definitely by quoting from statistics which have been gathered by the director of the General Motors Institute, Mr. Robert H. Spahr, in connection with a report three or four years ago to the Society for the Promotion of Engineering Education. This survey of the officers of companies in American industry showed the startling fact that graduates of engineering or technical colleges are many times more likely to be found in positions of authority than are graduates of other types of colleges or non-college men. For example, out of the 235 college-trained presidents in leading American industries, 151 were trained in engineering or technical colleges, and 84 in colleges of all other types. When we consider the fact that the number of graduates of other types of colleges is many times greater than from the engineering colleges, these figures are even more striking, for they indicate that the probability of an engineering-trained man becoming president of an American industrial organization is 10 or 20 times as great as the same probability for a man of different college training. When we consider 54,000 officers of all types in finance, production, engineering and sales, we find an even stronger predominance of engineering-trained men, to such a extent that we can say that the probability of an engineering-trained graduate becoming an officer in an American industrial organization is from 25 to 50 times greater than this probability for a man of different college training.

These figures are a striking refutation of the wishful thinking back of the old saw, which goes, "You will always find the graduate of an engineering school working, but you will always find him working for some one else." Probably many of you have heard this statement with reference to the graduates of your own local institution.

By way of summary, therefore, of this whole survey of the American program for social progress, I think we can reduce the argument to two very simple and direct statements of fact. One is that the engineer, through the very nature of his experience and field of interest, has a most important position in bringing to accomplishment the various elements of this great program. A second is that experience shows that the engineering type of training is an unusually excellent training for responsible position in American industry.

With these statements of fact in mind, the conclusions as to our policy in regard to the rôle of engineers in this program for social progress are quite clear. Engineers should be given a more important rôle in the determination of national policies directed toward this program. They should be given the encouragement and stimulation which will lead to their best performance in achieving many of these objectives. Their environment, whether in government or industry or educational institution, should be made conducive to productive effort. And those of us who have a responsibility for engineering education in this country should take fresh courage from realization of the fundamental importance of our task and conviction that such contributions as we and our institutions can make are of such public value as to justify our best efforts.