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THE ENGINEER; HUMAN AND SUPERIOR DIRECTION OF POWER[1]

THE forces of nature are the most enduring wealth of mankind. To know their laws and to learn how to apply them has made of a puny little being of about 130 to 200 pounds of flesh and bone—three fourths of which is merely water—a giant of which Gulliver's tales have no equal; and compared to which the largest and most muscular animals of present or former geological periods are merely drowsy, clumsy creatures. All this has been accomplished by his few grams of better brain-matter, which permitted him to gather scientific knowledge and thus to wield powers akin to those attributed to some of the gods of antiquity.

But the forces of nature, in wrong hands, can be diverted from their very highest purposes into the basest demoniacal utilization.

During the late war, one of the nations reputed for its scientific knowledge, staggered history by the wholesale, unscrupulous utilization of science and engineering in attempting to extend and perpetuate an anachronistic and domineering system of government. The other nations, in trying to withstand this onslaught upon right and decency, were in their turn compelled to enlist the talent of scientists and engineers alongside the efforts of soldiers and sailors.

And now, thank God, we chemists can turn again to the sphere of action where we truly belong. We can try anew to become apostles of construction instead of destruction; soldiers of progress, of peace and happiness.

Unfortunately, this does not mean to say that *all* which *all* chemists accomplish is *always* dictated by such lofty motives; no more than liter-

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ature, or art, or religion is never debased by low aims.

Whatever else this war has brought forth, it has at last taught the ignorant multitude that, in our modern complex civilization, chemists are as indispensable as engineers, notwithstanding the fact that the lawyer-politician still holds the floor.

Nor should the public be blamed too much. The work and purposes of the chemist are not easy to understand to the average man or woman, too often devoid of even rudimentary scientific knowledge, although in some cases they are the bearers of a college degree earned by a one-sided exclusively literary education.

What appears even less obvious, even to the better informed classes, is the relation of the chemist to the chemical engineer. It is less known that a man may be a scientific star of the first magnitude and yet be incapable of utilizing his science in the industries, or of applying it in the many other ramifications of the economics of our civilization—not to speak of the recent applications of science in war. It does not seem obvious to many that there is the same difference between a good grammarian or philologist and a successful writer, be the latter a novelist, an essayist, a journalist or a playwright; that a learned botanist will not necessarily make a successful farmer, no more than a mathematician will surely prove a good accountant, nor a good accountant an able business man, nor a philosopher a successful statesman.

In the same way, explorers frequently make unsuccessful settlers. The true scientist is an explorer in the broadest sense of the word. He explores the laws of nature. By direct observation or experiment, and aided by theoretical reasoning, he tries to correlate the observed facts until he believes that he is warranted to generalize thereon. He thus helps to discover new truths or laws of nature. These, in their turn will permit him to predict facts in advance until further observations or experiments either support him or point out that his generalizations or theories were based on insufficient research or faulty interpretation of the recorded data. Whenever this occurs, he is compelled to turn back on his steps and gather additional knowledge and try better theories. Thus are the methods of science and research. But before any such laboriously gathered knowledge can be utilized, there is a vast amount of further methodic work to be performed.

After a geologist has revealed and surveyed a body of ore in the mountain, the mining engineer and the metallurgist know very well that this does not necessarily mean a paying mine, or a successful smelting works.

So it is in chemistry. The experience of many a scientist has been confined exclusively to laboratory work, or to purely chemical subjects. This is frequently the reason of his weakness in dealing with practical matters, when he is inclined to concentrate his point of view too much on only a part of the subject with which he is confronted. He is apt to neglect other considerations which although seemingly unimposing from a scientific standpoint, frequently carry with them the very elements of success or failure in practical applications.

When, during the war, the problem came up to start the manufacture of optical glass for gunsights and other instruments used in our army or navy, it was easy enough to take care of the chemical side of this subject after raw materials of sufficient purity had been obtained and as long as the glass was produced merely in quantities of a few ounces where the mass could readily be melted in platinum crucibles. But when it came to produce tons of homogeneous optical glass for real wholesale use, then the most tantalizing problem resided in the proper construction and handling of large clay crucibles; this for the simple fact that the molten glass dissolved the clay of the pots and got spoiled by taking up impurities, in the same way as water would dissolve a container made of sugar or of dried mud.

Many a chemical reaction brilliantly successful in the laboratory as long as the operation could be limited to small quantities and carried out in glass, porcelain or platinum vessels, has been doomed to failure when attempts were made to run it on a permanent commercial scale. It needs quite some experience and a good deal of common sense to know when it is cheaper to simply burn up sawdust waste instead of trying to distill it or convert it into paper pulp, and to know when it is cheaper, for this purpose, to buy expensive wood in the shape of clear logs. It requires quite an effort of good judgment to know when it is less ruinous to burn waste flax straw from our linseed fields than to try to spin or weave it; to know when it is less injurious to one's bank account to leave natural soda and potash salts in lake water instead of obtaining them by the usual processes. That Boston clergyman of about twenty years ago may have had correct chemical information when he started that company for extracting the limitless tons of gold naturally contained in sea water, but if he had been just a little of a chemical engineer, he might readily have concluded that it was cheaper to leave all that gold in the ocean than to try to extract it by methods which cost more than the value of the gold.

Then again, there are cases where even the best of chemists committed errors of judgment and failed to solve problems because they lacked the daring of the engineer.

Sir Humphry Davy, one of the greatest chemists of his age, showed his lack of qualifications as a chemical engineer when he reported unfavorably on the project to use coal gas for the illumination of the City of London. One of his most emphatic objections was that it would require a gas holder as large as St. Paul's Church dome, and even after this was constructed, it would blow up at the first opportunity.

As an opposite example, I should cite the great Belgian engineer, Solvay, who revolutionized the manufacture of soda, one of the chemicals most indispensable to civilization and used in enormous quantities. His success was mainly due to the fact that he was more of an engineer than a chemist. In developing his process, he was unaware that this reaction was not new; that it was so old and so well known that several patents on this very subject were already on record and that, furthermore, the process had been tried commercially about half a dozen times in several countries, and had invariably been unsuccessful. Fortunately, all this discouraging information reached him only after his keen engineering talent had already demonstrated that this elusive chemical process could be controlled in the hands of an engineer and made to operate so successfully as to throw in the scrap heap the older processes used until then.

The pure chemist, confined by the walls of his classroom, his laboratory, or his library, sometimes fails to exercise sufficiently the sense of proportion.

Nor are the engineers, as a class, free from being carried away by a one-sided point of view, although their way of reasoning and grappling a problem is more along quantitative considerations.

The ways of thinking and acting of a chemist and that of an engineer are often along decidedly different points of view. Yet, if these points of view can be compromised, or harmonized, they bring forth good chemical engineering. Nor is this always an easy task. Too often I have seen cases where the engineer, regardless of well-established chemical facts of which he was conveniently ignorant, diligently went on designing the most elaborate and ingenious equipment, giving minute attention to every structural and mechanical detail, and then handed plans and specifications to the chemist to leave the "chemical details" of the problem to the latter. These "details" consisted in specifying a material about as strong as steel, resisting strong acids or other very corrosive agencies, extreme heat, and which should, furthermore, be furnished at a price about that of steel or bronze. When the chemist meekly answered that he knew of no material that would answer the purpose except platinum, iridium, or possibly gold, the information was received with a look of contemptuous disappointment on the part of the engineer.

In another case, a laboratory chemist had been carrying out a chemical process where he heated corrosive liquids under high pressure in sealed hard glass tubes of about half an inch in diameter. In the meantime, he hoped that any engineer forthwith would build him an apparatus with which to perform the same operation in ton lots.

Simple as it sounds, it requires quite some experience, quite some common sense before the chemical engineer knows when to specify stoneware instead of lead, or other metals, or *vice versa,* or to learn how to alter the design of an equipment so as to make it adaptable for each of these different structural materials. I well remember the look of disgust of an engineer who had drawn his specifications of heavy stoneware to within one sixteenth inch of margin, to find out when the apparatus was finally delivered, at the end of several months drying, and baking and waiting, that the dimensions had warped several inches and did not fit with the other parts of the equipment. That very day he learned that it pays to order his stoneware a long time in advance and to wait for its delivery before adjusting the final designs of the adjacent equipment according to what he got from the pottery. I am glad to see that during the competition of the last few years, stoneware manufacturers have made much progress.

In another case, a chemical engineer made a success of a different problem of pumping a corrosive liquid where delicate pumps made of expensive alloys or stoneware were most of the time out of order, until he superseded them by home-made pumps made of cast iron or cement. They corroded very fast, but their construction and replacement were so simple and inexpensive that he could afford to replace them rapidly with much less trouble or cost.

In many chemical industries, after once the initial chemical problems have been overcome, the manufacturing problems resolve themselves to cost of operation and mass production. No wonder then that in such industries the engineer's problems seem to dwarf those of the chemist to such an extent that sometimes the manufacturers seem to be astounded when one reminds them that after all their enterprise is essentially chemical. This is of little consequence in so-called "prosperous" times, when orders are abundant, profits considerable, and when the main problem is one of output. In times of keener competition the unchemically trained directors of such enterprises are sometimes unpleasantly reminded that they need clever chemists as well as good engineers and business men and that, while they were asleep on this subject, their keener competitors have been improving their industries along chemical lines.

Steelmakers or smelters, for instance, are apt to forget that metallurgy is, after all, a very chemical industry where most of the great strides were made through chemical considerations. The same can be said of sugar, glass and soap manufacturing.

To the wide-awake manufacturer, the present industrial depression should be an incentive to engage more chemists, to do more chemical research work, instead of laying off the men of their chemical staff, as has happened in too many instances since we got out of that fool's paradise of so-called "prosperity."

Most of our industries badly need "fertilizing" and fertilizing is better done while the land lies fallow than during planting or harvesting time.

Whenever I see such shortsightedness which is bound to stunt our industrial efficiency for the future, then I wonder whether some of the financial or business men at the head of large industrial enterprises are not occupying their position on an assumed and unearned reputation.

Some of our industries are more particularly adapted to our country on account of an exceptionally abundant supply of the raw materials they employ; this gives them at once a distinct advantage over other countries which have to import these raw products. But precisely in some of these industries, the chemical point of view has been much neglected, except in minor details.

For instance, we have that enormous industry of petroleum refining. Ever since petroleum was first discovered, the processes of rectification have not varied much from the general methods of fractional distillation by which different compounds are separated by order of volatility in light hydrocarbons of the gasoline type, somewhat higher boiling liquids of the kerosene type, then lubricating oils, vaseline or petroleum jelly, and the least volatile and hardest of all, paraffine.

It is true that in this general process of distillation, improvements have been introduced from time to time. For instance, the intermediate treatment with sulphuric acid, then later the destructive distillation at higher temperatures or the so-called "cracking" processes which break up the more complex hydrocarbon molecules of the heavier distilling liquids and thereby increase the yield of the lighter and more valuable gasoline.

Nevertheless, the fact remains that aside from a relatively small proportion of lubricants, the bulk of raw or refined petroleum is burnt as a fuel. This burning may be done directly in oil burning furnaces, or as refined kerosene in our lamps, or as gas from our gas works, or by a much more efficient way, in our internal combustion motors, varying from the smallest motorcycle engine to the heaviest Diesel generators.

There was a time when coal also was exclusively used as a fuel until the chemists succeeded in converting one of its least attractive by-products, coal-tar, into a series of the most startling syntheses, which opened an entirely new field in chemistry. These coal-tar derivatives include not only an endless variety of dyes, but the many other valuable synthetic substances used in the art of healing and sanitation, as well as the newer synthetic resinous products which have opened new possibilities in electrical insulation and numerous other industries, and the chemicals which are used in the art of photography. Nor should I omit to mention the new explosives obtained from the same source, and which are safer and easier to handle than dynamite or gunpowder, and which find greater and more lasting applications in mining, agriculture and engineering than in war. Agents of foreign interests had long ago started a propaganda campaign among our teachers of chemistry as well as among our congressmen and manufacturers, making them believe that the United States was not suited for this industry of coal-tar products, and that Germany could better supply us. But the war awakened us from our torpor when we were confronted by the fact that the coal-tar derivatives were the indispensable key to many of our most important industries and that the war could not be won without them, and that Germany had lulled us into inaction until, in experience, we were a full generation behind her. By supreme efforts, our chemists and business men overcame this fearful handicap; this achievement remains one of the most brilliant pages of our national history. And now it looks as if shortsightedness and politics were about to destroy what has been raised after so much effort.

But let us return to the subject of the petroleum industry: The abundant existence of this raw material, as well as natural gas, in America is mainly due to the special geological history of this continent. Geological changes here have been less violent, less metamorphic than in Europe or most other countries, so that the geological deposits or stores of these rather fugitive materials have been less disturbed, less broken up by subsequent upheavals.

Especially in natural gas do we possess a raw material which almost exclusively belongs to this country. When we reflect, however, that this raw material cannot readily be transported, we should seek methods to convert it into other commodities which lend themselves to easier transportation.

If we have acted as spendthrifts with our coal and petroleum, we have behaved as barbarians with our natural gas resources until there is little left of it. Yet natural gas contains valuable substances which under the hand of the chemist may be used as a starting point for syntheses perhaps more valuable than what has been accomplished with coal-tar. While the period of brutal waste is not yet ended, the dawn of a more enlightened utilization seems to be in sight. I learned recently that at least one of our more progressive and better organized industrial enterprises has undertaken the problem of more methodical use of natural gas along scientific and chemical lines. From the results already obtained, there is good hope that some day our natural gas resources may provide us with new synthetic products which may open entirely new possibilities in various other industries. I should add that the company in question, notwithstanding the present business depression, has not discharged its research chemists. On the contrary it has recently added considerably to its research staff and equipment, although endeavoring to cut unnecessary expenses in other directions.

Industrial alcohol is another chemical industry in the United States which seems susceptible of an incomparably wider development as soon as it is less hampered by fanaticism in a more efficient commercial production and easier distribution. The ignorant multitude does not class alcohol as a chemical industry. Most people can not see in alcohol anything but its use or abuse as a beverage.

And yet, outside of such uses, there is hardly a chemical susceptible of wider and more beneficial application in the arts, the industries and the household economics. Its value as a solvent, its use in varnishes, artificial leather, smokeless powder, is well known among chemists. But a much more extended use is possible as a liquid fuel. The fact that it is far less volatile than gasoline and mixes readily with water, makes it not only cleaner, but incomparably less dangerous, whether it be used in the household for heating or illuminating purposes, or whether it be used on a motor car or a motorboat, or stationary engine.

Furthermore, its sources of supply embrace all inexpensive starch- or sugar-containing vegetables, as well as the waste of our sugar refineries, all products of which this country has a prodigious supply.

Converting our perishable farm products into products like alcohol, which can be stored indefinitely and of which the transportation and handling are easy, is one of the ways of equalizing the uncertain fluctuations of the yield of our crops.

Long after every drop of petroleum or gasoline will have been extracted from our wells, every yearly agricultural crop will insure us a new supply of this valuable liquid fuel obtained by fermentation of starch- or sugar-containing liquids. I know of no country where there is such an abundant source of supply, as well as the industrial opportunities in conjunction with an extensive market within easy reach, provided industrial alcohol can be furnished to the consumer at a low enough price.

But unintelligent application of the Prohibition Act will offset all this, whatever good effects it may try to accomplish in other directions, by putting unnecessarily exaggerated restrictions or handicaps upon the manufacture or distribution of industrial alcohol.

Few people realize that the price at which alcohol can be delivered to the consumer at a profit is considerably influenced by whatever unnecessary red tape impedes manufacture, transportation or distribution. The well-intentioned manufacturer who is endeavoring to lower the cost of production, feels his efforts rather futile when they are wiped out at the selling and distributing end.

There is opportunity for considerable improvement in the technical end of this industry in the United States. In this respect, France and Germany were able to furnish better and cheaper alcohol than we were, because in those countries the industrial alcohol situation has always been more considered on its own merits. So has it come to pass that this branch of chemistry or chemical engineering has attracted fewer of our better scientists or engineers in the United States than in other countries. Justly or unjustly, this whole industry has been under the ban of social prejudice on the part of people who, in their zeal, can not discern between the drink evil and an indispensable chemical industry.

Yet, no less a man than the great Pasteur counts among the many illustrious chemists, biochemists and engineers, who have contributed to the development of the alcohol industry. It was Pasteur, while he was professor of chemistry at the University of Lille, who by undertaking to correct irregularities in the fermentation processes of a local distiller, discovered the fundamental truths relating to the phenomena of fermentation. Under his genius, the knowledge gained thereby became the starting point not only of radical improvements in the manufacture of fermentation processes, but they brought forth a veritable revolution in sanitation, surgery, and medicine. All this has sowed broadcast inestimable benefits on mankind, and has made the name of Pasteur sacred to every one who is not too ignorant to know something about what he has done for humanity.

If every annual crop of starch- or sugar-containing plants can furnish us an abundance of liquid fuel and solvents under the form of alcohol, we may look at this from another point of view and call it simply the stored-up energy of the sun. The photochemical action of the sun rays under the influence of the chlorophyl, or green matter of the plant leaves, brings about the most subtle creative chemical synthesis. Carbon dioxide, a product of combustion, one of the ultimate destruction products of plant or animal life, combines with water under the action of sunlight. Dead matter reenters the process of life. The first, or one of the first products of this synthesis is formaldehyde; the latter, in its turn, inaugurates a succession of further chemical syntheses which result in the formation of sugars, starch, cellulose, and other carbohydrates. No sun, no photochemical synthesis, no crops—no life! So that, after all, the whole living world is dependent upon a delicate photochemical reaction. Starvation, on one hand, or abundance of crops and foodstuffs, on the other, all within the range of photochemistry.

In the same way, our vast coal beds and our petroleum wells and our natural gas, are merely the result of light energy stored up from the plant or animal life of former geological periods. This, in itself, ought to impress us with the enormous possibilities of photochemical synthesis. And yet, here is a field where the scientist or engineer has accomplished next to nothing. In the utilization of this marvelous energy, we have not gone much beyond the art of making photographs.

So here is a power, an energy, which has been much neglected by scientist and engineer alike. Where is the Faraday, the Ampère, the Leonardo da Vinci, where is the Archimedes who shall show us how to use the sun rays for charging our electrical storage batteries, or who will teach us how to handle the photochemical action of sunlight, or to emulate nature in her synthesis of plant life? Who will utilize this delicate method instead of our hitherto brutal processes of synthesis. Nature in her methods of plant life synthesis does not treat with boiling solutions of alkalies or strong acids; she uses no high temperatures nor strong electric currents. If we want to be successful in this direction, we shall have to utilize equipment possessing large exposed surfaces similar to the leaves of plants. We may have to operate in rather dilute solutions instead of the concentrations which are ordinarily used in our present methods. We may have to find means for rapidly separating the formed products as fast as they accumulate. We may be compelled to work within narrow ranges of temperature, perhaps not exceeding those outside of which plant life stops.

But who knows what surprises are in store for us and how we may simplify all this after the subject once begins to receive enough attention.

In the past, scientists have taught the engineers how to transmute the forces of nature, but this took a very long time. About a century and a half ago, Lavoisier, by his memorable work in chemistry, got as far as to exclaim: "In Nature nothing is created, nothing is lost, there are only transformations." But he was thinking of *matter* as such. It took almost a century more before Mayer and Joule proclaimed the same truth in physics as far as forces of Nature or energy are concerned. Our present conception of the conservation and transformation of energy are of rather recent date. Nor were these fundamental truths readily accepted without opposition. Since then, progress has been rapid. Scientists and inventors alike have taught the engineer how to transmute the forces of Nature.

Let us take, for instance, a well-known chemical reaction—the oxidation of carbon and hydrogen; whether this oxidation be accomplished simply by the burning of coal, gas, or oil in furnaces under a steam boiler, or by the internal combustion in any variety of a gas engine, it gives heat which in turn is transformed into motion or motive power, which runs our factories, our ships, our trains, our automobiles, our flying machines. Or, inversely, motion can be turned into an equivalent amount of heat by friction or otherwise, as every one knows who ever operated an air compressor or had to deal with a badly lubricated axle.

But motion, whether it be furnished by water rushing from a waterfall, or by a steam or gas engine, or by a windmill, can be made to turn a dynamo and produce electrical energy. The latter, in turn, can be changed into motion, heat or light. Or again, we can bridge directly that jump between a chemical reaction and light by simply burning oil, gas, acetylene, or magnesium, and thus produce any range of even the most intense light. Or, in other cases, we use heat or electricity to decompose the most refractory substances in their elements, and some of our largest electro chemical industries in Niagara Falls are based on this. Or we may use either one of these forms of energy in chemical reactions which build up; which, in other words, bring about chemical synthesis.

But when it comes to transforming light energy into chemical synthesis, we have left thus far the monopoly of this agent to Nature; we have been acting as Rip Van Winkles.

In the museum of the Franklin Institute in Philadelphia exists an electrical machine which was used by Benjamin Franklin for his experiments. It was one of the very best electric machines of his day. Yet, at that time, it was a mere clumsy toy. When the weather was not too damp and all other conditions were propitious, the operator, after turning that glass globe until he was red in the face, could draw some insignificant sparks, or charge a Leyden jar, or give a harmless shock to the person who touched it. All this was not so very long ago. Yet that toy was the forerunner of our enormous electrical industries, and all the astounding modern applications of electrical energy; our electric generating stations which give us light, power and transportation, which move our trains, our ships, our factories, which generate power far beyond anything which unscientific man of antiquity, or of a few years ago, was able to dream of. That same electricity which gave us wireless telegraphy and the wireless telephone; which has made the world bigger, and, at the same time, smaller, by rendering every nook and corner more accessible.

Let those who at present lay off their research chemists, their physicists, their research engineers, remember that the tremendous gap between that toy electric machine of Franklin and the present electrical industry, would never have been bridged but for research, invention and good engineering.

L. H. Baekeland

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HERBERT HAVILAND FIELD

On April 5 there died in Zurich, Switzerland, from heart failure following influenza, one to whom science and especially zoology owes a great debt. Herbert Haviland Field was not only a man of marked ability and personal charm but he also possessed unusual breadth of vision as well as the power to make his visions realities. By virtue of these traits he made contributions of fundamental and permanent value to the progress of science though he was known to relatively few because of his modesty and self-elimination.

Born in Brooklyn, N. Y., April 25, 1868, of Quaker ancestry which included some of the prominent citizens of that municipality a century ago, young Field had his early education in that city, was graduated from the Brooklyn Polytechnic and went to Harvard. There he took his bachelor's degree in 1888 and kept on until he had won his M.A. in 1890 and his Ph.D. in 1891. His doctor's thesis, a masterful study of the early development of the urogenital organs in Amphibia, gave him at once a high place in the esteem of workers in zoology.

On going to Europe in the following year, he met a cordial reception at the Universities of Freiburg in Baden, Leipzig, and Paris, at each of which he was given the doctor's degree. Even at the start of his studies he was impressed with the failure of investigators to give due attention to the work of the past and recognized that this neglect was due in large part to the lack of means for obtaining an adequate record of the volumi-