SCIENCE

FRIDAY, MAY 5, 1911

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MSS. intended for publication and books, etc., intended for review should be sent to the Editor of SCIENCE, Garrison-on-Hudson, N. Y.

RESEARCH AS A FINANCIAL ASSET[1]

IT is only in our century that there could be much significance to such a title as "Research as a Financial Asset." This is an industrial century, and, whether we are proud of it or not, we are an industrial people. For some reasons it may be thought unfortunate that so large a proportion of man's energies should be devoted solely to the industries. In some eras we find that there was a predominance of art over industry; in others literature was predominant, in still others war and conquest. Once territorial discovery and acquisition predominated, and now, in our own times, the principles of community interest have so greatly developed that we are accustomed to seeing many people who, instead of directly producing their own necessities of life, are more generally producing some one little article which contributes in the lives of others. This we recognize as a natural tendency to a higher efficiency. Our intricate and delicately balanced system of work is becoming continually more complex, but is certainly still covered by the elemental laws of demand and of survival. New discoveries in our day are largely mental, instead of geographical, and the old battles of conquest have become wars with ignorance. They are struggles to overcome inefficiencies, attempts to broaden the common mental horizon, as our ancestors broadened their physical horizon. Very few people realize the rapidity with which

[1] Presented before the Congress of Technology at the fiftieth anniversary of the granting of the charter of the Massachusetts Institute of Technology.

technical advances are being made. Few realize how the way of this advance has itself advanced. I might make this more clear by an illustration.

Consider for a moment the increasing uses of chemical elements and compounds. New combinations in alloys, medicines, dyes, foods, etc., and new uses and new materials, are being produced daily. For a more simple comparison, consider only the advances in our technical uses of the metallic chemical elements.

Copper, iron and five other metals were known and used at the time of Christ. In the first 1,800 or 1,900 years of our era, there were added to the list of metals in technical use (pure or alloyed) about eight more, or a rate below three a century. There has been so much industrial advance made within the past twenty to thirty years that fourteen new metals have been brought into commercial use within this period. This is almost as many in our quarter century as in the total preceding age of the world. Of course this rate, as applied to metals, apparently can not continue, but there is no reason to question the possibility of the general advance it indicates. For centuries a single metal was made to serve for all uses which that metal could fill. Then two metals divided the field, each being used where it was preferred for any reason. Alloys began to displace metals to a limited extent. While the engineer still uses iron for his railroad, iron for his buildings and iron for his tools, these irons are different and have been specially developed for those uses. The electrical engineer prefers copper for his conductor, certain irons for the frames of apparatus, other special irons and steels for the shafts, the magnetic fields, etc., and the specialization to best meet specific wants is still under way. I suppose that this kind of complex development is largely responsible for research laboratories.

A research laboratory is a place where men are especially occupied with new problems, presumably not too far in advance of technical application. By this group devoting its entire attention to the difficulties of realizing already well defined necessities, or of newly defining and realizing together, the efficiency of these processes is increased. Men specially trained for this very purpose are employed and they are usually just as unfitted for successfully manufacturing as those who efficiently reproduce are of discovering or inventing. It is merely an extension of the principle of the maximum efficiency. A man with his entire attention devoted for months or years at a time to the difficulties of a single problem should be better able to reach a solution than the man who can devote only irregular intervals to it. He should then also be the better prepared for a second problem.

A research laboratory is also a place equipped with apparatus especially designed for experimental work. In a busy manufacturing plant, if a foreman has an idea pointing towards an improvement of his product he frequently has great difficulty in finding the time, the necessary idle apparatus, the raw materials and the incentive to try it. In the laboratory all of these are combined and there is added a system of cooperation, of permanently recording results and an atmosphere of research.

The mathematics of cooperation of men and tools is interesting in this connection. Separated men trying their individual experiments contribute in proportion to their numbers, and their work may be called mathematically additive. The effect of a single piece of apparatus given to one man is also additive only, but when a group of men are cooperating, as distinct from merely operating, their work rises with some higher power of the number than the first power. It approaches the square for two men and the cube for three. Two men cooperating with two different and special pieces of apparatus, say a special furnace and a pyrometer, or an hydraulic press and new chemical substances, are more powerful than their arithmetical sum. These facts doubtless assist as assets of a research laboratory.

When a central organization, such as a laboratory, has access to all parts of a large manufacturing plant and is forced sooner or later to come into contact with the various processes and problems, the various possibilities and appliances, it can hardly fail to apply, in some degree, the above law of powers.

As a possible means of illustrating the almost certain assistance which one part of a manufacturing plant may give another when they are connected by experimenting departments or research laboratories, and how one thread of work starts another, I will briefly review part of a single fairly connected line of work in our laboratory. In 1901 the meter department wanted electrically conducting rods of a million ohms resistance. These were to be one quarter inch diameter by one inch length. In connection with this work we had to become fairly familiar with published attempts at making any type of such high resistances. Some kind of porcelain body containing a very little conducting material seemed a fair starting formula after the resistance of almost all kinds of materials had been considered. Our own porcelain department was of a great help in showing us how to get a good start. We learned how and what to mix to get a fair porcelain, and we found that small quantities of carborundum or of graphite would give us the desired resistance about once in a hundred trials. The rods could be made, but the variation of their resistance when taken from the porcelain kiln and when they were made as nearly alike as we could make them, was often so many thousand fold that something new had to be done to make a practical success. A small electric furnace was then devised for baking the rods and this was so arranged that the rate of rise of temperature, the maximum temperature reached and the duration of heat at any temperature was under control and was also recorded. The desired result was obtained and this work was thus finished. It gave us a certain stock of knowledge and assurance.

At that time a very similar problem was bothering one of the engineering departments. Lightning arrester rods, part of the apparatus for protecting power lines from lightning, were needed. Their dimensions were $\frac{3}{4} \times 6$ inches and they needed to have a definite but, in this case, *low* resistance, and could apparently not be baked in a porcelain kiln. The necessary variations in such a kiln are so great that in practise many thousand rods were repeatedly fired and afterward tested to yield a few hundred of satisfactory product. All the cost of making an entire batch would have to be charged against the few units which might be found satisfactory, and in many cases there were none good in a thousand tested. It was evident that regulation and control of temperature was necessary. This was found to be impracticable in case any considerable number were to be fired at one time, as the heated mass was so great that the rods near the walls of the retort received a very different heat treatment from those near the middle and were consequently electrically different. This was still the case even when electrically heated muffles were used. This difficulty led to experiments along the line of a heated pipe, through which the rods could be automatically passed. Some time was spent in trying to make a practical furnace out of a length of ordinary iron pipe, which was so arranged as to carry enough electric current to be heated to the proper baking temperature. Troubles here with oxidation of the iron finally led to substitution of carbon pipes. This resulted in a carbon tube furnace, which is merely a collection of six-foot carbon pipes, embedded in coke powder to prevent combustion, and held at the ends in water cooled copper clamps, which introduce the electric current. By control of this current the temperature could be kept constant at any point desired. When this was combined with a constant rate of mechanical feed of the air dried rods of porcelain mixture, a good product was obtained. For the past seven years this furnace has turned out all the arrester rods, the number produced the last year being over 100,000 units.

In this work we were also forced to get into close touch with the electroplating department. The rods had to be copper plated at the ends, to insure good electrical contact. The simple plating was not enough. This introduced other problems, which I will pass over, as I wish to follow the line of continuous experiment brought about, in part, at least, by a single investigation. The electric furnace consisting of the carbon tube packed in coke was a good tool for other work, and among other things we heated the carbon filaments for incandescent lamps in it. We were actuated by a theory that the high temperature thus obtainable would benefit the filament by removal of ash ingredients, which we knew the ordinary firing methods left there. While these were removed, the results did not prove the correctness of the theory, but rather the usefulness of trying experiments. It was found by experiment that the graphite coat on the ordinary lamp filament was so completely changed as to permit of a hundred per cent. increase in the lamp life or of a 20 per cent. increase in the efficiency of the lamp for the same life, so that for the past four or five years a large part of the carbon lamps made in this country have been of this improved type. This is the metallized, or Gem lamp. Naturally, this work started a great deal of other work along the lines of incandescent lamp improvement. At no time has such work been stopped, but in addition to it, the new lines of metallic filament lamps were taken up. In fact, during the past five or six years, a very large proportion of our entire work has been done along the line of metallic tungsten incandescent lamps. In this way we have been able to keep in the van of this line of manufacture. The carbon tube furnace has been elaborated for other purposes, so as to cover the action under high pressures and in vacuo. Particularly in the latter case a great deal of experimental work has been carried out, contributing to work such as that connected with rare metals. In such a furnace, materials which would react with gases have been studied to advantage. Our experience with the metallized graphite led to production of a special carbon for contact surfaces in railway signal devices, where ordinary carbon was inferior, and suggested the possibility of our contributing to improvements in carbon motor generator brushes. On the basis of our previous experience and by using the usual factory methods, we became acquainted with the difficulties in producing carbon and graphite motor brushes with the reliability and regularity demanded by the motor art. Furnace firing was a prime difficulty. Here again we resorted to special electrically heated muffles, where the temperatures, even below redness, could be carefully controlled and automatically recorded. This care, aided by much experimentation along the line of composition, of proportionality between the several kinds of carbon in the brush, etc., put us into shape to make really superior brushes. The company has now been manufacturing these for a couple of years, with especial reference to particularly severe requirements, such as railway motors. In such cases the question of selling price is so secondary that we can and do charge liberally for delicacy and care of operation in the manufacture.

This carbon work naturally led to other applications of the identical processes or materials. Circuit breakers, for example, are now equipped with a specially hard carbon contact, made somewhat as motor brushes are made.

It is not my intention to connect all of the laboratory work to the thread which seemed to connect these particular pieces of work, but rather to show the possible effect in accumulating in a laboratory, experiences which should show on an inventory.

Among other considerations which appeal to me is one which may be worth pointing out. Probably almost every manufacturing plant develops among its workmen from time to time, men who are particularly endowed with aptitude for research in their line. They are usually the inventors of the company. They are often discovered in spite of opposition. They are always trying new things. They are almost of necessity somewhat inefficient in the routine production. In many plants they are merely endured, in a few they are encouraged. In my mind their proper utilization is a safe investment. A research laboratory assists in such a scheme. Sooner or later such a laboratory becomes acquainted with this type of men in a plant and helps them in the development of their ideas.

It is not a perfectly simple matter to measure the value of a research laboratory at any one time. In the minds of some, the proper estimate is based on the money already earned through its work, which otherwise would not have been earned by the company. This is a fair and conservative method which in our generation ought to be satisfactory when applied not too early to the laboratories. It does not take into account what we may call the good-will and inventory value, both of which should be more rapidly augmenting than any other part of a plant. The experience and knowledge accumulated in a general research laboratory is a positive quantity. In our own case we expended in the first year not far from $10,000, and had little more than expectations to show for it. Our expenses rapidly rose and our tangible assets began to accrue. Perhaps I can point to no better criterion of the value of a research laboratory to our company than the fact that its force was rapidly increased by a company which can not be particularly interested in purely academic work. Our annual expenditures passed the $100,000 mark several years ago. My own estimate of the value would probably be greater than that of others, for I am firmly convinced that proper scientific research is demanded by the existing conditions of our technical age.

Without going into exact values, which are always difficult to determine, consider for a moment the changes which incandescent lighting has witnessed in the past ten years. In this field our laboratory has been active, in contributing to both carbon and to metallic filaments. Moreover, all of the improvements in this field have been the product of research laboratories of trained men. In the case of our metallized carbon filament, which has now been in use several years, the efficiency of the light was increased by about twenty per cent. Among the carbon lamps of last year these were sold to the extent of over a million dollars.

A broader, but perhaps less accurate impression of changes recently produced, may be gained by considering the economy now possible on the basis of our present incandescent lamp purchases in this country and that which would have resulted if the lamps of only ten years ago were used in their stead. On the assumption that the present rate of lamp consumption is equivalent to about eighty million 25 watt tungsten lamps per year, and on the basis of one and a quarter watts per candle power as against 3.1 of the earlier lamps and charging power at 10 cents per kilowatt hour, we get as a result a saving of $240,000,000 per year, or two thirds of a million per day. Naturally, this is a saving which is to be distributed among producers, consumers and others, but illustrates very well the possibilities. It is interesting to note that we are still very far removed from a perfect incandescent illuminant, when considered from the point of view of maximum theöretical light efficiency.

I see from advertisements that 65,000 of the magnetite arc lamps, originally a product of the laboratory, are now in use. These must have been sold for something near $2,000,000. The supplying of electrodes, which we make and which are consumed in these lamps, should amount to about $60,000 per year.

Our study of the properties of the mercury arc produced our rectifier, which has been commercially developed within the past few years. Of these, about 6,000 have been sold. As they sell for not far from $200 per set, it is safe to say that this also represents a sale of over a million dollars. The advantage of these outfits over other available apparatus must also be recognized as not far from $200 for each hour through which those already sold are all operating.

In such a complex field as insulations and molded materials there have been many changes produced. As far back as 1906 we were using annually, in a certain apparatus, 30,000 specially drilled and machined soapstone plates, which cost $1.10 each. As the result of experiments on substitutes for such material, it was found that they could be molded by us in the proper shape, with holes in place and of a material giving increased toughness, at a greatly reduced cost. As the result of this fact, the price of the purchased material was reduced to us from $1.10 to 60 cents which in itself would have paid for the work. But further developments proved that the new molded material could be made for 30 cents, which the foreign material could not equal, so we have since produced it ourselves. This caused a saving of approximately $24,000 annually for this one molded piece. I have heard of other cases where prices to us have gone down, when we have obtained a little promise from our experimental researches.

In considering the research laboratory as a financial asset there is another view which might not be visible at first sight. It is the question of the difference between the value of the useful discovery when purchased from competitors in the business and when made by one's own company. It is not usually pleasant to have to purchase inventions after their value is known, no matter from whom, but to have to pay a competitor for such a discovery is doubly irksome. One is naturally unduly fearful of its value to the competitor, and he, in turn, is overestimating another's power to use it. The purchaser's profit is apparently limited to the differences between his efficiency of operating it and that of the original owner. A business usually comprises processes of making and selling something at a profit, and study of the making of the most modern, most improved, most efficient, is about as essential as the study of the limits of safe business credits.

I was recently informed by an officer of another large manufacturing company, where much chemical work is done and which established a research laboratory several years ago, that the most important values they got from their laboratory was the assurance that they were keeping ahead and are at least prepared for the new, if they can not always invent it themselves. Incidentally, he said that from one part of their research work they had produced processes, etc., which had saved $800,000 a year. They are at present spending in their several research departments a total of about $300,000 a year.

We hear frequent reference to the German research laboratories and a brief discussion may be in place. For the past fifty years that country has been advancing industrially beyond other countries. Not by newly opened territories, new railroads, new farm lands, new water power cities, but by new technical discoveries. In fact, this advance may be said to be largely traceable to their *apparent* over-production of research men by well fitted universities and technical schools. Every year a few hundred new doctors of science and philosophy were thrown on the market. Most of them had been well trained to think and to experiment; to work hard, and to expect little. The chemical manufactories began to be filled with this product and it overflowed into every other calling in Germany. These well educated young men became the docents, the assistants and the professors of all the schools of the country. They worked for $300 to $500 per year. They were satisfied so long as they could experiment and study the laws of nature, because of the interest in these laws instilled into them by splendid teachers. This condition soon began to make itself manifest in the new-making of things—all sorts of chemical compounds, all kinds of physical and electrical devices. I might say that pure organic chemistry at this time was academically most interesting. Its laws were entrancing to the enthusiastic chemist and consequently very many more doctors were turned out who wrote organic theses than any other kind. What more natural than that organic chemistry should have been the first to feel the stimulus? Hundreds, and even thousands of new commercial organic products are to be credited to these men and to that time. All the modern dye stuffs are in this class. Did Germany alone possess the raw material for this line? No! England and America had as much of that. But Germany had the *prepared men* and made the start.

It seems to me that America has made a start in preparing men for the research work of its industries. For example, it is no longer necessary to go abroad to get the particular training in physical chemistry and electro-chemistry which a few years ago was considered desirable. Advanced teaching of science is little, if any more advanced in Germany to-day than it is in this country. In my opinion the quality of our research laboratories will improve as the supply of home trained men increases, and the laboratories of this kind will be increasingly valuable when analyzed as financial assets. I am certain, too, that the industries will not be slow in recognizing the growing value of such assets. They merely want to be shown.

Probably in most industries there are

what I may call spots particularly vulnerable to research. For example, the efficiency of steam boilers, based upon the heat energy of the coal used and the efficiency of the engine using the steam, are continually being raised. We may expect, until the maximum calculable efficiency is reached, that this advance will continue. The reason is not far to seek. It is a vulnerable spot. Improvement is possible. A small increase in efficiency of a power plant is an ever-continuing profit. Great numbers of steam power plants exist and so inventors are influenced by the fact that new improvements may result in enormous total economies. Every rule of the game encourages them. I can make this clearer by illustrations.

Artificial light is still produced at frightfully poor efficiency. Electric light from incandescent lamps has been greatly improved in this respect, but there is still room for greater economies. It is still a vulnerable spot.

In the case of iron used in transformers, we have another such vulnerable spot. A transformer is practically a mass of sheet iron, wound about with copper wire. The current must be carried around the iron a certain number of times and the copper is chosen because it does the work most economically. No more suitable material than copper seems immediately probable, nor is there any very promising way of increasing its efficiency, but in the iron about which it is wound there is a vulnerable spot. The size of the iron about which the copper is wound may possibly be still much further reducible by improvements in its quality. In other words, we do not yet know what determines the magnetic permeability or the hysteresis of the iron, and yet we do know that it has been greatly improved in the past few years and that it can still be greatly improved.

Let us make this vulnerable point a little clearer by considering the conditions here in Boston. I assume there are approximately 50,000 kw. of alternating current energy used here. Nearly all of this is subject to the losses of transformers. If the transformers used with this system were made more than ten years ago, they probably involve a total loss, due to eddy and hysteresis, of about $1,000 per day, at the ten-cent rate. Transformers as they are made to-day, by using improved iron, are saving nearly half of this loss, but there still remains over $500 loss per day, to serve as a subject for interesting research work.

It should also be noted that Boston uses only a very small fraction of the alternating current energy of this country.

Consider for a moment two references to the sciences and industry in Germany and England. Dr. O. N. Witt, professor in the Berlin Royal Technical High School, reporting to the German government in 1903, says: "What appears to me to be of far greater importance to the German chemical industry than its predominant appearance at the Columbian World's Fair, is the fact which finds expression in the German exhibits alone, that industry and science stand on the footing of mutual deepest appreciation, one ever influencing the other," etc. As against this, Professor H. E. Armstrong, of entirely corresponding prominence and position in England, says of England: "Our policy is the precise reverse of that followed in Germany. Our manufacturers generally do not know what the word research means. They place their business under the control of practical men . . ., who, as a rule, actually resent the introduction into the work of the scientifically trained assistants." If the English nation is to do even its fair share of the work of the world in the future, its attitude must be entirely changed. It must realize that steam and electricity have brought about a complete revolution, that the application of scientific principles and methods is becoming so universal elsewhere that all here who wish to succeed must adopt them.

So long as motors burn out, so long as subways are tied up by defective apparatus, so long as electric motors run too hot, so long as street cars can catch fire from so-called explosions of the current, so long as the traffic of a whole city can be stopped by a defective insulation or a ten cent motor brush, there will probably be the equivalent of research laboratories somewhere connected with the electrical industries, where attempts will be continually made to improve.

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RECLAMATION OF THE ARID WEST[1]

THE benefits derived by applying science to industry and the still greater benefits that may be expected when all great problems are attacked in the scientific spirit and on the scientific methods are to a certain extent exemplified by the opportunities afforded and results now accomplished in the conservation of the natural resources of the nation.

The reclamation of the arid west is simply one of a number of items of national importance upon whose correct solution by true scientific methods rests largely, not merely the material prosperity of the nation, but, more than this, the perpetuation of free government, and of high standards of individual liberty.

The stability of a republic or democracy, whichever we may term it, rests not upon its wealth, but upon the character of the individual citizen and voter. The greatest commonwealths are not necessarily those having the greatest natural resources, but rather those in which the human units are strong. The strength of the unit, the family or the voter, is not derived from material wealth, but from ability to act and think independently and to exercise that intelligent self-interest which binds him to the great mass of his fellow men. If, for example, he is working in a factory or on a railroad line, he is, of course, interested in keeping his job. Beyond this, he has little concern with the condition of municipal, state or federal affairs. These are entirely too remote to touch him, and if he lives in a tenement, he has no concern beyond paying his rent and getting the most he can for it.

But take this man, indifferent to forms or details of government, and put him upon a 40-acre farm. Assuming that he has reasonable industry and intelligence, his whole view-point of life changes. He is transformed from being more or less of a nomad, shifting from flat to flat, or from town to town, and indifferent to the general welfare. He now becomes a land-owning citizen and voter, interested in every public movement for better roads, better schools, better local government and everything which leads up to the stability of the institutions of the state as upon these rest the value and comfort of his home.

This thought has been most pithily embodied in a statement attributed to Edward Everett Hale where he asks "Whoever heard of a man shouldering his musket to fight for his boarding house?"

The problem of the reclamation of the arid west is being attacked primarily for the purpose, not of making men rich, but

[1] Presented before the Congress of Technology at the fiftieth anniversary of the granting of the charter of the Massachusetts Institute of Technology.