INDUSTRIAL RESEARCH IN AMERICA

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BY

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INDUSTRIAL RESEARCH IN AMERICA.

Germany has long been recognized as preëminently the country of organized research. The spirit of research is there immanent throughout the entire social structure. This is not the time or place, however, nor is it necessary before this audience, to refer in any detail to the long record of splendid achievement made by German research during the last fifty years. It is inscribed in luminous letters around the rock upon which Germany now stands secure among the nations of the world.

The virility and range of German research were never greater than they are to-day. Never before have the superb energy and calculated audacity of German technical directors and German financiers transformed so quickly and so surely the triumphs of the laboratory into industrial conquests. Never has the future held richer promise of orderly and sustained progress, and yet the preëminence of Germany in industrial research is by no means indefinitely assured. A new competitor is even now girding up his loins and training for the race, and that competitor is strangely enough the United States,—that prodigal among nations, still justly stigmatized as the most wasteful, careless, and improvident of them all.

To one at all familiar with the disdain of scientific teaching which has characterized our industry, and which still persists in many quarters, this statement is so contrary to the current estimate that its general acceptance cannot be expected. It will have served its purpose if it leads to a consideration of the facts which prove the thesis.

The country of Franklin, Morse, and Rumford, of McCormick, Howe, and Whitney, of Edison, Thomson, Westinghouse, and Bell, and of Wilbur and Orville Wright, is obviously a country not wholly hostile to industrial research or unable to apply it to good purpose. It is, however, not surprising that with vast areas of virgin soil of which a share might be had for the asking, with interminable stretches of stately forest, with coal and oil and gas, the ores of metals, and countless other gifts of nature scattered broadcast by her lavish hand, our people entered upon this rich inheritance with the spirit of the spendthrift, and gave little heed to refinements in methods of production and less to minimizing waste. That day and generation are gone. To-day their children, partly through better recognition of potential values, but mainly by the pressure of a greatly increased population and the stress of competition between themselves and in the markets of the world, are rapidly acquiring the knowledge that efficiency of production is a sounder basis for prosperity than mere volume of product, however great. Many of them have already learned that the most profitable output of their plant is that resulting from the catalysis of raw materials by brains. A far larger number are still ignorant of these fundamental truths, and so it happens that most of our industrial effort still proceeds under the guidance of empiricism with a happy disregard of basic principles. A native ingenuity often brings it to a surprising success, and seems to support the aphorism, "Where ignorance is profitable, 'tis folly to be wise." Whatever may be said, therefore, of industrial research in America at this time is said of a babe still in the cradle, but which has, nevertheless, like the infant Hercules, already destroyed its serpents and given promise of its performance at man's estate.

The long-continued and highly organized research which resulted in the development of American agricultural machinery has led to the general introduction of machines which reduce the labor cost of seven crops $681,000,000, as measured by the methods of only fifty years ago.

The superhuman dexterity and precision of American shoe machinery, which has revolutionized a basic industry and reduced competition to the status of an academic question, present American industrial research at its best. They are not the result of the individual inspiration of a few inventors, as is commonly supposed. They represent years of coördinated effort by many minds directed and sustained by constant and refined experimental research.

You need not to be reminded that the ubiquitous telephone is wholly a product of American research. Munchausen's story of the frozen conversation which afterward thawed out is a clumsy fable. Think of the Niagaras of speech pouring silently through the New York telephone exchanges where they are sorted out, given a new direction, and delivered audibly perhaps a thousand miles away. New York has 450,000 instruments—twice the number of those in London. Los Angeles has a telephone to every four inhabitants. Why should one care to project one's astral body when he can call up from the club in fifteen seconds? Our whole social structure has been reorganized. We have been brought together in a single parlor for conversation and to conduct affairs, because the American Telephone & Telegraph Company spends annually for research, the results of which are all about us, a sum greater than the total income of many universities.

The name of Edison is a household word in every language. The Edison method is a synonym for specialized, intense research which knows no rest until everything has been tried. Because of that method and the unique genius which directs its application, Italian operas are heard amid Alaskan snows and in the depths of African forests; every phase of life and movement of interest throughout the world is caught, registered, transported, and reproduced, that we may have lion hunts in our drawing-rooms and the coronation in a five-cent theatre. From his laboratory have come the incandescent lamp, multiple telegraphy, new methods of treating ores, and a thousand other diverse inventions, the development of a single one of which has sometimes involved millions.

The development of the automobile, and especially of the low-priced American car, is a thing of yesterday. To-day a single manufacturer turns out two cars a minute, while another is expanding his output to 500 cars a day. Every 23 days the total engine horse power of new cars of one small type equals the energy of the entire Mississippi River development at Keokuk. Every 46 days this engine output rises to the total energy development at Niagara Falls. The amount of gasoline consumed upon our roads is equal to the water supply of a town of 40,000 inhabitants, and its cost on Sundays and holidays is $1,000,000.

It goes without saying that any such development as that of the automobile industry in America has been based upon and vitalized by an immeasurable amount of research, the range and influence of which extend through many other industries. It has accelerated the application of heat treatment more than any other agency. One tire manufacturer spends $100,000 a year upon his laboratory. The research department organized by my associates for one automobile company comprised within its staff experts in automobile design, mathematics, metallography, and heat treatments, lubrication, gaseous fuels, steel and alloys, paints and painting practice, in addition to the chemists and physicists and assistants for routine or special work.

The beautiful city whose hospitality has so greatly added to the pleasure and success of the present meeting of our society is the home of two highly scientific industries of which any community may well be proud. The Bausch & Lomb Optical Company, through its close affiliation with the world-famed Zeiss works at Jena, renders immediately available in this country the latest results of German optical research. The Eastman Kodak Company is perhaps more generally and widely known than even the Zeiss works, and in capital, organization, value of product, and profit of operation will bear comparison with the great German companies whose business is applied science. Like them it spends money with a lavish hand for the promotion of technical research and for the fundamental investigation of the scientific bases on which its industry rests. As you have happily been made aware, this work is carried on in the superb new research laboratories of the company with an equipment which is probably unrivalled anywhere for its special purposes. The laboratory exemplifies a notable feature of American industrial research laboratories in that it makes provision for developing new processes, first on the laboratory scale and then on the miniature factory scale.

To no chapter in the history of industrial research can Americans turn with greater pride than to the one which contains the epic of the electrochemical development at Niagara Falls. It starts with the wonderful story of aluminum. Discovered in Germany in 1828 by Wöhler, it cost in 1855 $90 a pound. In 1886 it had fallen to $12. The American Castner process brought the price in 1889 to $4. Even at this figure, it was obviously still a metal of luxury with few industrial applications. Simultaneously Hall in America and Heroult in Europe discovered that cryolite, a double fluoride of sodium and aluminum, fused readily at a moderate temperature, and, when so fused, dissolved alumina as boiling water dissolves sugar or salt, and to the extent of more than 25 per cent. By electrolyzing the fused solution, aluminum is obtained.

On August 26, 1895, the Niagara works of the Pittsburgh Reduction Company started at Niagara Falls the manufacture of aluminum under the Hall patents. In 1911 the market price of the metal was 22 cents, and the total annual production 40,000,000 pounds.

A chance remark of Dr. George F. Kunz in 1880 on the industrial value of abrasives turned the thoughts of Acheson to the problem of their artificial production, and led to the discovery in 1891 of carborundum and its subsequent manufacture on a small scale at Monongahela City, Pennsylvania. In 1894 Acheson laid before his directors a scheme for moving to Niagara Falls,—to quote his own words:

"To build a plant for one thousand horse power, in view of the fact that we were selling only one-half of the output from a one hundred and thirty-four horse power plant, was a trifle too much for my conservative directors, and they one and all resigned. Fortunately, I was in control of the destiny of the Carborundum Company. I organized a new board, proceeded with my plans, and in the year

1904, the thirteenth from the date of the discovery, had a plant equipped with a five-thousand electrical horse power, and produced over 7,000,000 pounds of those specks I had picked off the end of the electric light carbon in the spring of 1891."

The commercial development of carborundum had not proceeded far before Acheson brought out his process for the electric furnace production of artificial graphite and another great Niagara industry was founded. In quick succession came the Willson process for calcium carbide and the industrial applications of acetylene, phosphorus, ferro-alloys made in the electric furnace, metallic sodium, chlorine and caustic soda first by the Castner process, later by the extraordinarily efficient Townsend cell, electrolytic chlorates and alundum.

Perhaps even more significant than any of these great industrial successes was the Lovejoy & Bradley plant for the fixation of atmospheric nitrogen, which was perforce abandoned. It is well to recall, in view of that reputed failure, that the present-day processes for fixing nitrogen have made little, if any, improvement in yields of fixed nitrogen per kilowatt hour over those obtained in this pioneer Niagara plant.

In the year 1800 a young assistant of Lavoisier, E. I. du Pont by name, emigrated to this country with others of his family, and settled on the banks of the Brandywine near Wilmington, Delaware. He engaged in the manufacture of gunpowder. To-day the du Pont Company employs about 250 trained chemists. Its chemical department comprises three divisions: the field division for the study of problems which must be investigated outside the laboratory, and which maintains upon its staff experts for each manufacturing activity, together with a force of chemists at each plant for routine laboratory work; second, the experimental station, which comprises a group of laboratories for research work on the problems arising in connection with the manufacture of black and smokeless powder, and the investigation of problems or new processes originating outside the company; third, the Eastern Laboratory which confines itself to research concerned with high explosives. Its equipment is housed in 76 buildings, the majority being of considerable size, spread over 50 acres. Since no industrial research laboratory can be called successful which does not in due time pay its way, it is pleasant to record that the Eastern Laboratory is estimated to yield a profit to its company of $1,000,000 a year. In addition to the generous salaries paid for the high-class service demanded by the company, conspicuous success in research is rewarded by bonus payments of stock.

In Acheson and Hall have already been named two recipients of the Perkins medal, the badge of knighthood in American industrial research. The distinguished and thoroughly representative juries which award the medal annually had previously bestowed it upon Herreshoff for his work in electrolytic copper refining, the contact process for sulphuric acid, and the invention of his well-known roasting furnace, and upon Behr for creative industrial research in the great glucose industry. In 1912 it was received by Frasch, and this year was awarded Gayley.

The Gayley invention of the dry air blast in the manufacture of iron involves a saving to the American people of from $15,000,000 to $29,000,000 annually. A modern furnace consumes about 40,000 cubic feet of air per minute. Each grain of moisture per cubic foot represents one gallon of water per hour for each 1,000 cubic feet entering per minute. In the Pittsburgh district the moisture varies from 1.83 grains in February to 5.94 grains in June, and the water per hour entering a furnace varies accordingly from 73 to 237 gallons. In a month a furnace using natural air received 164,500 gallons of water, whereas with the dry blast it received only 25,524 gallons. A conservative statement, according to Professor Chandler, is that the invention results in a 10 per cent increase in output and a 10 per cent saving in fuel.

Especially notable and picturesque among the triumphs of American industrial research is that by means of which Frasch gave to this country potential control of the sulphur industry of the world. There is in Calcasieu Parish, Louisiana, a great deposit of sulphur 1,000 feet below the surface under a layer of quicksand 500 feet in thickness. An Austrian company, a French company, and numerous American companies had tried in many ingenious ways to work this deposit, but had invariably failed. Misfortune and disaster to all connected with it had been the record of the deposit to the time when Frasch approached its problem in 1890. He conceived the idea of melting the sulphur in place by superheated water forced down a boring, and pumping the sulphur up through an inner tube. In his first trial he made use of 20 150 H.P. boilers grouped around the well, and the Titanic experiment was successful. The pumps are now discarded, and the sulphur brought to the surface by compressed air. A single well produces about 450 tons a day, and their combined capacity exceeds the sulphur consumption of the world.

An equally notable solution of a technical problem which had long baffled other investigators is the Frasch process for refining the crude, sulphur-bearing Canadian and Ohio oils. The essence of the invention consists in distilling the different products of the fractional distillation of the crude oil with metallic oxides, especially oxide of copper, by which the sulphur is completely removed, while the oils distill over as odorless and sweet as from the best Pennsylvania oil. The copper sulphide is roasted to regenerate the copper. The invention had immense pecuniary value. It sent the production of the Ohio fields to 90,000 barrels a day, and the price of crude Ohio oil from 14 cents a barrel to $1.00.

Turning from these examples of individual achievement so strongly characteristic of the genius of our people in one aspect, let us again consider for a moment that other and even more significant phase of our industrial research, namely, that which involves the coördinated and long-continued effort of many chemists along related lines.

Chemistry in America is essentially republican and pragmatic. Most of us believe that the doctrine science for science's sake is as meaningless and mischievous as that of art for art's sake or literature for literature's sake. These things were made for man, not for themselves, nor was man made for them. Most of us are beginning to realize that the major problems of applied chemistry are incomparably harder of solution than the problems of pure chemistry, and the attack, moreover, must often be carried to conclusion at close quarters under the stress and strain induced by time and money factors. Under these circumstances it should not excite surprise that a constantly rising proportion of our best research is carried on in the laboratories of our great industrial corporations, and nowhere more effectively than in the research laboratory of the General Electric Company under the guidance of your past president, Dr. Whitney. As to the laboratory method, Dr. Whitney says in a personal letter: "We see a field where it seems as though experimental work ought to put us ahead. We believe that we need to get into the water to learn to swim, so we go in. We start back at the academic end as far as possible, and count on knowing what to do with what we find when we find it. Suppose that we surmise that, in general, combustible insulation material could be improved upon. We try to get some work started on an artificial mica. Maybe we try to synthesize it, and soon come to a purely theoretical question, for example: Is it possible to crystallize such stuff under pressure in equilibrium with water vapor corresponding to the composition of real mica? This may lead a long way and call in a lot of pure chemistry and physical chemistry. Usually we just keep at it, so that, if you haven't seen it on the market, we're probably at it yet."

In striking contrast to the secrecy maintained between individual workers in large German research laboratories is the almost universal custom in America to encourage staff discussion. In the General Electric Laboratory, as in many others, the weekly seminars and constant helpful interchange of information have developed a staff unity and spirit which greatly increases the efficiency of the organization, and raises that of the individual to a higher power.

Many evenings could profitably be spent in discussing the achievements of this laboratory. Their quality is well indicated by the new nitrogen tungsten lamp, with its ½-watt per candle, which combines the great work of Dr. Coolidge on ductile tungsten with the studies of Langmuir and others of the staff on the particular glass and gas and metal which are brought together in this lamp.

Any attempt to adequately present the enormous volume of research work, much of which is of the highest grade, constantly in progress in the many scientific bureaus and special laboratories of the general government or even to indicate its actual extent and range, is of course utterly beyond the limits of my attainments or of your patience. The generous policy of the government toward research is unique in this, that the results are immediately made available to the whole people. Heavy as some of the government reports are, they cannot be expected to weigh more than the men who write them. Some, like the Geochemistry of F. W. Clarke, are of monumental character. A vast number are monographs embodying real and important contributions to scientific knowledge or industrial practice. Some, as would be expected, are little more than compilations or present the results of trivial or ill-considered research.

The United States is still essentially an agricultural country, and agriculture is, in its ultimate terms, applied photochemistry. The value of our farm property is already over $42,000,000,000, and each sunrise sees an added increment of millions. Even small advances in agricultural practice bring enormous monetary returns. The greatest problem before the country is that of developing rural life. While our people still crowd into already congested cities, some are beginning to realize that Long Acre Square is not a wholly satisfying substitute for Long Acre Farm, and to question whether the winding, fern-fringed country roads of Vermont may not be a better national asset than the Great White Way.

Chief, therefore, among the government departments, in the volume of industrial research is of course the Department of Agriculture, which includes within its organization ten great scientific bureaus, each inspired by an intense pragmatism and aggressively prosecuting research in its allotted field. The magnitude of these operations of the Department may be inferred from the fact that it spent for printing alone during the fiscal year just ended $490,000. The activities of its army of agents literally cover the earth, and its annual expenditure runs to many millions. The Bureau of Soils, the Bureau of Plant Industry, the Bureau of Animal Industry, and the Forest Service have to do with the very foundations of our national existence and prosperity, and their researches have added billions to the national wealth. The Bureau of Chemistry, through its relation to the enforcement of the Pure Food Law and the inspection of meats before interstate shipment, is as ubiquitous in its influence as the morning newspaper and touches the daily life of the people almost as closely. The consumer is by no means the only one benefited by its activities. Manufacturers are protected from the unfair competition of less scrupulous producers. The progress of research is stimulated not only by investigations within the Bureau, but by their reaction upon the manufacturers of food products who are rapidly being brought to establish laboratories of their own. The food work of the Bureau is supplemented and extended by the laboratories of the state and city Boards of Health, of which that of Massachusetts has been notable for productive research. Special laboratories within the Bureau carry its influence and investigations into other fields, as in case of the Paper and Leather Laboratory.

The Office of Public Roads of the Department, mindful of the fact that less than ten per cent of the total road mileage of the country has ever been improved, maintains a large organization of engineers, chemists, and other scientists to conduct investigations and compile data the ultimate purpose of which is to secure efficiency and economy in the location, construction, and maintenance of country roads, highways, and bridges.

The research work of the Department of Agriculture is greatly augmented and given local application through the agency of 64 state agricultural experiment stations established for the scientific investigation of problems relating to agriculture. These stations are supported in part by federal grants, as from the Hatch and Adams funds, and for the rest by state appropriations. Their present income exceeds $3,000,000. All are well equipped; one of them, California, includes within its plant a superb estate of 5,400 acres with buildings worth $1,000,000.

The station work is organized upon a national basis, but deals primarily with the problems of the individual states. The efficiency of their work is stimulated by the requirement of the Adams Fund that appropriations shall be confined to definite projects. The number of such projects during 1910 was 335, and during 1911, 290. The reduction in number in no way implies diminished activity, and is due to more careful selection and preparation, with elimination of trivial and merely demonstrational projects. While the work of the stations necessarily covers a wide range of subjects, many of which would not be regarded as chemical in nature, a notable proportion has to do directly with chemical projects. Only the briefest reference can be made to a few of these.

At Connecticut, Osborne's studies of proteins and their feeding values have developed differences as great in their assimilability as those existing between the different carbohydrates.

Kansas has a department for the study of problems in handling and milling grain with an experimental baking plant for testing the bread-making capacity of flours. The millers are actively coöperating.

Minnesota has a similar thoroughly modern baking and testing laboratory for studies in wheat and flour chemistry and technology.

Arizona finds that date ripening may be so hastened by spraying the immature fruit with acetic acid that choice varieties are caused to ripen in that region.

The Cornell Station has demonstrated that the growth of a legume with a nonlegume gives the latter a greater protein content than when grown alone.

Wisconsin has established the significance of sulphur as a plant-food; grain crops, for example, remove nearly as much sulphur as they do of phosphoric acid, whereas the soil supply of sulphur is far less.

Vermont is studying the forcing of plants by means of carbonic acid gas.

Idaho has raised the protein content of wheat by 50 per cent. Kentucky has developed a method for the detection of bacillus typhosus in water, and North Dakota is conducting very extensive field tests on the durability of paints and oils.

These are of course mere surface references which hardly touch the real work of the stations. An enormous amount of research and routine work on fertilizers is constantly carried on by methods standardized by the Association of Official Agricultural Chemists. The theory of the action of fertilizers engages the effort of many research workers who find the problem far more complex than the old plant-food theory.

It may be said without fear of contradiction that through the combined efforts of the Department of Agriculture, the Experiment Stations, the Agricultural Colleges, and our manufacturers of agricultural machinery there is devoted to American agriculture a far greater amount of scientific research and effort than is at the service of any other business in the world.

No other organic substance occurs in such abundance as wood, and few, if any, are more generally useful. About 150,000,000 tons of wood are still wasted annually in the United States. The Forest Products Laboratory, which is maintained by the Forest Service in coöperation with the University of Wisconsin, has for its purpose the development and promulgation of methods for securing a better utilization of the forest and its products, and its research work is directed to that end. The laboratory is splendidly equipped with apparatus of semicommercial size for work in timber physics, timber tests, wood preservation, wood pulp and paper, and wood distillation and chemistry.

In the United States Patent Office Dr. Hall has developed a remarkably comprehensive index to chemical literature, which now contains 1,250,000 cards and which is open to every worker. The Bureau of Fisheries devotes $40,000 to a single study, and the Geological Survey $100,000 to the investigation of the mineral resources of Alaska. It spent in 1913 $175,000 for engraving and printing alone.

The superb Geophysical Laboratory of the Carnegie Institution of Washington is also constantly engaged in the most refined researches into the composition, properties, and mode of genesis of the earth's crust. The Smithsonian Institution is honored throughout the world for the efficiency of its effort to increase and diffuse useful knowledge among men.

The Bureau of Mines of the Department of the Interior was established to conduct in behalf of the public welfare fundamental inquiries and investigations into the mining, metallurgical, and mineral industries. Its appropriation for the current fiscal year is $662,000, of which $347,000 is to be devoted to technical research pertinent to the mining industry. The Bureau has revolutionized the use of explosives in mines. Over $8,000,000 worth of coal is now bought on the specification and advice of the Bureau, while more than 50 of the larger cities, a number of states, and many corporations have adopted the Bureau plan of purchase. Our own Dr. Parsons, as chief mineral chemist of the Bureau, is carrying its researches into new and interesting fields.

Perhaps no better evidence could be adduced of the present range and volume of industrial research in America than the necessity, imposed upon the author of such a general survey as I am attempting, of condensing within a paragraph his reference to the Bureau of Standards of the Department of Commerce. Its purpose is the investigation and testing of standards and measuring instruments and the determination of physical constants and the properties of materials. To these objects it devotes about $700,000 a year to such good effect that in equipment and in the high quality and output of its work it has in ten years taken rank with the foremost scientific institutions in the world for the promotion of industrial research and the development and standardization of the instruments, materials, and methods therein employed. Its influence upon American research and industry is already profound and rapidly extending. The Bureau coöperates with foreign governments and institutions, and is constantly consulted by state and municipal officials, technical bodies, commissions and industrial laboratories, as a court of highest appeal.

I cannot better conclude this cursory and fragmentary reference to governmental work in applied science than with the words of the distinguished Director of the Bureau of Standards:—

"If there is one thing above all others for which the activities of our government during the past two or three decades will be marked, it is its original work along scientific lines, and I venture to state that this work is just in its infancy."

In view of the evidence offered by Germany of the far-reaching benefits resulting from the close coöperation which there obtains between the university laboratory and the industrial plant, it must be admitted with regret that our own institutions of learning have, speaking generally, failed to seize or realize the great opportunity confronting them. They have, almost universally, neglected to provide adequate equipment for industrial research, and—which is more to be deplored, since the first would otherwise quickly follow—have rarely acquired that close touch with industry essential for familiarity and appreciation of its immediate and pressing needs. There are happily some notable exceptions. Perhaps foremost among them stands the Massachusetts Institute of Technology with its superb engineering and testing equipment, its Research Laboratory of Applied Chemistry, and the meritorious thesis work of its students in all departments. The Biological Department has been especially active and successful in extending its influence into industrial and sanitary fields, while unusual significance attaches to the motor vehicle studies just concluded and the more recently inaugurated special investigations in electricity, since both were initiated and supported by external interests. About two years ago the Institute brought vividly before the community the variety and extent of its wide-spread service to industry by holding a Congress of Technology, at which all of the many papers presented recorded the achievements of Institute alumni.

The Colorado School of Mines, recognizing that $100,000,000 a year is lost through inefficient methods of ore treatment, has recently equipped an experimental ore dressing and metallurgical plant, in which problems of treatment applicable to ores of wide occurrence will be investigated. The Ohio State University has established an enviable reputation for its researches in fuel engineering. Cornell has been especially alive to the scientific needs of industrial practice, and a long experience with technical assistants enables me to say that I have found none better equipped to cope with the miscellaneous problems of industrial research than the graduates of Cornell. It may, in fact, be stated generally that the quality of advanced chemical training now afforded in this country is on a par with the best obtainable in Germany, and that home-trained American youth adapt themselves far more efficiently to the requirements and conditions of our industries than do all but the most exceptional German doctors of philosophy who find employment here.

Several of the great universities of the Middle West, notably Wisconsin and Illinois, have placed themselves closely in touch with the industrial and other needs of the community, and are exerting a fundamental and growing influence upon affairs. In the East, Columbia has recently established a particularly well equipped laboratory for industrial chemistry, and is broadening its work in this department.

The Universities of Kansas and of Pittsburgh are carrying forward an especially interesting experiment in the operation of industrial research fellowships, supported by the special interests directly concerned. These fellowships endow workers for the attack of such diverse subjects as the chemistry of laundering, the chemistry of bread and baking, that of lime, cement, and vegetable ivory, the extractive principles from the ductless glands of whales, the abatement of smoke nuisance, the technology of glass, and many others. The results obtained are intended primarily for the benefit of the supporters of the individual fellowships, but may be published after three years. The holder of the fellowship receives a proportion of the financial benefits resulting from the research, and the scale of sums allotted has progressively risen from $500 a year to $2,500, and even to $5,000. While some doubt may reasonably be expressed as to the possibility of close individual supervision of so many widely varying projects, the results obtained thus far seem entirely satisfactory to those behind the movement, which has further served to strongly emphasize the willingness of our manufacturers to subsidize research.

The present vitality and rate of progress in American industrial research is strikingly illustrated by its very recent development in special industries. It has been said that our best research is carried on in those laboratories which have one client, and that one themselves.

Twenty-five years ago the number of industrial concerns employing even a single chemist was very small, and even he was usually engaged almost wholly upon routine work. Many concerns engaged in business of a distinctly chemical nature had no chemist at all, and such a thing as industrial research in any proper sense hardly came within the field of vision of our manufacturers. Many of them have not yet emerged from the penumbra of that eclipse, and our industrial foremen as a class are still within the deeper shadow. Meantime, however, research has firmly established itself among the foundation stones of our industrial system, and the question is no longer what will become of the chemists. It is now what will become of the manufacturers without them.

In the United States to-day the microscope is in daily use in the examination of metals and alloys in more than 200 laboratories of large industrial concerns. An indeterminate but very great amount of segregated research is constantly carried forward in small laboratories, which are either an element in some industrial organization or under individual control. An excellent example of the quality of work to be credited to the former is found in the development of cellulose acetate by Mork in the laboratory of the Chemical Products Company, while a classic instance of what may be accomplished by an aggressive individualism plus genius in research is familiar to most of you through the myriad and protean applications of Bakelite. The rapidity of the reduction to practice of Baekeland's research results is the more amazing when one considers that the distances to be travelled between the laboratory and the plant are often, in case of new processes and products, of almost astronomical dimensions.

Reference has already been made to the highly organized, munificently equipped, and splendidly manned laboratories of the du Pont Company, the General Electric Company, and the Eastman Kodak Company. There are in the country at least fifty other notable laboratories engaged in industrial research in special industries. The expenditure of several of them is over $300,000 each a year. The United States Steel Corporation has not hesitated to spend that amount upon a single research, and the expenses of a dozen or more laboratories probably exceed $100,000 annually. The limits of any address delivered outside a jail unfortunately preclude more than the merest reference to a very few. One of the finest iron research laboratories in the world is that of the American Rolling Mills Company. Equally deserving mention from one aspect or another are the laboratories of the Fire Underwriters, the National Carbon Company, the Solvay Process Company, the General Bakelite Company, Parke, Davis & Co., the Berlin Mills Company, the United Gas Improvement Company, the National Electric Lamp Association, Swift & Co., the Pennsylvania Railroad, and many others.

Research in the textile industries has been greatly stimulated by the various textile schools throughout the country, of which the Lowell Textile School with its superb equipment is perhaps best known. The fermentation industries have been brought up on a scientific basis largely through the efforts of the Wahl-Henius Institute at Chicago and other special schools. In the paper industry general research is mainly confined to the Forest Products Laboratory at Madison, its branch laboratory for wood pulp at Wausau, the Bureau of Standards, the Paper and Leather Laboratory of the Agricultural Department, and the laboratory of Arthur D. Little, Inc., at Boston. Our own special equipment for this purpose includes, as does that of some of the other laboratories named, a complete model paper mill of semicommercial size.

There is no school of paper making in the country, and one of our most urgent industrial needs is the establishment of special schools in this and other industries for the adequate training of foremen, who shall possess a sufficient knowledge of fundamental scientific principles and method to appreciate the helpfulness of technical research. The Pratt Institute at Brooklyn is fully alive to this demand, and has shaped its courses admirably to meet it.

The steel industry in its many ramifications promotes an immense amount of research, ranging from the most refined studies in metallography to experimentation upon the gigantic scale required for the development of the Gayley dry blast, the Whiting process for slag cement, or the South Chicago electric furnace. This furnace has probably operated upon a greater variety of products than any other electric furnace in the world. Regarding the steel for rails produced therein, it is gratifying to note that after two and one-half years or more no reports of breakage have been received from the 5,600 tons of standard rails made from its output. The significance of this statement will be better appreciated when we consider that in 1885 the average total weight on drivers was 69,000 lbs. It had risen to over 180,000 lbs. in 1907, and reached a maximum of 316,000 lbs. in that year. The weight of rails during the same period had increased from 65–75 lbs. to 85–100 lbs. In 1905 conditions were so bad that out of a lot of 10,000 tons 22 per cent was removed the first year because of depressions in the head. In 1900 the American Railway Engineering Association took the matter in hand, and studied the influence and extent of segregation of specific impurities. The work was at first confined to phosphorus, but has been extended to other constituents. Fay called attention to the highly deleterious influence of sulphide of manganese.

The great railway systems have been quick to coöperate in these researches, which with others of fundamental importance have been extended by the American Society for Testing Materials, the Master Car Builders' Association, and other organizations. Materials of construction have constituted a fertile subject of inquiry in the Structural Materials Testing Laboratory of the United States Geological Survey.

There could well be a further great enlargement of the field of industrial research in special industries through the initiative and support of national trade associations, to the great benefit of their membership. The American Paper and Pulp Association, for example, should subsidize studies in the utilization of waste sulphite liquors, the paper-making qualities of unused woods and fibres, the hydration of cellulose, new methods of beating, the yields from rags, the proper use of alum, and so on. The American Institute of Metals could not do better than initiate investigations into zinc losses, the physical properties of alloys, and the production of alloys to specifications defining the properties desired, the application of the electric furnace to the industry, and the preparation of new alloys by electric or other methods. A similar opportunity knocks at the door of the American Foundrymen's Association. Some few associations, like those of the Bakers and the Laundrymen, are already active to good purpose; others, like the Yellow Pine Lumber Manufacturers' Association, are aroused; but, to the great majority of those powerful organizations, research is still an academic question to be discussed by their members individually if they so choose. Every industry has, however, its broad research problems, and its points especially vulnerable to research attack, among which it should be easy to select those of general interest to the industry as a whole.

There are in the country many analytical, testing and commercial laboratories, and in most of these special researches are conducted for clients, often with gratifying results. It is to be regretted, however, that there is not a more general appreciation among commercial chemists of the scale and quality of equipment and organization essential for really effective industrial research. As this broader viewpoint is attained and the engineer's habit of mind acquired, we may expect a great extension of independent research and the cessation of complaint regarding the trend of prices for analyses.

Among the relatively few private or incorporated laboratories with highly organized staff and adequate special equipment should be mentioned those of the Institute of Industrial Research at Washington, which has done notable work on the corrosion of metals, paint technology, canning, road material, cement, and special mill problems; the electrochemical laboratories of FitzGerald & Bennie at Niagara Falls, which have so successfully specialized on the construction and operation of electric furnaces to meet the requirements of special processes and products; the ore sampling and treating plant of Ricketts & Banks; and the Pittsburgh Testing Laboratory.

Industrial research is applied idealism. It expects rebuffs, it learns from every stumble, and turns the stumbling-block into a stepping-stone. It knows that it must pay its way. It contends that theory springs from practice. It trusts the scientific imagination, knowing it to be simply logic in flight. It believes with F. P. Fish, that "during the next generation—the next two generations—there is going to be a development in chemistry which will far surpass in its importance and value to the human race that of electricity in the last few years,—a development which is going to revolutionize methods of manufacture, and more than that is going to revolutionize methods of agriculture;" and it believes with Sir William Ramsay that "the country which is in advance in chemistry will also be foremost in wealth and general prosperity."

With these articles of faith established in our thought, let us consider where they lead us. Within the last few days Frank A. Vanderlip, than whom no one speaks with more authority upon financial matters, has told the assembled representatives of the electrical industries that they are facing a capital requirement of $8,000,000 a week for the next five years,—a total within that period of $2,000,000,000. As chemists, we are ourselves entering upon an era in which the capital demands of industries now embryonic or not yet conceived will in the not distant future be equally insistent and even more insatiable. Have we as chemists given a thought to this aspect of the development of our science or planted the seeds of the organization which may some day cope with it? In the electrical and other established engineering professions it is significant that the great industrial applications of the sciences involved have been in large part due to the activities of firms and organizations like Stone & Webster, J. G. White & Co., Blackwell, Viehle & Buck, and the United Gas Improvement Company, which by an orderly but inexorable evolution passed from the status of engineers to that of engineers and bankers. Our own profession has not yet evolved the chemist and banker, but such an evolution, or at least the close alliance of chemistry and banking, is a fundamental prerequisite if the results of industrial research are to find their full fruition in America. Let me add that no field within the purview of the banker is more ripe for tillage or capable of yielding a richer harvest.

We need, however, to lead the banker to the chemical point of view, and even more do we ourselves require to be taught the financial principles involved in the broad application of chemistry to industry. To the ideals of service which inspire our profession and which are so finely exemplified in Cottrell and made effective in the Research Corporation, we should add a stronger impulse to direct personal initiative in affairs. We shall need for years to prosecute a vigorous campaign for a better understanding by the general public of what chemistry is and what research is. The popular imagination is ready to accept any marvel which claims the laboratory as its birthplace, but the man in the works still disbelieves that two and two in chemical nomenclature make four. We need a multiplication of research laboratories in special industries, each with an adequate staff of the best men obtainable and an equipment which gives full range to their abilities. In nearly every case this equipment should include apparatus of semicommercial size in which to reduce to practice the laboratory findings. Nothing is more demoralizing to an industrial organization, and few things are more expensive, than full-scale experimentation in the plant.

These laboratories should each be developed around a special library, the business of which should be to collect, compile, and classify in a way to make instantly available every scrap of information bearing upon the materials, methods, products, and requirements of the industry concerned. Modern progress can no longer depend upon accidental discoveries. Each advance in industrial science must be studied, organized, and fought like a military campaign. Or, to change the figure, in the early days of our science, chemists patrolled the shores of the great ocean of the unknown, and, seizing upon such fragments of truth as drifted in within their reach, turned them to the enrichment of the intellectual and material life of the community. Later they ventured timidly to launch the frail and often leaky canoe of hypothesis, and returned with richer treasures. To-day, confident and resourceful, as the result of many argosies, and having learned to read the stars, organized, equipped, they set sail boldly on a charted sea in staunch ships with tiering canvas bound for new El Dorados.