ground together without burning. Such cements are suitable only for use under ground and in moist locations.

The manufacture of Puzzolan cements in this country has practically been abandoned.

The remarkable growth of the Portland cement industry is not equalled by any other manufactured article. This is due to the economy, durability, and plasticity of cement and concrete work. While large engineering work, such as dams, bridges, and heavy reinforced concrete buildings, consume large quantities of cement, the bulk of consumption at the present day is in a multitude of small uses. It takes an average shipment of only five barrels a day to take care of the average customer of a large cement company.

For example, there is a steady increase in the application of cement to new uses on the farm, such as silos, fence posts, barn floors, feeding floors, watering troughs, corn cribs, etc. There, as elsewhere, concrete is rapidly displacing all forms of wood construction, this process being hastened by the continually advancing cost of lumber.

Beautiful effects are now being obtained in concrete surface finishes and its use in decorative work is advancing rapidly.

The use of Portland cement will continue to increase until the campaign of education of the small user has reached its finality. In this direction a great work is being done to educate the general public in the proper use of cement by individual manufacturers by the Association of American Cement Manufacturers, and by the cement shows which are given in several of the largest cities every year.

In conclusion, it will be seen from the foregoing that most of the problems of utilization of wastes or by-products of the blast furnace have been solved, and that these solutions, in addition to being highly profitable, are powerful factors towards the conservation of our natural resources.

Portland cement manufactured from slag, to a large extent, replaces wood; the waste gases displace coal, and reclamation of the flue dust conserves the deposits of iron ore.

THE TECHNICS OF IRON AND STEEL.¹

By THEODORE W. ROBINSON, Vice-President, Illinois Steel Co., Chicago, Ill.

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The basis of modern civilization is the increased productiveness of labor and the accumulated wealth that has resulted from the universal use of iron and steel. The manufacture of iron and steel represents a comprehensive application of scientific research and discovery, and the indebtedness of society to our institutions of technical learning is exemplified in no more forceful way than by their influence upon our most important industry. Human progress since medieval times has been closely allied with iron's progress. The essential elements of existence have

ever been food, raiment, habitation and transportation, and the difference between our modern conditions and the conditions of the past is fundamentally the difference of the labor efficiency with which these necessities are produced. Closely analyze all the fields of human endeavor and, whether it be in the essentials of existence or the luxuries of life, somewhere the world's greatest metal will be found playing a vital part. The political demarcation of nations has been wrought and maintained by the war products of the foundry and the forge, but it is in the realm of industry that there has been found that potency of iron which has caused the progress of the last century to surpass the accomplishments of twenty centuries. Let him who questions this statement compare the average conditions of living within these periods, and let him recall that the revolutionary inventions of modern civilization are directly due to or have been permitted by the use of our most precious metal.

It is manifestly impossible in a brief address to trace the evolution of the iron and steel industry, much less to attempt a detailed description of its manufacture. We may, however, briefly discuss some of the salient changes and economies that have taken place within the past fifty years. The underlying principles of the manufacture of iron and steel are the same to-day as they were half a century ago. The mining of ore, of coal, and of limestone; the manufacture of coke; the smelting of these raw materials into pig iron; the refining of pig iron into wrought iron or steel, and its rolling or forging into the finished product—all these steps are essentially the same as they were before; and the blast furnace, converter, open-hearth furnace and rolling mill are still the agents of reduction and conversion. No industry has been more ready to recognize the merits of discovery and invention, or quicker to reap the benefits, and a well equipped iron and steel plant is to-day the very embodiment of applied science. To this is due the fact that as measured by quality, quantity, cost, and diversity of product, the efficiency of former operations has been revolutionized.

It is of interest to briefly record the progress made in this country in the manufacture of iron prior to 1860, partially that we may have a better conception of the remarkable development that has followed. The first pig iron made in America was manufactured in 1644 at Lynn, about ten miles from Boston, and there, too, was refined the first bar iron made in this country. The capitalization of this pioneer enterprise was \$5,000, and a skilled workman commanded a wage of about 55 cents a day. Referring to this industry, Governor Winthrop said that, "the iron work goes on with more hope, it yields now about seven tons per week." Such was the inception of the American iron and steel industry, and with the little plant at Lynn as a nucleus, Massachusetts for a hundred years after the settlement at Plymouth was the chief seat of this country's activity. To the Boston iron works the credit is due of rolling in 1846 some of the first iron T rails ever produced in America, and fifty years ago Massachusetts was still one of the most

¹ Presented before the Congress of Technology at the Fiftieth Anniversary of the granting of the charter of the Massachusetts Institute of Technology.

important centers of our nail industry. Even at this later period our iron plants consisted of small units of mine and mill located throughout the country with special reference to the proximity of local ores, fuel and water power facilities.

But the industry was expanding, and the year before the Massachusetts Institute of Technology was founded America produced a little over 900,000 tons of pig iron. An index of the accomplishment of fifty years prior and subsequent to 1860 is had in the 1810 production of 54,000 tons of pig iron, as against over 27,000,000 tons of pig iron produced in 1910. Such a phenomenal growth has, of course, been made possible by our wealth of natural resource; but raw material is of but potential value until won by the arts of industry, and even when converted is largely valueless until transported to its point of consumption. Cheap conveyance is a vital factor and the beneficent influence of iron and steel upon the progress of prosperity of this nation and of the world finds no more striking exemplification than its use in the art of transportation. Without the steel rail our prairies, forest and mines would still largely lie in their pristine glory and the interior fastnesses of the continents would be inviolate. Fifty years ago this country had but 30,000 miles of railroad. Transportation was expensive, slow and served little more than the important centers. The Pacific Coast was many weeks distant from the Atlantic Seaboard and the stage-coach and the pony express were essential elements of communication. The maximum capacity of the freight cars on the Pennsylvania Railroad was 9 tons, and our waterways largely dominated our commerce and industry. To-day our country is served by 240,000 miles of railroad; our freight cars are of fifty and even 100 tons capacity and the cost of transportation has been so lowered that the average remuneration of at least one of our large systems is less than five mills per ton mile. The effect of these changes is partially indicated by the 23,000,000 immigrants who have come to this country since 1860, by the increase of 60,000,000 in our inhabitants, and by the rapid movement westward of the center of our population.

But how comes it that in the short span of less than a generation such strides could be made in an industry which has basically changed but little? The application of scientific research is alone responsible and it is primarily responsible because it made possible the economic development of the Bessemer and open-hearth processes, which were given to the world a few years prior to 1860. The Bessemer process was a metallurgical failure until Mushet's discovery of the efficacy of carbon and manganese addition, and it could not have been a commercial success without the mechanical improvements of many later workers in the field. The success of the open hearth was even slower. The development of the steel industry accentuated the necessity of exact methods. The comparatively rough-and-ready way of producing wrought iron would not answer for the more difficult accomplishment of high-grade steel. As it became

recognized that the price of success was the scientific vigilance of technical men, the chemist, the metallurgist, the mechanical engineer, the steam engineer and the electrical engineer—all became essential factors. In the early stages, tonnage, as an essential element of cost, was a main consideration. Now quality stands first, and while tonnage has gone on apace, the strict inspection that commands production to-day subordinates volume to character. Under our superlative wealth of natural resource and under the insistent demand for maximum output, the questions of waste and conservation were secondary questions, and the time and money involved in the utilization of by-products were not thought commensurate with the return. But scientific management has brought about a new order of things: the selection and use of the raw materials entering into the manufacture are all subject to the analysis and control of the chemical laboratory. Chemistry is the monitor of the various steps in the transformation of ore to the finished product and with the physical laboratory stands sponsor for both the twelve-inch gun and the almost invisible wire that is drawn through the diamond die. Nearly every domain of science is called upon. The knowledge and control of heat is fundamental in the development of power and in the reduction of fabrication of steel. The essence of economic production lies in an intelligent application of the laws of hydraulics, hydrostatics, thermodynamics, and strength of materials. Electricity and magnetism play a prominent part in the transmission of power and illumination, and the refining of steel by electric energy is a departure destined to have an important future.

A modern steel plant is indeed a complex but wonderfully efficient machine. The remarkable influence that steel has exerted in the last century has been made possible by the radical reduction in its cost of manufacture. The price of steel rails affords a measure of what has been accomplished in this regard. Less than fifty years ago steel rails made their advent in this country at an equivalent of approximately 8 cents per pound. To-day rails sell for $1\frac{1}{4}$ cents per pound, or less than one-sixth of their former cost. While the reduction in cost during the last decade is naturally proportionately less than in the few decades that preceded, it is significant that in spite of the general increase in the prices of commodities the relative price of steel in this country, as shown by the commodity index, has continued to decrease in recent years. It is an eloquent testimonial to the efficiency of modern methods and to the conservatism of our iron masters that this has been accomplished in spite of the decreasing richness of our ores and a substantial increase in the cost of both labor and material.

In studying the causes of our cost reductions, two prominent factors appear. First, the fuel required to convert ore into a finished product has been largely reduced; second, the intensity of production, which roughly measures the increased efficiency of labor, has been enormously increased. At the mine in transportation, at the furnace and in the mill, ma-

chinery has taken the place of men, and a man in the steel industry to-day accomplishes from ten to fifty times as much work as did his predecessor fifty years ago.

In 1860 a thousand tons of pig iron per month was an extraordinary production for a blast furnace, and one and a half gross tons of coke was required for each gross ton of pig iron produced. To-day an output of 18,000 tons per month from a single furnace excites little comment, and the average coke consumption of the modern American furnace is a gross ton of coke for each ton of pig iron. This increase in tonnage, and decrease in fuel is the result of the uniformity and enlargement that has followed scientific management and not because of any radical departure in blast-furnace practice. In the refining of pig iron the gas producer, the regenerative furnace, the hot metal mixer, and the improvement in our prime movers have been important elements in the reduction of fuel; but it is mainly due to the substitution of the open hearth and the Bessemer converter for the puddle furnace that we are able to produce steel with nearly one-fourth less coal than was formerly required to produce iron. Our prime movers fifty years ago consisted essentially of slide valve steam engines in conjunction with low-pressure flue boilers, having an over-all efficiency of but 4-5 per cent. of the total heat in the fuel realized as work in the engine. To-day high-pressure water tube boilers and compound condensing engines with efficient valve gear have more than doubled the thermal efficiency, and the combination low-pressure steam turbine and non-condensing compound steam engine gives us a thermal efficiency of even 16 per cent. In other words, one ton of fuel with such an installation is able to do as much work as four tons of coal was formerly able to do.

The introduction of the gas engine marks another epoch in power production. With a thermal efficiency of 25 per cent., a given quantity of blast-furnace gas produces in the gas engine at least twice the amount of power obtainable with the modern boiler and steam engine. The gas engine when combined with the electric generator permits the highest development in plant concentration and in the production and transmission of power. With modern equipment the blast furnace produces a surplus amount of gas over and above its own heat and power requirements equivalent to at least 500 pounds of coal for each ton of iron produced. A notable example of the efficient use of blast-furnace gas as a by-product is presented in the new Gary, Indiana, plant of the United States Steel Corporation. There has been erected or is in process of installation over 100,000 horse power in gas engine units varying from 2,500 horse power to 4,000 horse power each, and the contemplated plant when finished will have more than 200,000 horse power in gas engines using blast-furnace gas. These, when aided by the surplus gas from the connected by-product coke ovens, will not only furnish all the heat, light and power required for all the mill departments, practically without the aid of coal, but will afford,

as well, a substantial surplus available for neighboring industries.

It can be readily appreciated, therefore, that the aggregate saving of fuel in the iron and steel industry must be enormous, and one whose effect upon the conservation of the nation's coal supply must be important. The following figures based upon actual practice give an approximation of what this annual saving amounts to: Last year the United States produced 27,298,545 tons of pig iron and 25,917,281 tons of Bessemer and open-hearth steel. Had the same coke ratio been required to smelt this pig iron as that required in 1860 we should have used 23,000,000 net tons of coal more than we actually did use. Moreover, had the pig iron which was converted into steel last year been converted into wrought iron, we should have consumed 33,000,000 tons more coal than that which was actually burned. The measure, then, of last year's fuel economy in our iron and steel industry was approximately 56,000,000 tons of coal. But this is not all. The production of coke in the United States last year was about 41,000,000 net tons, made mostly in the bee-hive oven. Had this same tonnage of coke been produced in by-product coke ovens, 10,000,000 tons less coal would have been required and there would have been an additional saving of by-products in surplus, gas, tar and ammonia of a value of \$39,000,000. Basing our calculations on 1910 production and giving coal an arbitrary value of a dollar a ton, these savings in the iron and steel and coke industries amount to \$107,000,000 per year, as the sum of what we have done and what we will shortly do toward the conservation of our coal supply.

Such are some of the savings that have permitted our manufactured products to successfully enter the markets of the world. The United States has been one of the world's great granaries. The United States is now one of the world's great workshops. Fifty years ago our exported foodstuffs surpassed in value the exports of all our manufactured products. To-day the value of our manufactured products sold abroad largely exceeds the value of the shipments from our farms. In 1860 we exported iron and steel to the value of \$6,000,000. Last year we contributed \$179,000,000 in iron and steel to the markets of the world.

While we are largely indebted to the development of the natural sciences for such results, the technics of iron and steel embrace a wider field. The science of modern organization and the ethics of management represent in themselves as marked a departure as we find in the actual operations of our works.

Half a century ago the ownership and control of our iron works lay largely in the individual, by actual ownership or through small organizations. Plants were small and comparatively numerous. There was close contact between employer and employee and the workmen were few and their duties correspondingly varied. The economies of specialization, intensity and concentration were largely unknown or impractical.

To-day our mines and mills are principally con-

trolled by large corporations. Ownership stands in thousands of small and widely scattered stockholders, and policy and operation are guided by their representatives. Plants are large and intensified production is commanded by armies of skilled men working with specialized machinery.

In achieving high efficiency and resultant low costs, the large corporation is an economic necessity. Its effectiveness in the elimination of waste is the power of large financial resource and concentrated direction. There is no better exemplification of the composite force of many owners than the plant at Gary. This, our latest extensive plant, has arisen in four years from the unbroken sand dunes of lower Lake Michigan, and is a striking illustration of the possibility of \$55,000,000 when expended by a highly developed organization.

But the change that has come with our modern system is more than in the material improvement of plant and machinery. There has followed a clearer conception of the relationship of the public, the wage earner and the investor. Industrial success means

loyalty and team work, and intelligent management appreciates that profits if they are to be sustained must not be preferential to justice and humane treatment. Coöperation with one's competitors, pension funds for the superannuated, systematic endeavor for the prevention of accidents, voluntary compensation for the injured, recognition of faithful service, elimination of Sunday work, profit-sharing, sanitary surroundings, the club, the hospital—all these are manifestations of a humane and efficient policy.

Business administration in our complex industrial life embodies many elements beside the natural sciences. There is the science of men as well as the science of machines, and both are necessary for the broadest type of industrial efficiency.

A training that is either too cultural or too specialized does not harmonize with present requirements and the Massachusetts Institute of Technology, in recognizing the commercial as well as the technical needs of the times, is but maintaining her tradition for progressive thought and leadership in method.

SCIENTIFIC SOCIETIES.

INDIANAPOLIS MEETING, AMERICAN CHEMICAL SOCIETY.

Four hundred and thirty-two members and guests attended the summer meeting at Indianapolis, which was the largest summer meeting of the American Chemical Society ever held. The meeting was an unusually successful one, both from the standpoint of work accomplished and the general enjoyment of those present.

Those members who appeared a day early were treated to an automobile ride around the famous Indianapolis Speedway, followed by a dinner at the University Club.

The general meeting itself opened on Wednesday morning, June 28th, with an address by Charles Baskerville, on "The Chemistry of Anesthetics," and by W. Lash Miller, on "The Chemical Philosophy of High School Textbooks." At the close of this session Dr. W. F. Hillebrand presented a preliminary report for the Committee on the Quality of Platinum Laboratory Utensils, which was afterwards discussed in the sessions of the Industrial Division.

The hospitality of the local members knew no bounds and a complimentary luncheon was served each day. Also an unusually attractive complimentary "smoker" was held at the German Club House on Wednesday night, at which mementoes were distributed, consisting of bakelite cigar holders, watch fobs bearing the Society's emblem, and steins, also stamped with the Society's pin in blue and gold. On Thursday evening a public lecture by A. D. Little on "The Earning Power of Chemistry" was delivered at the German House, followed by a concert in the German House gardens. Visits to manufacturing plants were a feature of the meeting, among which should be especially mentioned Eli Lilly & Co., the Van Camp Packing Co., Kingan & Co., E. C. Atkins & Co., Encaustic Tile Co., Nordyke & Marmon Automobile Co.,

Fairmount Glass Works, the Indianapolis Water Works, and the Polk Sanitary Milk Co. An especially interesting program was also arranged for the visiting ladies, all of whom expressed themselves as thoroughly pleased with the entertainment given.

On Friday evening nearly two hundred members and guests gathered at the Columbia Club for the usual midsummer banquet. The banquet was a great success. The tables were decorated with flags and flowers, the menu offered was of the best and the speeches were greatly enjoyed. Dr. H. W. Wiley acted as toastmaster and introduced as the special speakers of the evening Governor Marshall, of Indiana, and ex-Vice-President Fairbanks. Many ladies attended the banquet, which was also graced by the presence of Mrs. Marshall. One of the best orchestras in the West furnished music during the evening.

A transcript of the minutes of the meetings of the Industrial, Fertilizer, Agricultural and Food, and Pharmaceutical Divisions follows, as well as an account of the meeting of the Rubber Section. The record of papers in the Organic, Physical and Inorganic Divisions and the Biological Section will appear in the regular proceedings of the Society.

Division of Industrial Chemists and Chemical Engineers.

GEORGE D. ROSENGARTEN, *Chairman*.

Dr. Rosengarten thanked the Division for his election and requested the earnest coöperation of its members in order to secure papers of value and further the work of the Division.

The reading of the minutes was dispensed with.

The report of the secretary was read and accepted, of which the following is an extract:

"The secretary has to report for the Executive Committee that since the last meeting they have elected as Chairman of the Division in the place of George C.