

gold, the Hickman machine for converting starch to cane sugar, and the electrical process by which spruce wood was transformed into Australian wool with the grease in and the burrs attached, is just now figuring its losses on synthetic rubber. It left to other communities the formula of the Altoona cobbler for burning ashes, the process for converting water into kerosene, and the Lamoine diamonds. Men who turn a box of strawberries upside down and require a pastor's certificate of character from the office boy, rush into misapplied chemistry with never a thought of expert investigation or advice. The pity is the greater when one realizes, as every chemist does, the generous scale by which are measured the rewards of chemistry properly applied and wisely administered. Ten years ago a Massachusetts company with a capital of \$20,000 was organized to conduct a manufacture based on chemistry; two years ago it charged off \$700,000 on real estate and equipment; to-day it has a surplus of over \$1,000,000. The great Badische Anilin und Soda Fabrik, the Elberfeld Co., Brunner, Mond & Co., the E. I. duPont de Nemours Powder Co., Meister, Lucius & Bruning, the Solvay Process Co., and many others well-known to every chemist are among the most profitable industrial organizations in the world. The one thing lacking for an enormous development in this country of equally profitable enterprises based on chemistry is a reasonable appreciation by our business men of the earning power of chemistry.

The ordinary investor who may safely trust his own judgment in matters involving cotton, wheat, mortgages, railroad shares or telephones is not equipped by training or experience to decide upon the validity of propositions involving chemistry. He must, if he would avoid disaster, rely upon the opinion of disinterested experts. Such opinion should cover the soundness of the chemistry involved, the state of the art relating to the manufacture, the patent situation, the available market, the nature and extent of competition, the supply of raw material, the stage of development of the process, the cost of plant and the costs of production. These last should be itemized and the basis for conclusions regarding every item should be fully stated. Large allowances should invariably be made for depreciation and in most cases equally liberal allowances for contingencies. Secret processes should be left to the fool and his money.

In this environment and on this occasion I cannot forbear making a brief concluding reference to that organization of chemists which now enjoys your hospitality. At Northumberland, Pa., there lies the body of an obscure English dissenting clergyman who went through life on a salary of £30 a year, although he had enriched the world by the discovery of oxygen. It was around the grave of Priestley on July 31, 1874, that the idea of the American Chemical Society first took form in the minds, and may I add the hearts, of a few American chemists met to do honor to his memory. Subsequent meetings were held in New York at the home of that Nestor among American chemists, Prof. Charles F. Chandler until on April 20, 1876, the Society was formally organized. From

a feeble organization of distinctly local character, with only 200 members in 1887 it has through the service and self-sacrifice of a long series of devoted officers become the largest chemical society in the world, with 5,500 members, and is to-day the most powerful influence in America for the advancement of chemical science. Its claim upon the loyalty and support of every American chemist can no longer be denied or set aside. With equal justification it may appeal to the whole community for recognition and encouragement.

There are in the country at least 100,000 doctors and nearly 125,000 lawyers. There are only 10,000 chemists to carry on a work incomparably more important than litigation and no less beneficial than medicine to the life of the community if that life is to be worth living. Some measure of the mere material benefits which chemistry can offer may be found in the fact that the annual production of the chemical industries of the United States is already nearly equal in value to our agricultural products. Let us, however, not forget that these benefits have come, as many more will follow, because chemists have never faltered in pursuing truth for years through the labyrinth of difficult researches with no better guide than the slender and often broken thread of an hypothesis. Turgot has said: "What I admire in Christopher Columbus is not that he discovered the new world but that he went to look for it on the faith of an idea."

THE UTILIZATION OF THE WASTES OF A BLAST FURNACE.¹

By EDWARD M. HAGAR, President, Universal Portland Cement Co., Chicago.

Received May 22, 1911.

Until the last decade, practically the only utilization of the wastes or by-products of a blast furnace was the use of a portion of the waste gases to raise the temperature of the incoming blast through heating the brick work in so-called hot stoves, and in some cases a small portion of the power value of the gases was obtained by burning them under boilers to generate steam for driving the blowing engines.

At the present time the calorific value of the waste gases is being utilized directly in gas engines for blowing purposes and for generation of electric power, a considerable portion of the slag is used in the manufacture of Portland cement, and the flue dust, consisting of the finest ore and coke particles, is being collected and converted so as to be rechargeable into the furnaces.

The aggregate saving or profits resulting from these three developments is a matter of millions of dollars per annum, and in a modern blast furnace plant, it would almost seem that pig iron was the by-product; and, indeed, the investment in the equipment to utilize these former wastes exceeds that of the blast furnace itself.

The writer, in his work, has come in contact with

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

these evolutions, with plants in operation, or under construction, of a capacity to produce twelve million barrels of Portland cement per annum from slag and limestone, using over one million three hundred thousand tons of slag in a year, these plants being driven entirely by electric current generated by gas engines directly from the waste blast-furnace gases, the power requirements being forty thousand horse power for twenty-four hours every working day. In one of the cement plants the first commercial method for reclaiming flue dust was discovered.

By using the blast-furnace gases directly in combustion engines, after suitable washing to remove the grit, the power obtained from a given amount of gas is equal to at least two and one-half times that obtainable by burning the gas under boilers for generating in steam engines.

A modern blast furnace of the usual size, with gas blowing engines, and gas engines driving electric generators, will provide sufficient gas to furnish seven thousand kilowatts electric power, in addition to driving its own blowing engines.

This permits the most modern steel works, such as those at Gary, Indiana, to practically do away with the use of coal for power purposes, operating the rolling mills by electric power from the surplus gases.

The United States Steel Corporation, of which the Universal Portland Cement Co. is a subsidiary, has already installed two hundred and fifty thousand horse power gas blowing and gas electric units, which, it can easily be figured, displaces or saves the consumption of approximately a million tons of coal per annum as compared to the old-fashioned method.

With the modern high blast pressures, and the use of fine Mesaba ore, the finest of the particles, together with the coke dust, are blown out through the top of the furnaces and are caught in the flues, dust catchers and gas washers.

The iron ore in this dust amounts to fully 3 per cent. of the total ore charged, which aggregates the large amount of approximately a million and a quarter tons per annum in this country. Until within a few years, this dust has been thrown away or used as filling, although containing about 40 per cent. metallic iron.

For many years efforts were made to use this material by compressing it into briquettes, but the cost of the operation, together with the fact that the briquettes disintegrated and the dust was again blown out, led to an abandonment of the briquetting plants.

The first commercially successful method of utilizing the dust was discovered by passing the material through the cement kilns at South Chicago. Experiments showed that with the proper heat treatment the coke dust could be burned off and the iron ore conglomerated into nodules or nuggets averaging over 60 per cent. iron content. These nodules, when fed to the blast furnace, were easily and completely reduced. The fact that the sinter of the flue dust contains such a high percentage of iron and that all of the sinter is reduced, together with its physical shape assisting the steady movement of the charge downward in the blast furnace, thereby preventing

so-called slips, makes the sinter more valuable per ton than any ore.

It was necessary to derive mechanical means for preventing the accumulation of the sinter on the walls of the kiln. Plants have been in operation for some years using this process, with endless chains carrying scrapers constantly passing forward through the kiln, and cooled in water on their return outside of the kiln.

Recently other methods of utilizing dust have been devised which may prove successful commercially, and the indications are that within a short time the greater portion of this former waste will be prevented.

The development of the Portland cement industry in this country and the extension of its uses have been marvelous, and the following table shows a remarkable increase in the production of Portland cement in the United States every year since 1895, when this country first reached the production of approximately one million barrels:

Year.	Production of Portland cement of United States Barrels.	Production of Universal Portland cement Barrels.	Percentage of Universal to total American production of Portland cement.
1895.....	990,324	.....	..
1896.....	1,543,023	.....	..
1897.....	2,677,775	.....	..
1898.....	3,692,284	.....	..
1899.....	5,652,266	.....	..
1900.....	8,482,020	32,443	0.39
1901.....	12,711,225	164,316	1.29
1902.....	17,230,644	318,710	1.85
1903.....	22,342,973	462,930	2.08
1904.....	26,505,881	473,294	1.78
1905.....	35,264,812	1,735,343	4.92
1906.....	46,463,424	2,076,000	4.55
1907.....	48,785,390	2,129,000	4.36
1908.....	51,072,612	4,535,000	8.89
1909.....	62,508,461	5,786,000	9.27
1910.....	73,500,000—Gov. est.	7,001,500	9.52

It may be of interest to note the increasing percentage of the total American production shown by universal Portland cement, which is the only Portland cement manufactured in this country using slag as one of the raw materials. With the new plant now approaching completion the aggregate production of Universal Portland cement in the Chicago and Pittsburgh districts will amount to over one-eighth of the country's total. Expressed in weight, the output of the finished product will be over two million gross tons per annum. Our plants in the Chicago district will consume all the available slag that is suitable for the purpose from an aggregate of nineteen blast furnaces in the South Chicago works of the Illinois Steel Company and in the Gary Works of the Indiana Steel Company.

Comparing the pig iron production and Portland cement production of this country in figures of long tons, the percentage of Portland cement to pig iron in 1890 was six-tenths of 1 per cent., in 1900 $10\frac{3}{10}$ per cent., and in 1910 47 per cent. The continuation of any such relative growth would mean that before 1920 the tonnage of Portland cement would considerably exceed that of pig iron. I would hesitate, however, to predict that such would be the case.

Portland cement is defined by the United States Government as the product obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least one and seven-tenths times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent. of the calcined product.

From this definition it will be seen that the raw material for Portland cement is not limited to any particular form of material, it may be made from any combination of materials that together furnish the proper elements. In this country Portland cement is manufactured from a number of raw materials, which, with a few exceptions, may be classed under four heads:

First.—Argillaceous limestone (cement rock) and pure limestone.

Second.—Clay and shale and limestone.

Third.—Clay or shale and marl.

Fourth.—Slag and limestone.

In all cases the raw mixture is a combination of some form of clay and some form of lime, and in the first and fourth classifications the clay materials contain some lime. This simply reduces the proportion of lime material necessary for a proper mixture.

In the manufacture of Portland cement from slag and limestone the molten slag flowing from the furnaces is granulated by a stream of water, loaded into cars and transported to the cement plants, where it is dried in rotary driers, and receives the first grinding; it is then mixed in automatic weighing machines, with the proper proportion of ground and dried calcite limestone. These are then ground together and burnt to a hard clinker at a temperature of nearly 3000° F. in rotary kilns, using pulverized coal for fuel.

This clinker, after seasoning, is crushed and ground and mixed with a small percentage of gypsum to regulate the setting time. The cement is ground to such fineness that 96 per cent. passes through a sieve having ten thousand meshes, and 80 per cent. passes a sieve with forty thousand meshes to the square inch. It is then conveyed to the stock house for storage prior to shipment.

It is necessary to use a flux in furnaces supplying slag for cement manufacture, a pure calcite limestone. The limestone burnt with the slag must also be a pure calcite stone. It is also essential that the ores be of a uniform and proper character.

Inasmuch as Lake Superior ores are noted for their remarkable uniformity of analysis, the resultant slag obtained from the use of these ores and a pure calcite limestone is more uniform in its analysis than any form of natural clay deposits used in the manufacture of Portland cement, and the variation in the proportions of the two raw materials used in the manu-

facture of Portland cement from slag is less than those of any other materials mentioned above.

In addition, the opportunity for analysis and selection of the proper ingredients through the use of an artificial material is a great advantage as compared to the necessitous use of natural materials just as they are found with their variations in analysis at different depths.

In the intense heat of the kiln, under the influence of the oxidizing flame, any sulphides in the slag are completely burned out.

The rotary kiln commonly used ten years ago was sixty feet long and six feet in diameter. This has gradually been increased in length and diameter until the modern kiln is one hundred and forty to one hundred and fifty feet long and eight to ten feet in diameter, and there are a few even larger kilns in use. Kilns are usually set at an incline of three-quarters of an inch to the foot. With the lining and contents the modern kiln weighs one hundred and fifty tons, and in revolving upon two bearings presents interesting constructional features.

In the case of the plant at Buffington, Indiana, using twenty-six thousand horse power, situated between South Chicago and Gary, Indiana, electric power is supplied at twenty-two thousand volts from the steel works at these points. Each piece of machinery is driven by its individual motor, supplied with alternating current at four hundred and forty volts. The high tension line is connected through the cement plants, and the gas engines at these two steel works, fourteen miles apart, operate continually in parallel. This enables the cement plant to draw its power from either source, or from both sources at the same time, as may be desirable. It has happened that one of these works has supplied power to operate the cement plant and furnished additional power at the same time to the steel works at the other end of the line.

The method of manufacture above described is the standard method of manufacturing Portland cement from natural deposits, and the finished product differs in no way from other Portland cements in chemical analysis, fineness, specific gravity, color, nor in the operation in practical work. It has no peculiarities whatever and has no limitations as to its applications. There is no difference, from the chemist's point of view, between the manufacture of Portland cement from natural deposits, such as limestone and clay or shale, and its manufacture from limestone and slag. Slag is really a mixture of the clay from the ore with the lime content of the stone used as a flux in the furnace.

Our method of manufacture of Universal Portland cement does not embody any real invention, nor is it based on any patents. It is simply an adaptation to an artificial raw material of the regular Portland cement process formerly applied only to natural deposits.

True Portland cement in which slag is used as one of the raw materials should not be confused with puzzolan or so-called "slag cements" which are simply mechanical mixtures of slag and slaked lime

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.

Received May 22, 1911.

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.