

of collection and distillation at present yields of only 18 to 20 per cent are obtained. This loss of at least one-third of the volatile oil by evaporation remains still to be overcome.

Some chemists have established new industries, and many have cooperated to improve old ones, but this work of Herty's in making, practically alone, such a change in an industry that had been stationary in methods for a hundred years, is almost unique.

As to other improvements in manufacture, not much progress has been made. The French method of bleaching rosin seems too slow and laborious, and many chemical methods have been suggested instead, but up to the present have not made much headway. Methods of distillation without the use of direct heat, such as using superheated steam, or distillation in vacuum have been suggested but have had little influence as yet on methods of manufacture. The United States Bureau of Forestry has recently been studying the question of chipping, and has published results indicating that a $\frac{1}{2}$ inch chip gives about as good a flow of oleoresins as an inch chip, besides being less injurious to the tree. They further recommend chipping every four days instead of once a week, thereby increasing the yield in a season. It has been objected that the tree may not be able to stand this excessive bleeding. The method is still to be tried in practice.

When turpentine was comparatively high in price, many substitutes, chiefly from petroleum distillates, and many methods of adulteration were found. Presumably we must give the chemist credit for these too. The question of adulteration particularly became a serious problem and provoked a flood of literature devising tests for various impurities and additions. Most of the large consumers finally evolved specifications to fit their requirements, and many states have passed laws for preventing and punishing adulteration, so that conditions now are much improved, for which we may also thank the chemist. There is still much work to be done, however, in standardizing turpentine specifications to fit the consumers specific requirements. As they now stand, with rather arbitrary figures on specific gravity and distillation, we, no doubt, often include material he really does not want, and exclude material he could perfectly well use.

Rosin has usually been too cheap to suffer from adulteration except with dirt or brickbats. The chemist has little to do with its purity or grading. Recently, however, the United States Bureau of Chemistry has proposed a series of permanent standards, for the different grades of rosin, based on definite transmissions of red and yellow light for each grade.

In extending the markets for Naval Stores the chemist has done little for turpentine. It has had three uses for many years: (1) As a solvent for gums in the manufacture of varnishes; (2) as a vehicle in the manufacture of paints; (3) as a thinner in the application of paints. The chemist has more often striven to avoid its use in these fields than he has to extend it. Two new fields have been opened within recent years, by chemists—one the manufacture of synthetic camphor. This has been carried on to a considerable extent in a commercial way, and will be again, whenever satisfactory relations exist between the market prices of turpentine and camphor. If the yields of camphor could be made more satisfactory it would no doubt become a permanent industry. But at present, with the price of the raw material, turpentine, and of the finished product, camphor, independent variables, and no large margin in any case existing above the fixed manufacturing cost, the outlook is not enticing to the investor. The second new field opened by the chemist is the manufacture of synthetic rubber. Synthetic rubber can be made from isoprene, and isoprene can be made from turpentine, but whether this is the best way to make synthetic rubber, and whether turpentine is the best source of isoprene, and whether synthetic rubber can compete with natural rubber in the long run anyway, are still open to discussion.

With rosin the chemist has had more opportunity. He puts it into shrapnel shells and sometimes into varnish. In the presence of an alkali, rosin acts as an acid, forming resinates. Combined with an amount of soda insufficient to saponify the whole, it forms rosin size, extensively used in the manufacture of papers, where the rosin deposited in the paper prevents the spreading of ink and moisture. This accounts for a very considerable amount of the medium grades. A somewhat higher grade of rosin, when saponified, forms a valuable constituent of, or addition to, many soaps. Combined with zinc, manganese or the alkaline earths, rosin gives resinates used extensively in varnishes.

A very large amount of rosin, particularly of the lower grades, is distilled for the production of rosin oil. The lower grades of rosin oil when mixed with lime, set to form a semi-solid mass (axle grease) extensively used as a lubricant. Better grades are used extensively in the manufacture of printing ink, so that the marvelous increase in printing and paper during the last fifty years has furnished an outlet for rosin in two directions. All of these varnish, soap, paper and printing industries have furnished abundant fields where the chemist has exercised and continues to exercise his ingenuity on rosin and its products.

In the manufacture of rosin oil the yields and quality are not always what they should be. Recent suggestions of different methods of distilling promise much larger yields of better quality oil with smaller amounts of by products.

To conclude, we find the chemist has been particularly valuable in three departments of the Naval Stores Industry. He has improved largely the quality and quantity of product, has standardized grades and prevented adulteration, and has been very successful in finding products and derivatives to fit the markets, or in finding markets to fit his products. This last field especially is far from worked out. There is still a wide scope for the energies of the chemist.

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CONTRIBUTIONS OF THE CHEMIST TO THE STEEL INDUSTRY

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To demonstrate the service that chemistry has rendered to an industry such as that of steel, whose whole foundation is chemistry, and where even the messenger boys about the works speak of carbon, phosphorus, sulfur, silicon, etc., almost as freely as they use the terms of the baseball field, would require volumes. In fact, volumes have been published on the part taken by one element alone. To present, therefore, in a brief outline the success that chemistry has achieved in this tremendous industry is a most difficult task, and it is with considerable hesitation that this paper is presented. Perhaps by picturing the past at a time when the chemist was an almost unheard of factor in the iron and steel industry, in contrast with the present conditions, the object of this paper might be attained.

Harking back somewhat more than half a century with an old furnace man who possessed a mind as active and clear as it was at the time of which he spoke, despite his ninety years, he made the following statement: "A water wheel at the flour mill ran the blower, supplying air to us at the forge several hundred feet distant. Here the pig iron, brought up in canal boats from a charcoal furnace forty miles down the river, was melted in the run out, subsequently tapped into two forge fires, there worked to nature, and forged into blooms under a trip hammer run by the old-fashioned overshot water wheel. . . The blooms were cut in two pieces about 80 to 100 pounds each and then shipped by canal to Pittsburgh to be rolled into sheets, bars or rods, and then into wire; or to be melted in crucibles and made into steel. Charcoal was the fuel we used. It made mighty fine iron and steel, and that without your chemists. Two tons was a day's output, but we made it right and never had any rejected."

Picture the forge with its two "fires," but little larger than fire-places, its "run out" an enlarged blacksmith's forge on top of a hearth or crucible, and its ten men coming to work at 3 A.M. and quitting at 3 P.M. with two tons of good iron, then worth almost \$250, to the credit of the sweat of their brows and twenty cords of wood sent up in smoke. Then remember that before this iron became steel it must be heated, forged or rolled into bars, cut up, charged into crucibles, melted, cast and again hammered into bars at the expense of much time and labor. This was the iron and steel business previous to 1860, with wood for fuel and no chemist. The product was expensive and its use limited; only 40,000 tons of cast steel were produced in 1872, sixteen years after the introduction of Henry Bessemer's process.

In the year 1915, with this picture in our minds, we walk through the latest steel plant, wherein are embodied the experience of the many previous years of the chemists and the engineer's efforts.

The locomotives are placing drafts of cars of 50 tons capacity, so that their contents may be added to the almost mountainous piles over which moves what appears to be a bridge without any approaches, but which is a huge crane capable of handling 2500 tons every 12 hours. It scoops up, at each mouthful, tons from the piles and quickly places the ore, limestone and coke in the respective bins from which definite measured quantities are being continually taken and by means of an inclined elevator carried to the top of a blast furnace stack and dumped into its capacious mouth, fully 85 feet above the ground. Every twenty-four hours this stack has produced 500 tons of iron of definite predetermined composition and at a fuel efficiency of 60 per cent, the highest so far obtained from any heating furnace using fuel. The molten slag, instead of being thrown over the dump, is granulated and used for making cement or as a fertilizer. The waste gases from the stack, after all possible heat has been abstracted, are burned to generate steam for the turbines producing the electricity used about the plant. To keep this blast furnace in operation requires engines for blowing 40,000 cu. ft. of air per minute at 15 to 20 lbs. per sq. in. pressure, a condensing pump, ten 350 H. P. boilers, and a water purifying plant with a capacity of 60,000 gallons per hour.

The molten iron as it comes from the blast furnace is caught in ladles holding 30 tons each and hauled by a locomotive to the open hearth department 1000 yards away. This department is contained in a building almost 1000 ft. long \times 175 ft. wide \times 90 ft. high. It includes, in addition to the 500-ton electrically tilted mixer, ten 75-ton open hearth furnaces. Into the mixer the molten iron is poured as one would pour cream from a pitcher, and from this mixer or reservoir a weighed quantity of molten iron is poured into a smaller ladle and charged into the open hearth furnace together with definite predetermined quantities of scrap steel, iron ore, and limestone or sand.

The steel making is begun, and after about eight hours of boiling, as it were, the requisite amounts of ferro-manganese, ferro-silicon or aluminum are added; then the 75 tons of steel are teemed into ingots weighing from 3 to 8 tons. As soon as the steel has solidified the ingots are stripped from the moulds by a huge machine, almost human in its action, then carried off to the soaking pits where they are kept hot until ready to be rolled and cut into billets. The capacity of this department is over 2000 tons of ingots per day. In the meantime drillings from a test ingot have been analyzed by the chemist, thus checking the efforts of the melter to produce steel of a definite desired composition, and the ingots are bloomed to the correct size for the next step. This blooming is done in a building over 300 ft. long \times 75 ft. wide, containing, in addition to the soaking pits at one end, a blooming mill equipped with the necessary mechanical handling devices, operated by a 20,000 H. P. reversing engine and also hydraulic shears capable of cutting a 20 \times 20 in. bloom.

Following our product from the blooming mill to the bar

mill, we see it charged, perhaps in the form of billet 4 in. \times 4 in. \times 11 ft. into a continuous furnace of a capacity of 150 tons per day; thence it emerges, almost automatically, at the opposite end heated to the correct rolling temperature, and twisting and writhing like a snake it passes from one set of rolls to another and then loops back and forth through another set of rolls, finally emerging a bar over 300 ft. long, 2 in. wide and 0.260 in. thick. This mill will turn out 300 tons of this per day in straight lengths, and varying in thickness not more than 0.010 in. from the size mentioned.

The steel mill just pictured is the home of small things as well as large, and just as the efforts of the engineer have produced the 500 tons per day furnace, the 20,000 H. P. engine and the trains of rolls weighing tons in themselves, seemingly so rough or crude, and just as these in turn have enabled the manufacturer to turn out bars of steel with a variation in size of 0.010 in. and less from the desired thickness, so have the efforts of the chemist been bent towards not only estimating and controlling those elements which are found in steel in large quantities, but also those to be found there in the most minute amounts, all with the greatest accuracy and speed.

Steel would not exist were it not for the element carbon; therefore, the determination of this element is most frequent. Although the most obvious method was to burn the metal and collect the CO₂, it was not until the last five years that this was done with assurance—a result attained through the high temperature obtainable with the electric furnace, the development of refractories and the ease with which oxygen can be obtained. Fifteen to twenty minutes after the sample is taken the melter is advised of the carbon content of his 75 tons of molten steel, the necessary additions are made and steel to the required analysis is cast; and this whether or no that analysis includes simply the usual elements, carbon, manganese, phosphorus, sulfur and silicon or the elements chromium, nickel, vanadium, tungsten, titanium or any of the other elements which are used in the production of the alloy steel. For so has the analytical chemist improved his methods that to-day the estimation of almost all the afore-mentioned elements is but a matter of minutes, and the accuracy a few thousandths of one per cent.

The extent of the analyst's work may be judged from a consideration of the data in Table I.

TABLE I—INGOTS AND CASTINGS—GROSS TONS
Electric and all other

Years	Bessemer	Open hearth	Crucible	Electric and all other	Total
1898.....	6,609,017	2,230,292	89,747	3,801	8,932,857
1899.....	7,586,354	2,947,316	101,213	4,974	10,639,857
1900.....	6,684,770	3,398,135	100,562	4,862	10,188,329
1901.....	8,713,302	4,656,309	98,513	5,471	13,473,595
1902.....	9,138,363	5,687,729	112,772	8,386	14,947,250
1903.....	8,592,829	5,829,911	102,434	9,804	14,534,978
1904.....	7,859,140	5,908,166	83,391	9,190	13,859,887
1905.....	10,941,375	8,971,376	102,233	8,963	20,023,947
1906.....	12,275,830	10,980,473	127,513	14,380	23,398,136
1907.....	11,667,549	11,549,736	131,234	14,075	23,362,594
1908.....	6,116,755	7,836,729	63,631	6,132	14,023,247
1909.....	9,330,783	14,493,936	107,355	22,947	23,955,021
1910.....	9,412,772	16,504,509	122,303	55,335	26,094,919
1911.....	7,947,854	15,598,650	97,653	31,949	23,676,106
1912.....	10,327,901	20,780,723	121,517	21,162	31,251,303
1913.....	9,545,706	21,599,931	121,226	34,011	31,300,874

Included in the total for 1913 are about 714,357 tons of ingots and castings which were treated with ferro-vanadium, ferro-titanium, ferro-chrome, nickel, or other alloys, of which about 625,430 tons were ingots and about 88,927 tons were castings, as compared with about 892,501 tons in 1912, of which about 689,392 tons were ingots and about 103,109 tons were castings. Of the total in 1913 about 74,924 tons were Bessemer steel ingots or castings, about 599,890 tons were open hearth, about 28,279 tons were crucible, about 11,254 tons were electric, and about 10 tons were miscellaneous. Of the total production of steel ingots in 1913 about 625,430 tons were treated with ferro-vanadium, ferro-titanium, ferro-chrome, nickel or other alloys, of which about 53,751 tons were Bessemer ingots, about 535,577 tons were open hearth, about 25,281 tons were crucible, and about 10,821 tons were electric.

Therefore, assuming the sizes of the heats of steel made by the respective processes to average 10, 50, 1.5 and 6 tons, and each heat to have required one determination of each of the five usually estimated elements, we would have for the year 1913 the interesting data in Table II, in which round figures only are used.

DETERMINATIONS	Bessemer	Open hearth	Crucible	Electric
Carbon.....	954,000	432,000	81,000	5,700
Manganese.....	954,000	432,000	81,000	5,700
Silicon.....	954,000	432,000	81,000	5,700
Sulfur.....	954,000	432,000	81,000	5,700
Phosphorus.....	954,000	432,000	81,000	5,700
Nickel.....	.....	7,000	3,400	1,800
Chromium.....	.....	5,400	7,700	900
Vanadium.....	.....	2,700	1,700	500
Titanium.....	5,300	1,100	.....	.....
Total.....	4,775,300	2,176,200	417,800	31,700
GRAND TOTAL.....	7,401,000 determinations			

These figures are startling, and yet they do not, by any means, wholly represent the analytical work connected with the production of the steel itself. It is not to be understood that these figures represent the actual conditions, for it is very questionable if one-half the Bessemer steel heats are analyzed; on the other hand, however, many companies make two and three check determinations on a single heat of open hearth steel. The figures as a whole are very probably far short of showing the work of the analytical chemist associated with the production end of the steel industry. The analyses connected with the blast furnace, such as those of pig iron, ores, slag, coal, coke, gases, refractories and water, should be added to these and also those determinations made upon the ordinary or regularly used ferro-alloys and metals, not to mention those necessary for the production of alloy steels containing chromium, nickel, vanadium, titanium, cobalt, tungsten, copper, molybdenum, and perhaps uranium, either singly or in combination.

Frequently much of this steel when it reaches the consumer is again analyzed so that the part analytical chemistry plays in the steel industry is seen to be extensive and absolutely indispensable. Without it we could not ride from New York to Chicago in twenty hours nor drive with safety in an automobile at a fair rate of speed, nor would we have our high structures, huge bridges or viaducts, nor any of the modern mechanical equipment for operating our factories.

To obtain the high fuel efficiency of the blast furnace, the control of the Bessemer converter and of the open hearth furnace has necessitated an extensive and careful study of the weights and volumes of gases, high and low temperature measurements, heats of combustion of gases and fuel. Thus physical chemistry is seen to be an essential aid, since the metallurgy of steel involves principles which are not only chemical but also physical and mechanical. The moisture of the air was of sufficient economic importance to the efficiency of the blast furnace that its removal by refrigeration was undertaken, following a study of the physical chemistry of the blast. In the Talbot open hearth furnace, a bath of molten steel is used to excite the reaction between molten pig iron and iron ore, with a saving of fuel, since the materials themselves burn each other as it were, an achievement following the study of the thermochemical reaction between carbon and oxide of iron.

Not only has inorganic chemistry in its analytical, physical and thermo phases played a highly important part in the steel industry, but also organic chemistry is entering the field. The production of coke is accompanied by the making of coal tar which is the source of benzol and many other valuable bases used throughout the chemical and allied industries. It is now proposed by one of the largest steel producers, to take up this feature and develop it.

In concluding this presentation, which, on account of the broadness of the subject is necessarily very incomplete, mention should be made of the part electricity has more or less recently played. While the process of making steel with electricity is primarily electrothermic, an extensive chemical study of refractories and electrodes was necessary before the process attained its present status. The high temperature which could

thus be gotten enabled the use of hitherto impossible combinations for slags with the result that steels of a greater purity became possible and these from scrap or iron containing high percentages of objectionable elements such as phosphorus and sulfur; the chemist was thus also enabled to produce ferro-alloys otherwise impossible.

It is hoped that this article may give to those unfamiliar with the metallurgy of iron and steel some idea of the all-important part chemistry has had in the success of one of the greatest of the world's industries.

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CONTRIBUTIONS OF THE CHEMIST TO THE IRON AND STEEL INDUSTRY

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The contribution of chemistry to the iron and steel industries may be said to have begun with the introduction of the great pneumatic processes of steel making in the latter part of the 19th century. The Bessemer process, brought out in 1863, and the Siemens-Martin open hearth process which followed soon after, produced a revolution in the iron industry that gave the chemist his first opportunity. Before the days of steel, iron making was largely an empirical art, and no one considered the estimation or control of the impurities which usually accompany the metallurgy of iron to be a matter of vital importance. It was, of course, known through the operation of the puddling and crucible processes that certain elements could be depended upon to confer hardness and toughness, but the very important quantitative rôles in the metallurgy of iron played for good or ill by the ever-present five elements—carbon, manganese, sulfur, phosphorus and silicon—were not understood. It was by means of his original researches into the methods for determining and controlling these so-called impurities that the chemist began to force his coöperation upon the more or less unwilling body of contemporary metallurgists. Even within the metallurgical memory of the present writer, which does not comprise more than a third of a century, iron masters were loathe to recognize the necessity for well-equipped laboratories under the charge of college-bred chemists.

After the ore is mined and shipped, the iron industry begins in the blast-furnace in which chemical reactions involving enormous energy exchanges take place. Just as soon as the professional chemist was allowed to win his way from the laboratory into the works, revolutionary changes in output and economy were very soon accomplished. This move forward constitutes, in the opinion of the writer, the first great contribution to the iron industry made by the chemist.

In the meantime, the steel maker, in charge of the rapidly developing pneumatic processes, required to know and follow the content of carbon, manganese and other impurities during the progress of a heat. Analytical chemistry came to the rescue by devising quick methods of analysis. So rapid has been the development along this line of chemical contribution that the modern metallurgist can literally obtain his information while he waits and thus modify and control the degree and duration of his heats. The writer has information that by a recent method even carbon by combustion can be accurately determined in eight minutes from the time the sample drillings are delivered to the laboratory. The development of modern methods of rapid and accurate analysis may be held to constitute another great contribution of chemistry to the metallurgy of iron and steel.

Modern metallurgy has not been satisfied with the development and improvement of ordinary carbon steels, for modern industrial requirements have demanded the production of alloy steels possessing marvelous and, until very recently, unheard of and undreamt of physical properties. The ores of the rarest elements have been unearthed to produce these wonderful