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IN THE HISTORY OF
THE ROLLING MILL
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PRESIDENTIAL ADDRESS
DELIVERED BEFORE
THE AMERICAN SOCIETY OF MECHANICAL
ENGINEERS
NEW YORK MEETING DECEMBER 1900
... BY ...
CHARLES H. MORGAN
SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.

BY CHARLES H. MORGAN, WORCESTER, MASS.

PRESIDENTIAL ADDRESS, 1900.

In undertaking to discharge the pleasant and honorable obligation of making an annual address before you it is natural and reasonable that I should turn for inspiration and material to that small part of the boundless domain of mechanics in which it has been my pleasure and privilege to serve. Younger men may tell of what may be done; older men of what has been done. May I speak then of the rolling mill and what it has done; quickly trace its development; and show the mighty part it has played in the nation's growth. To show that with Watt's immortal invention harnessed ahead, and the hand of the mechanical and metallurgical engineer guiding behind, the rolling mill has been the plowshare which has opened the furrow and made possible the seedtime and harvest of the hour.

Important as I believe the rolling mill to be, I am not unmindful of the fact that this Society is not composed entirely of men interested in it. There are, I am sure, among the members young men engaged in rolling mill work, and older men engaged in other and highly important work, to whom a brief narrative of the landmarks of some part of the history of rolling would be of interest. If, then, ought I have to say may to some rolling mill friend seem well known and familiar, my only apology is that I do so in my desire to record that which may be of general interest to all. For I have often found it to be true that the axioms of my neighbor's trade were the problems of my own, the things by daily contact trite to him, of interest to me.

It is easy to magnify the importance of one's special work, and yet I am very bold in urging the claims of the rolling mill as an epoch maker. May the testimony I have to bring yield, under your impartial analysis, reasonable percentages of interest, pleasure and profit, but of self-assertion barely a trace.
In his annual address before the Society in 1892, our honored Past President, Mr. Charles H. Loring, pays a splendid tribute to the steam engine and its illustrious inventor, James Watt. In forceful, striking manner the influence of that invention upon the race is shown. May I ask of you another review of that address and thoughtful consideration as to what share of the truths there so ably told fairly belong to the contemporary and collaborer of Watt—Henry Cort, and the monument of his genius, the rolling mill.

"The great historian," says Mr. Loring, "who looks back a century hence upon the present era will point out that the great underlying cause of the wonderful progress made by mankind during the last 100 years was the steam engine. It is what no other machine ever was, the creator of physical power. The immortal inventor died without dreaming that he had placed on earth an infant Hercules whose club with an ever increasing might would batter down the institutions of preceding ages."

I indorse that tribute with this distinction only,—Watt's engine is the Hercules, but the rolling mill is his club. Disarm him, take his club away, and how little with his vast strength can he do? The steam engine may be "what no other machine ever was, the creator of physical power," but the rolling mill has ever been the creator of the harness for using that power.

Without travelling too far afield, a bit of the biography of Henry Cort, and his contemporary relationship to the work and time of Watt, is inseparably a part of any summary of the development of the rolling mill. Henry Cort was essentially to the rolling mill what James Watt was to the steam engine. There is a singular similarity between the two men and the interdependency between the development of the inventions they wrought.

They were contemporaneous, poor, engaged in other work until brought together face to face with two undeveloped bedrock basic inventions—a steam engine and a rolling mill. Both dropped the old work for the new, and developed inventions originally not their own, (for other engines preceded Watt's and other mills Cort's), but the great fundamental similarity lies in the fact that both were men who found two splendid inventions brought (as have so many lesser ones before and since) to that point in the life of inventions where development drags and waits a master-hand to give it impetus. Both were men quick to see
the needed thing and apply it, and at one stroke push the poor uncompleted thing over the dividing line and send it on its way a master product.

Henry Cort was born in 1740, at Lancaster, England. In 1765, at the age of twenty-five, we find him in London, engaged as a navy broker. Here, by sales of iron to the Government, he had pointedly thrust upon him knowledge of the conditions of England’s iron industry. Within ten years after reaching London, so dependent for her iron supply had England become that Russia and Sweden, from whom she imported it, increased the price nearly two hundred per cent. No forge or furnace in England could make iron fit for the navy’s use. Such a condition of things, striking at once at the root of England’s maritime and naval supremacy, was intolerable. Then came one of those rare conjunctions of circumstances, too potent and far-reaching to be a mere creature of chance.

Three men almost simultaneously worked and linked together the product of their work—Watt, Cort, and the Edinburgh chemist, Black. No happier example of the power of scientific and mechanical unity can be found than in the cooperation of these three men, the scientist Black, and the mechanics Watt and Cort.

In his annual address in 1899, before the Iron and Steel Institute, Sir William Roberts Austen speaks of Black and Cort as two remarkable men who were looking for the dawn of the nineteenth century as we are for that of the twentieth, and whose work evidenced the fact that our progress received no check from the failure of industrial workers to assimilate the teaching of science.

Dr. Joseph Black, who was a professor of chemistry in Edinburgh University, previous to his familiarity with Cort’s work, had interested himself in aiding Watt—indeed Watt was financially his debtor. A moment’s digression concerning the relations of these men, as also the moral and physical aid of Watt to Cort, is, I feel, justifiable here. Black had a friend and fellow chemist, Dr. Roebuck, engaged in mining and wrestling with the old question of pumping the mines. To him Black introduced Watt as a young man who had invented a steam engine of increased power speed and economy as compared to Newcomen’s. Roebuck’s interest was instantly aroused, and, corresponding with Watt, eventually had him come to Kinneil House, Roebuck’s home. There every assistance was given by Roebuck. Buildings were furnished in which to erect a working engine, the cylin-
ders for which Roebuck cast at the Carron works, of which he was proprietor, and from which he sent a corps of his best skilled English workmen to help Watt. Watt is described as a "sickly, fragile man and a constant sufferer from violent headaches. He was, by nature, timid, desponding, painfully anxious, easily cast down. . . . On the other hand, Dr. Roebuck was accustomed to great enterprises, a bold, undaunted man, disregardful of expense where he saw before him reasonable prospect of success. . . . The result was Dr. Roebuck eventually became a partner in the invention to the extent of two-thirds—took upon himself the debt owing by Watt to Dr. Black, and undertook to find the required money to protect the invention by a patent."

Such was the friend to whom Black introduced Watt, and such was the moral and material backing Roebuck gave that Watt, in writing to a friend, says: "I have met with many disappointments, and I must have sunk under the burden of them if I had not been supported by the friendship of Dr. Roebuck." And yet it is of such a man as Roebuck—who ruined himself financially with his tireless energy—that the best the biographer can say in a Cyclopedia of Biography published in Glasgow is, "Roebuck, John, a physician and experimental chemist, born at Sheffield in 1718, died, after ruining himself by his projects, in 1794."

Such was the advent of Watt and his engine, and the part Black played in it. The new invention had about gained a fair footing when Henry Cort began his work. Cort—the man with whom Sir William Roberts Austen says "Black was soon to become familiar"—the man of whom Watt, in writing to Dr. Black, says: "Mr. Cort has been most illiberally treated by the trade; I shall be glad to be able to be of any use to him."

Of how great a use he really was, no human mind can ever know. Omniscience alone can measure the help to the struggling Cort of such kindly, sympathetic appreciation as that of Watt. Watt, of all men, who, when struggling in the initial throes of his own work, had the friendly interest of Black and the broad shoulders of Roebuck to sustain him. There was singular fitness now that it should be this same Black and Watt, and the assistance of their discoveries and inventions, that should be the key for Cort to open his own. With the chemical researches of Black and the steam engine of Watt ready and available, Cort went at the very root of the method of puddling iron and the machinery for rolling it.
Possessed of a small competency saved from his brokerage business (some £20,000), Cort dedicated the whole of it to perfecting the processes and machinery for manufacturing iron. He leased a site and built a mill at Fontley, near the government docks in Portsmouth Harbor, and here, between 1777 and 1783, prosecuted the work which culminated in his patents for improvements in the process of the manufacture of iron and the manipulation of it by the use of the grooved rolls. There in those two obscure patents, Nos. 1,351 and 1,420 of 1783 and 1784, respectively, are bound up the first real beginnings of the art of rolling iron and steel; beginnings that were no mere fortuitous accidental discoveries, but discoveries made by a man who saw what was needed and went for it with incisive directness. With his skilled method of "puddling," an end came forever to the manufacture of iron "no longer fit for the navy's use." With his first use of the grooved rolls, the limitations of the old slow hammer were burst, and an evolution started, the end of which is not yet. It is impossible to overstate its value. At the very start it brought emancipation from dependence upon Russia and Sweden, aside from the financial freedom it secured. Nor from the standpoint of pounds, shillings and pence, can the mind fully grasp the significance of Cort's invention. As early as 1786, only two years after the date of the patents, Lord Sheffield said: "If Mr. Cort's very ingenious and meritorious improvements in the art of making and working iron, the steam engine of Boulton and Watt, and Lord Dunonald's discovery of making coke should all succeed, it is not asserting too much to say that the result will be more advantageous to Great Britain than the possession of the thirteen colonies [of America]."

An invention which in two years was able to throw a searchlight into the future and reveal possibilities calling forth such an utterance must be stamped as something more than ordinary. In 1865, about eighty-two years after Cort's invention, William Fairbairn said: "Henry Cort's inventions have conferred an amount of wealth on Great Britain equal almost to six hundred million sterling, and have given employment to six hundred thousand men." Surely such declarations justify the assertion of kinship between the development of the rolling mill and that of the nation.

The temptation is strong to trace in detail the tragic career of poor Cort, but it is not within the limits or purpose of this paper to do so. I may, however, briefly say that, reaching the limits of
his twenty thousand pounds, he entered into that fatal partnership with the Jellicoes, by which the capital of the father, Adam Jellicoe (then Deputy Paymaster in the Navy), was put into the business. Cort's patents were assigned to Jellicoe as collateral, and later were confiscated by the government upon the discovery of Adam Jellicoe's defalcation, and that the capital advanced by him had been taken from government funds.

His biographer says "He may be said to have been . . . the author of our modern iron aristocracy. These men of gigantic fortunes have owed much—we might almost say everything—to the ruined projector of 'the little mill at Fontley.' Their wealth has enriched many families of the older aristocracy and been the foundation of several modern peerages, yet Henry Cort, the rock from which they were hewn, is already all but forgotten. . . . He has been the very Tubal Cain of England . . . and while the great iron masters, by freely availing themselves of his inventions, have been adding estate to estate, the only estate secured by Henry Cort was the little domain of 6 feet by 2 in which he lies interred in Hampstead Churchyard."

I may say that it was my pleasure during the recent trip of the Society abroad to have had made a photograph of "the little domain of 6 feet by 2 . . . in Hampstead Churchyard." The markings on the headstone were much obscured, but by a little effort they were cleared and a satisfactory photograph obtained.

I have felt it to be of interest, and worthy the emphasis given, to outline thus the life of a man with whose work the real art of rolling began. Before Cort's time, strictly speaking, there was no such thing as the manufacture of bar iron by rolling, although it is but just to say that Christopher Polhem of Sweden, who had done valuable work with plain rolls, anticipated in his writings the possibilities of grooved rolling, stating, in substance, that financial and other limitations restrained him and that it must be left for others to work out. Cort was the man who worked it out. The art as he found it was simply the crude refinement of the pig iron in small quantities into the wrought iron mass—its manufacture into bars, alone by hammering—with a finishing pass between plain rolls for uniform thickness before cutting in the ordinary slitting mill.

Cort reorganized the whole scheme—metallurgically and mechanically. Laying the foundation of modern puddling—minimiz-
ing the use of the hammer and practically discarding its use for finished work, he took his refined mass at once to his grooved puddling rolls and thence on to the finishing; using, as he says in his patent, "a groove of the required diameter when the iron is designed for bars, half flats, or thimble iron, either plain for squares and flats, or concave for bolts and the like."

Then, for the first time, the infant industry for rolling stood alone, all before had been but gathered strength for taking the first step. To trace minutely its growth would fill volumes. As an index of immediate effects of Cort's improvements, take, for example, the work of Richard Crawshay, one of the first iron masters to appreciate and adopt them. In 1787 he was struggling away at Cyfartha, making, under the hammer, barely 10 tons of bar iron per week, and that none too good; yet in 1812 (twenty-five years later), in a letter read before the House of Commons, describing his process, he states: "I took it from a Mr. Cort, who had a little mill at Fontley, in Hampshire, . . . by which I am now making more than 10,000 tons of bar iron per annum" (equivalent to 200 tons per week). From thence on, these outputs have mounted up until, in the United States alone, there were rolled in the year 1890 (excluding all flat roll products) about 5,000,000 tons of iron and steel—equivalent to 100,000 tons per week, and, in 1899, over 8,000,000 tons—equivalent to 167,000 tons per week, every pound of which passed through grooved rolls like those first used in the "little mill at Fontley."

The mill used by Cort was, of course, of the ordinary 2-high type. Modification after modification succeeded Cort's 2-high mill, calling forth all sorts of types, kinds, and classes, among them the familiar reversing and 3-high mills, all evolved by the demands of advancing civilization in ever varying and countless combinations, for something bigger and better, longer and stronger.

THE CONTINUOUS MILL.

It has been the privilege of the writer to have been allowed to add his contribution to this development of the rolling mill; to have shared in aiding the development of that type of mill known as continuous mill, and the large family of auxiliaries that have grown up about it. Like all inventions, it had its day of small beginnings. There are footprints of tentative efforts made in France to use it. The first recorded patent and first actual use
seems to have been that of an American, J. E. Serrell, in 1842-43. Its use was, however, restricted by him to the rolling of lead pipe and copper, and with his efforts his use of the mill ceased. His countryman, Henry B. Coner, in 1859, secured a patent for a continuous mill, but never constructed one of this type.

Like Cort’s invention, other men thus had their hand on the tiller before the captain grasped it. By every consideration, the credit for first impressing the continuous mill into the service of rolling iron and steel, for successfully combining its essential elements, and for gaining it the wide application it now enjoys, is due to Mr. George Bedson of Manchester, England. He first made the mill go.

This mill, as its name implies, works continuously upon the metal. The rolls are placed closely in tandem and the metal led by means of guides directly from pass to pass, without the intervention of any human labor. There are no interruptions, no catching or looping, but a continuous onward transit of the metal from the bite of the roughing rolls to the discharge of the finishing. Each pair of rolls, by carefully arranged gearing, being speeded according to the reduction of each successive pass, to take up the corresponding elongation. Phenomena peculiar to this mill had to be combated, but the door was at once opened for vastly increased lengths, weights, and speeds. Europe, at that time, was rolling easily 50-pound billets by the Belgian or Looping System; the United States but 15 pounds on ordinary 2 and 3-high mills. The Bedson Mill at once handled from 70 to 80 pounds (which was rapidly increased until to-day 300-pound billets are commonly rolled).

The Hon. Abram S. Hewitt, statesman, iron master, and wire manufacturer, speaking of this in his report as United States Commissioner to the Universal Exposition, at Paris, in 1867, says: “Generally there may be said to exist a prevailing willingness and practice in the European works to handle iron in larger masses... than we do in the United States... wire rods are frequently to be found in the departments ranging from 30 to 50 pounds in weight, rolled in trains... no greater in speed than we employ in the United States for 15-pound billets... but the most remarkable specimen of rolling was in the English department exhibited by Richard Johnson and Nephew, of Manchester, in the shape a coil of No. 3 wire rod, weighing 281 pounds, in length 530 yards, rolled from a
single billet. . . This wonderful specimen of wire rod . . . was rolled in a machine invented by George Bedson.

The first of these continuous mills erected in the United States was at the works of the Washburn & Moen Manufacturing Company, Worcester, Mass. Mr. Ichabod Washburn, the founder of that company, recognizing the great possibilities of this mill, negotiated with Mr. Bedson for one of them, and assumed, personally, the entire financial risk of the venture.

In the spring of 1869 this mill, designed and constructed by Mr. Bedson, was erected and put in operation, under the supervision of the writer, at the Washburn & Moen Company's works, of which he was then general superintendent. This mill is shown in Fig. 1, and consisted of 16 stands of rolls placed in tandem, and rolled 1¼-inch billets, weighing from 70 to 80 pounds. For the general reader, I may say that it is evident that continuous rolling of a billet in a plane always at the same angle to its axis, would produce flattening of the mass only. To obtain elongation, compression in planes varying in angle with that of the axis is necessary, similar to the rotation of the metal by the blacksmith upon the horn of the anvil between each successive blow. In Mr. Bedson's mill this was accomplished by placing each pair of rolls (after the manner of the universal mill) at an angle of 90 degrees to its predecessor. This secured the desired end perfectly, but entailed vast annoyance in the care and management of the mill. By it was necessitated the use of one system of gearing above the floor line and another in a pit below it. Accessibility to these, as also to the rolls themselves, in changing and adjusting, was seriously impeded. In the next continuous mill, Fig. 2, which was designed by the writer in 1878, and used by him at the Washburn & Moen Company's works, all rolls were placed in a horizontal plane, all the gearing in a single plane, and the very essential requisite of varying the plane of compression secured by the use of twist guides, whereby the metal was turned 90 degrees in travelling between each successive pass; a device universally adopted in these mills.

It would be quite impossible to trace each minute development. As in all new things, surprises constantly had to be met and overcome. Nicety of adjustment became inseparably a feature of the system. Exactitude in the corresponding speed and passes of the rolls was difficult. Without it one of two things was inevitable—delivery to a pass faster than its capacity to receive it,
40 SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.

Fig. 1.—Bedson Continuous Rod Mill, 1889.
producing lateral looping; or slower than its capacity to receive it, producing stretching. Of the two alternatives, the latter was preferable, for the relief by looping was interfered with by the guides—it was cumulative in effect, and attended with serious menace to the safety of the mill and its operatives. Stretching, however, threw a demand upon the heated metal greater than many grades of good iron could withstand, by reason of their low tensile strengths and lack of homogeneity. For this reason the use of the continuous mill, as originally installed, was greatly lessened in rolling common grades of iron; so much so, that the next mill built by the Washburn & Moen Company, in 1877, was a 3-high mill adapted to the Belgian system. The improvements in Bessemer and Open Hearth steels, with their greater tensile strength and homogeneity, ultimately brought a product for rolling for which the continuous mill was well adapted.

**Belgian or Looping System.**

With increase in weight and decrease in the section of the finished product there arose the practice of *continuous* or *simultaneous* rolling of the metal in 3-high mills by serpentine looping on each side of the mill. This was distinguished from the “back and forth” rolling, in which the metal was discharged free from the rolls at each pass. This type of mill was used by Europe before the United States adopted it—presumably first in Belgium, the name “Belgian” having come to be understood as meaning a looping mill. It was the use of these mills which for some time enabled the European manufacturers to roll the 30 and 50-pound billets referred to by Mr. Hewitt while we were rolling but 15 and 20 pounds on the “back and forth” 3-high mills. It was a mill of this Belgian type which was first designed and erected by the writer to follow the original Bedson continuous mill, as already mentioned. A plan of this mill is shown in Fig. 3. It is believed that this was the first “Belgian” mill erected in the United States, although other mills were erected at or about that time by others. At all events it was one of the very first of these mills thoroughly carried out and put in for permanent and effective service in this country. The roughing was done on a 2-high mill capable of handling 4-inch billets, reducing to 1½ inches. From this size it went to the looping or Belgian mill, and rolled to the ordinary wire rod. This system is now used quite largely in this country for rolling wire rods.
Combination (Continuous-Belgian) Mills.

The combination or joint continuous-Belgian mill (Fig. 4) was an effort on the part of the writer to secure a consolidation of the merits of both systems. A mill of this type was put in operation by the writer in 1881 at the works of the Washburn & Moen Company. It roughed billets of about 100 pounds in weight from 1 3/16 inches to 5/8 inches on the continuous mill, and finished from 5/8 inches on the Belgian mill to the ordinary wire rod. This was the first mill of this type built in this country, or in any country. One of the chief merits of this system is that it rolls common iron equally as well as does the looping or Belgian system, and that, too, with less labor. It has since been adopted by the advocates of the Belgian system as a compromise recognition of the claims and merits of the continuous plan.

With increase in size and weight of billets, as has been said, the accessories of the mill began to grow, although the need for something new at the delivery end of the mill soon followed. The leap from billets and coils of 15 and 20 pounds to those of 70 and 80 forced a "policy of expansion." The mill itself had undeveloped capacity—the limitation lay in the heating and reeling, two collateral functions of the mill which have had a rapid and interesting growth.

Heating.

Heating in Cort's time had probably been done in some form of "direct-fired" furnace (similar to an ordinary puddling furnace), the metal charged and discharged from the same door. These furnaces were in every way extravagant, consuming large quantities of fuel, most of the heat being lost up the chimney; a heavy percentage of the metal was lost by oxidation, and, in later years, the higher carbon steels were seriously injured by the abruptness with which they were exposed to the full intensity of the heat.

In course of time there developed a class of furnaces known as "gas-fired" (as distinguished from direct-fired). Heating was obtained by the combustion of "producer gas" (a gas obtained by the distillation of coal).

Fuel economy, intensity of heat, and facility of regulation were important advantages of this method of heating. The chief advantage, however, lay in the ease with which an "oxidizing" or a
Fig. 4.—Combination (Continuous-Bellian) Mill, 1881.

SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.
“reducing” flame could be secured, for by it the oxidizing, or “scale-waste” of direct-firing, was very materially reduced.

Modifications of these furnaces followed, until two general types came into accepted use—the “Ekman continuous” and the “Siemens regenerative.” Both were gas-fired, and therefore had all the general advantages of that method of firing; but both aimed specifically at greater efficiency by utilizing the waste heat escaping with the products of combustion. They aimed at the same thing, but effected it quite differently. The Siemens regenerative (the last in point of time—1856—but the first to be generally accepted) secured “regeneration” by causing the waste heat on its way to the stack to pass through the interstices and to be absorbed by fire-brick “checker-work” placed in suitable chambers. Alternation in heating the checker-work was had between two pair of these chambers, through which the inflowing gas and air, respectively, passed on their way to the furnace, absorbing the heat of the fire-brick checker-work, uniting at a high temperature with a high resultant flame. These furnaces stood in great favor, and deservedly so, for steel making, but they had disadvantages for reheating cold metal. Charged and discharged, as they were, from the same door, there was often confusion in the order and system of receipt and delivery, the last billet in often being the first one out (something like the experience our steel friends have when order and sequence at the soaking pits is disturbed and uncertainty exists as to which ingot should come next). But above all was the disadvantage of exposing the cold steel to the full intensity of the heat. Efforts have been made to overcome this by the use of two furnaces of high and low temperature, respectively; but the neatest, simplest, and most effective design for securing this end has been that of Gustave Ekman, of Sweden (1843), nor was the element of absorption of waste heat neglected. The very same design is made to do double duty and secure both ends, and therein lies the great beauty and adaptability of these furnaces. For regeneration, or recoupment of the heat, Siemens depended upon the absorptive action of the fire-brick, from whence it was returned to the furnace. Ekman at once made the oncoming metal itself absorb the escaping heat, an arrangement in itself manifestly simple and effective, but vastly so in the light of the fact of the greater absorptive capacity of the metal over the fire-brick.

Nor does Ekman stop here. After running the gauntlet of the
SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.
cooler billets, the heat is met by a "stove," or similar device, placed in the stack, by which further retention of the heat was secured and used in heating the air-blast. Such a furnace is shown in Figs. 5 and 6. Length, it will be seen, is a distinguishing feature—it might almost be said to be a part of the stack placed horizontally. The billets are charged at the cooler, and, by gradations approach the higher heat. With high carbon steel

**FIG. 6.—EKMAN FURNACE.**

this is absolutely imperative, and desirable with any metal. It might almost be said to be a simultaneous heating and "soaking" effect, to use a steel-maker's term—the billet delivered ready and in perfect condition for rolling.

In connection with this quasi "soaking" feature lies that of absorption of the waste heat. Ekman, as will be seen from the illustration shown, places a second low bridge wall transversely across the furnace bed (Fig. 5). This retards and tends toward confinement of the heat at the hot end. Escaping over the bridge, the heat envelops and is either absorbed by the long line
of oncoming billets, or, passing them, is arrested by the stove in the stack. Gradation in heating and passage of the bridge was effected by withdrawal and insertion of the billets at the side doors shown. In a modification of this furnace, called the "roll oven," seen by the writer at Hoerde, Germany, about 1880, this was effected by giving the billets an octagonal section, and rolling them the entire length of the furnace by barring through lateral doors. In all these furnaces, the bottoms were of sand.

A decided improvement in effecting the transit of the metal was that made by William D. Allen about twenty years ago, then general superintendent of the Henry Bessemer Works at Sheffield, England. Mr. Allen placed the metal on skids made of wrought-iron pipe protected from burning by maintenance of a water circulation through them. This was a decided improvement, dispensing with barring, lessening the friction, and made possible the movement of the entire mass of billets onward by a hydraulic pusher, which he placed at the charging end of the furnace.

From this point on, the manifest advantages of this type of furnace have claimed attention, and caused a rapid growth and development of important modifications. Two of these, designed by the writer, are here shown, the "gravity discharge" (Figs. 7 and 8), and the "suspended roof" furnaces (Figs. 9 and 10). Both, as will be seen, have all the essentials of the Ekman-Allen furnace. In the former (gravity discharge) the billets are pushed to the hottest zone of the furnace, from which they descend by an incline (set at an angle greater than the angle of friction) to the feed rolls and thence on to the mill, thus avoiding the slow and laborious operation of barring the metal out employed in the Allen and other furnaces. The inclination upward of the furnace bed is given to secure the gravity discharges at a point above the floor line instead of below it, as would be necessary if the bed was horizontal. Great furnace capacity can be secured by placing a series of these furnaces side by side, fed from the billet pile by a common conveyor in the rear, and all discharging by gravity upon a common system of feed rolls for delivery to the mill as shown in Fig. 8.

In the feed roll system, shown in Fig. 8, the delivery rolls are conical, with an extension of lesser diameter and consequent lesser surface speed. The cold billets retained by lateral guides are conveyed on the inclined surfaces of the rolls until at or near the
FIG. 7.—MORGAN GRAVITY DISCHARGE FURNACE.
furnace, where the guides are "switched" or withdrawn, and the billets allowed to fall and travel at the slower speed upon the small ends of the roll below, being brought to a standstill by any suitable stop.

The development of the suspended roof furnace was an outgrowth of the necessity for using billets small in section but long in length. Experience has shown that in rolling finished products of small section, complete uniformity was obtained with less loss from oxidation by the use of billets correspondingly small in section than by using shorter lengths of larger section. The usual length of billet for the "suspended roof furnace" is 30 feet, the length suited to the ordinary freight car.

The necessity of lateral presentment of billets to flame for uniform heating I have already shown. To effect this, therefore, with a 30-foot billet called for corresponding increase in furnace width: length had already reached 30 to 50 feet for securing continuous and gradual heating. To support a roof suitably over such dimensions necessitated something more than the means ordinarily used. The writer devised a roof consisting of a series of arches supported by skewbacks, suspended from transverse girders resting upon the furnace walls; suspension being had by attachment to water pipes running through the skewbacks (Fig. 9). This roof has had a thorough practical test for five years past, and has worked quite satisfactorily. The essential points of Ekman and Allen are easily recognized in it, except that heat localization, which Ekman secured by his second bridge wall, is here obtained by the reverberatory effect of the roof arches, and the water-pipe skids of Allen are confined to the cool end of the furnace only, by looping back, though in some instances they have been deflected downward through the bed.

The method of charging these furnaces is shown in Fig. 10, the billets being run into the furnace in the direction of their length (not broadside, as in former Ekman-Allen furnaces). They are presented gradually broadside to the hottest zone, and discharged again longitudinally; a power pusher starting them forward to the bite of the rolls, which are placed close to the furnace door. Special reference is due to the ease with which repairs to this roof can be made without material interference with its structure. Parts of the arches or skewbacks can, with perfect ease, be taken out and replaced without affecting contiguous parts, these roofs having enough spring and flexibility to adapt
SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.
themselves to the stress of heating and cooling, or to any ordinary strain. They are, in addition to the purposes above outlined, well adapted for heating such long pieces as old rails for re-rolling.

REELS.

Increase in weight from the 15 and 20-pound billets rolled in the old mills to the 70 and 80-pound billets rolled in the original Bedson continuous mill forced improvements in reeling. The old hand reels were tried, but the labor was too exhausting, and even when used they cramped and hampered the full efficiency of the continuous mill.

A power traction reel, as shown in Fig. 11, was designed and used by the writer in 1869. It worked well, but its capacity was, after a time, exceeded. With the ever-increasing length and weight of coils, new factors had to be reckoned with. Originally,
SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL

Fig. 11.—Morgan Traction Rod Reel.
wire rods were discharged and spread over an expanse of iron flooring—the free end inserted by an attendant into the reel, which was speeded to overtake the roll discharge and gather the accumulated loops from the floor. The great floor space required for the larger coils—the high reeling speed required for "take-up"—the danger to attendants and loss from entanglement—these

and other difficulties gradually forced this reel aside. The writer designed and used at the works of the Washburn & Moen Manufacturing Company a reel such as shown in Fig. 12.

The automatic pouring reel, Fig. 12, has a hollow vertical shaft, on the upper end of which was fastened a disk. Near the outer edge of the disk a row of upright pins were attached thereto, nearer the centre of the shaft, and about six inches from the per-
iphery was a second row of upright pins. This reel was provided with another disk or platform attached to a shaft, which was inserted and projected through the shaft of the reel; at the lower end thereof was a hydraulic cylinder and piston for moving the last-named lifting-platform, and for the removal of the rods after reeling. Between the two rows of pins the wire rod was coiled as it issued from the finishing rolls of the mill, and conducted through a pipe which guided it to the reel. The operation was somewhat like pouring a small stream of water into a revolving tub. All the difficulties of floor looping were eliminated by placing the reel close to the finishing rolls.

This reel has been almost exclusively used by the Washburn & Moen Manufacturing Company in connection with its mills. It is properly a landmark in the evolution of automatic power reels. Like Cort's invention, however, the child was so attractive that rival claims of parentage contested. With varying successes, they were carried through courts of minor jurisdiction until the Supreme Court of the United States, with the wisdom and equity of a Solomon, refused to divide the child, and irrevocably awarded it to the writer as his own.

Another form of reel designed by the writer and one of his associates was the "laying" or "whirling pipe" reel. As the name would indicate, the wire rod was laid in a receptacle by means of a rotating pipe. These reels were not used by the Washburn & Moen Manufacturing Company, but received a most flattering compliment and endorsement from the wire-rod fraternity by the very general way in which they were appropriated and used without so much as "by your leave, sir." A singular incident to this method of reeling was the gradual spiral twist given to the rod—thought, at first, objectionable. It appeared in time, however, that imperfections in the rod by "under or over filling" in the rolls were thus distributed spirally upon the rod, and not straight and longitudinally. The inventors built better than they knew, for by this quality the excessive wear upon the die in cold drawing was distributed around its inner surface, and not confined to wearing and cutting at one point.

Accessories.

I have already noted the influence upon development of the demand for greater things. The design of the mill and the accessories about it soon came to have the imprint of the specific
use intended. Little by little the limitations of human endurance were reached. With each new device there still lingered enough of direct human labor to fatigue and hinder. All these had to stand aside, until the function of labor has become largely *supervisory* and *directory*, rather than *exoditory*.

Originally, the *furnace* and the *mill*, the *heating* and the *rolling*, comprised the whole. To-day, appliances, formerly mere convenient accessories, have risen to the dignity of indispensable parts. Human nature and the native distaste for physical effort could fairly be counted upon to prompt some mechanical relief, but something more than love of ease and relief from labor inspired the growth of the modern accessories. *Necessity forced the issue*; developing the beautiful adjuncts now inseparably a part of every modern mill.

Stand before one of Mr. Carnegie's magnificent mills and watch the great glowing mass come on, over the *feed rolls*, from somewhere—actuated by something—enter the rolls, be lifted, turned, and carried on the *feed table*, operated by somebody, discharged, and sent out and away, on the automatic carriers, a finished billet, plate or beam. How many men would it take, and how long would it take them, to do the work that has been done by the "*mere accessory"*? How much would the mill have rolled without it?

I have already shown how the capacity of the continuous mill for rolling greater wire rod products forced an evolution in *its* accessories. Nowhere has this been greater than in the mills built for *miscellaneous* uses. In and around the Pittsburg district, continuous mills have in recent years found great favor for rolling such products as merchant steel, billets, hoop, and cotton tie, etc. Continuity of operation has been the touchstone throughout. Here again, however, *length* of the finished product forced recognition. A 6,000-pound *ingot* with the initial heat of the converter, without reheating, is easily rolled directly and continuously to 1-inch square bar. When so rolled it involves a length of nearly 800 feet; luxury of yard room to accommodate which few mills can afford to give. Handling the straight 800-foot product was impracticable; reeling it equally so and, in fact, undesired. Stoppage of the moving metal by fixed cutters during delivery from the mill there could not be, with the attendant buckling of the oncoming mass. To meet the requirements, a *shear*, shown in Fig. 13 (called by the workmen the *flying shear*)
SOME LANDMARKS IN THE HISTORY OF THE ROLLING MILL.
was designed by an associate of the writer. Cutting in transit is the function of the machine. It is designed with knives upon a radial arm moving in company with the metal and while acting upon it. The arm returned to its original position allows the continued discharge of the rolled metal, which, striking a trigger, applies the pressure, actuating the shear for a renewed cut. The action is entirely automatic, cutting to required lengths, and is used for handling the delivery from the mill of the heavier sizes of finished products.

The continuous mill had been applied to miscellaneous rolling but a short time before it was called upon for service in rolling hoop and cotton tie. The mill adapted itself perfectly to the new work, but the accessories at once came into prominence. Heavy devices for cutting billets were of little service in handling the flat and limp red-hot cotton tie, which had about as much consistency as a piece of wet paper. Devices for automatically cutting and coiling were first used, but the practice finally settled upon a looping distribution of the metal upon a travelling table or apron, somewhat after the manner of the old floor delivery of wire rods, except being done uniformly and mechanically. By this means gradual cooling of the flat steel was secured without contact of the metal with itself, thus ensuring a uniform blue finish desirable in some varieties of flat rolled products. This was designed by the inventor of the flying shear.

I have referred to the influence of great production upon the development of the mill and its accessory. It is worth perhaps a passing note to speak of the influence upon them of economy and refinement.

Economy and Refinement.

There is a seeming incongruity in the application of eternal laws to a rolling mill, yet the Divine command to “gather up the fragments that remain, that nothing be lost,” must be here implicitly obeyed. Economy in fuel consumption, scale waste, and crop ends has usually had some attention; but as precision and refinement in finished product and demands for something better and cheaper grew, economy grew with them. Economy in moving, in lifting, and in carrying. Economy in using air and water, for, free as they are, yet at high pressures they are costly luxuries, to be used with economy only. In all these economies accessories played a part.
The foundryman’s plea that half the machine is built in the foundry is true; with this amendment, that part of that half is built at the forge and mill. We no longer “allow plenty for finish,” be it machinery steel or foundry casting. Casting and rolling must be done with reasonable exactness. The roller’s old worn gauge is now an inmate of the museum. It is the micrometer he now must use. He stands between “limit gauges.” Thus far can he roll, but no farther, and hundredths and thousandths are units familiar to his ear. The result is nicety, refinement, and economy everywhere, and the mill and its accessory must be designed to meet them.

A recent accessory of the merchant mill—a storage system—has been designed by the writer’s associates, the whole function and purpose of which is economy. Economy in time, economy in material. Ordinarily a jobbing merchant mill runs on part time—its use is intermittent, depending upon the receipt of orders and the lengths and quantities of the material required. This intermittent use of the mill has been demoralizing to the whole plant. Aside from the loss upon idle and unproductive equipment, there has been the direct loss and expense of frequent roll changing and adjustment in filling small and miscellaneous orders. The continued use of the mill for products carried in stock has been prohibitive by reason of the great waste from crop ends. Length of merchant bar, like that of the original wire rod, has been determined by the vehicle for transportation—one by the length of the freight car, the other by that of the farm wagon. Cutting the varied lengths of commerce from these ordinary merchant-bar lengths has been highly wasteful of large quantities of valuable metal. To obtain relief from these extravagances—i.e., idleness of the mill and waste of material—the storage system has been evolved. By its use the finished piece, straightened, cooled, and uncut, is carried laterally to storage racks having compartments of large capacity in which standard sizes and sections are kept separately and in stock. Shearing facilities are placed at each end of the racks, and most of the cutting is done only upon receipt of orders, and then to specific or multiple lengths. As a result there is a saving of metal, a saving of time, a more continued use of the mill, and an enlarged efficiency by greater freedom in the use of heavier billets.
CONTINUITY.

No single aspect of modern manufacturing is more striking and pronounced than the drift towards continuity of operation. Not that of the continuous mill alone, although that mill has done its full share; but everywhere, in all lines of work, the search for economy and despatch has weeded out slow and needless intermediaries and unified functions before separate and distinct. Operations which heretofore hindered and delayed have now disappeared from the continuous mill, until it is a familiar sight to see a billet, one end still in the furnace—its length in all the reducing passes of the mill, and the other end coiled on the reel, a finished wire rod—a continuous and simultaneous performance of heating, rolling and reeling upon the same piece of metal without cut or separation of its parts. No less striking is the operation of rolling larger sections. The metal, a few moments ago a 6,000-pound ingot, and now a four by six-inch billet, is carried onward to the mill, a part of its length moving on the feed table, part moving faster through the passes of the mill, part being cut by the “flying shear,” part caught up and carried away on the conveyor, and part being delivered on the car for transportation from the mill.

Here again are parts of the same mass of steel being fed, rolled, cut, conveyed and delivered, continuously and simultaneously. There is something a bit dramatic in the sight of a bar resting on the car ready for shipment, while the parent from which it sprung is still away back in the bite of the roughing rolls.

So it is everywhere. Be it the making of a newspaper or an envelope, from roll to finished product—folding, cutting, printing, stamping, and counting—it is continuous to the end. It is in the very spirit of the times—quickness, continuity, and economy. In a recent review of the astronomy of the century, Professor Dolbear, of Tufts College, drops a little sentence, “Creation is a continuous process.” If the scientist finds creative processes continuous in his domain, no less so does the engineer find it in his own. Creation of the raw materials upon this planet has been a continuous process, and so is fast getting to be the creation of the finished products from them.

WEALTH OF THE COUNTRY.

In conclusion, then, may I ask, What has the rolling mill been worth to our country? Over a hundred years ago (as we have
one of England's statesmen, in substance, said it was worth to that country more than the whole of certain thirteen colonies. What has it been worth to those colonies? What has it done for them? Vastness of the question makes brevity of reply. Who can measure, estimate, or enumerate the indebtedness and dependence of the nation to the offspring of the "little mill at Fontley"? There were the colonies strung like a filament along the eastern shore, and all that great work to the westward to be done. To tunnel mountains, dig mines, bridge rivers, lay rails, fell forests, sow, reap, and ship the grain. It was a task enough to daunt the bravest. Watt's Hercules lent its strength, but the rolling mill put into his hand a club of "ever increasing might" with which to "batter down the institutions of preceding ages," and Hercules needed all his strength to swing it. I know it suggests the old spirit of "Who shall be greatest?"—the rivalry of cooperating and interdependent parts—but it was rough justice that awarded Solomon's blacksmith the honored chair. Why not this tribute to his successor—the rolling mill of to-day? How far would we have gone, and how much would we have done without it? With each new demand the mill has been equal to the occasion. Transportation and communication, the vanguard of all civilization, would have been helpless without it, to say nothing of all the every day dependencies upon it. Particularity of these would be but tedious enumeration. Its work is in the web and woof of all we do.

The steamer going East and the railroad going West are built and burdened with the products of the mill. How much of the great West, and all the wealth which is in it, would have been ours without the help of the rolling mill?

There come to mind the doubting and uncertain days when the far West lay too big and boundless to be understood—when the mind of the statesman, Webster, could not grasp it—would not vote "one cent from the public treasury to place the Pacific coast one inch nearer to Boston than it is now," and was "about trading that worthless territory for some valuable concessions in relation to the cod fisheries."

Those were curious days in the light of to-day: when the appraised value of the West was expressed at Washington in such figurative terms as "interminable desert," "arid plain," "impassable mountains," "not worth a pinch of snuff," "region of savages and wild beasts," "deserts of shifting sands, dust, cactus, and prairie dogs."
And so it was, and so it would be now, but for the products of the rolling mill.

One statesman said: "Have you made an estimate of the cost of a railroad to the mouth of the Columbia?" "How are you going to apply steam?" The rolling mill has solved his problem and answered his question.

Another statesman, in similar vein, said: "All the gold of Peru would not pay a penny on a pound of the cost it would be to build a railroad over the mountains to Oregon." Well, probably it would not if the rails for the road were all forged under the old tilt hammer in use before Cort's time.

Has it paid to cross the mountains? Mountains "impassable for wagon roads" until the undaunted spirit of Marcus Whitman found the trail and blazed the pathway for us. Last year the iron horse, harnessed in the trappings of the rolling mill, and shod with its products to give it foothold, drew from these "impassable mountains" one hundred and seventy millions of gold, silver, and copper! Has it paid?

'Tis the poet's license to use our language in aesthetic sense; I claim the plain man's privilege to use it in the literal. We know whose the strong hand that has made the material welfare of our country. We know, and that right well, "what master laid its keel, what workman wrought its ribs of steel, in what a forge, in what a heat, were shaped the anchors of its hope."

And so it ever will be. As long as human beings come and go, the rolling mill will serve until mankind shall cease to know a physical want unsatisfied, or longing unfulfilled—and that will be when stars grow cold and "the wide firmament is rolled up like a scroll."