floor, whereby friction is avoided, and long lengths can be got out almost perfectly straight.

In strip mills, instead of there being only one housing screw to keep down the top chock, there are usually two, one near each end of the chock (fig. 500). This prevents any tendency of the chock to rock; the rocking, by allowing the short rolls to get slightly out of parallel with each other, causes the strip to be curved sideways and uneven in thickness.

The rolls must be adjusted with great nicety; if a strip intended to be finished 2 inches wide by No. 12 B.G. thick enters the finishing rolls quite straight, but leaves them with one edge $\frac{1}{10000}$ inch thicker than the other, it will be found to be bent so much out of line that a straight line drawn between the two ends of the strip will show it to be hollow on the edge by more than 1 foot in 40 feet.

The strip, if not straight, can be straightened by tapping it with a hammer, in the same way as a saw blade is straightened—namely, by very slightly crushing, and so stretching the inner side of the curve. Considerable skill and practice, however, are needed to do such work properly.

Light strip is either folded up in much the same way as a skein of wool, into lengths of 14 feet, when it is known as "hoops," or is wound up into a circular coil, and called "strip"; in either case it is secured by twisting a bit of soft iron round it here and there to keep it together while travelling. Gas strip used for welding up into gas pipes is sent away in lengths without being doubled or coiled.

The output of an ordinary strip mill, with 9-inch rolls, is about 15 or 16 tons of strip, 3 inches wide, per shift.

"Bright cold rolled sheets," such as are made into steel pens, and are used for other special purposes, consist of strip, usually about 6 inches wide, cut into handy lengths, carefully pickled, close annealed, and slowly rolled in oil between very short stiff rolls, these processes being repeated as often as may be necessary; they can be had to any gauge, varying not more than $\frac{1}{1000}$ inch from the thickness ordered.

BIBLIOGRAPHY.

"On Modern Appliances for Reversing Rolling Mills." By B. Walker. *Iron and Steel Inst. Journ.*, 1871, p. 417.

"Reversing Rolling Mills." By Graham Stevenson. *Iron and Steel Inst. Journ.*, 1872, vol. ii., p. 47.

"Napier's Differential Friction Gear for Reversing Rolling Mills." By R. D. Napier. *Iron and Steel Inst. Journ.*, 1872, vol. ii., p. 43.

"Suggested Improvements in Handling and Shearing Steel Plates." By Andrew Lamberton. *West of Scot. Inst. Journ.*, 1895, vol. ii., p. 143.

"American and English Methods of Manufacturing Steel Plates." By Jeremiah Head. *Min. Proc. Inst. C.E.*, May 5, 1896, vol. cxxvi.

"The New Armour-Plate Mill at Creusot." *Engineering*, May 1, 1903, p. 583.

CHAPTER XXXV.

ROD MILLS.

Introductory.—No mills have undergone such interesting developments as those employed for rolling the small rods intended to be drawn out when cold into wire. Such bars are so very small in section, and therefore cool so rapidly, that when rolled by hand in the old form of mill it was not easy to deal with billets more than 10 lbs. in weight, or to finish them to sizes below ¼ inch in diameter and 14 feet in length. In 1860, a mill starting with a billet 1¼ inches square, could not turn out more than five tons of ⅜ rods in twenty-four hours. Since then inventors have been continually devising means to run the rod faster through the trains of rolls, until so little time is now occupied in the transit, that the rod leaves the mill practically as hot as it enters, the high speed of travel naturally yielding greatly increased outputs.

A single modern mill with finishing rolls of the same size as those used in 1860 has turned out as much as 400 tons of No. 5 rod 0·212 inch in diameter in twenty-four hours, from billets 5 inches square, and has produced a No. 6 rod 0·160 inch in diameter, weighing about 1 ton, 6½ miles long, all in one length. How this has been rendered possible will be explained in this chapter.

The Belgian or Looping Mill.—In no branch of rolling was the advantage of the three-high mill so naturally conspicuous as in the production of these small sections, which could be finished in half the time when they could be rolled on the backward as well as on the forward journey; sections down to ¼ inch in diameter, which formerly had to be drawn cold through dies, were at once rolled off hot, with enormous saving in the cost of production. Moreover, it was soon perceived that as such small sections were extremely flexible when hot, it was not necessary to wait for the whole piece to leave the rolls, and to then enter the end which had last left into the second pass. Immediately the first end of the piece emerged from between the rolls, on the catcher's side, he could seize it with his tongs, bend it round in a half circular loop, and return it through the next return pass to the roller, who in his turn could catch it, bend it round, and pass it back once more through the third pass. The rod was thus bent in the form of the letter **S**, one end being between the middle and bottom roll, the centre between the middle and top roll, and the other end between the bottom and middle roll again, and all parts travelling on through the rolls; seeing that three portions of the rod were being rolled at the same instant, of course a further great decrease was effected in the time needed to finish it.

With rapid rolling the catcher returned the rod so soon that the roller, who was occupied in entering the rod into the first pass, had not time to turn his attention to the bar just rushing towards him before it was upon him, and accordingly a third man was employed to enter the rod into the third pass. Then, to give the men room to work properly, instead of putting all three passes in one stand of three-high rolls, each pass was in a separate pair of rolls, and each pair of rolls in its own housings. Fig. 501 shows a mill of this description, which is generally known as the Belgian wire mill. The billet was roughed out or broken down in the first stand of rolls in the ordinary way, but when small enough to bend readily—*i.e.*, about ⅝ inch in diameter—it was passed to the second stand forming a loop, a mill of this type being therefore known as a looping mill.

The number of stands of rolls which were coupled up thus was not confined to three, but ran up to six or eight, according to the number of passes required to reduce the billet to the size of rod needed.

When one man only was employed on each side of the mill, and each had to enter the rod through every pass on his own side, one rod had to be finished completely before the roller could find time to enter a second; but with a man stationed to attend to only one or two stands of rolls, as soon as the rod had passed his stands the roller at the first pair was able to enter a second, so that two or even three rods might be in the mill at once, and each bar travelling through two or three pairs of rolls at one time; in fact, billets could be fed into the mill as fast as they ran out of the final pass, which practically was never running empty, and the speed of this pass determined the output of the mill.

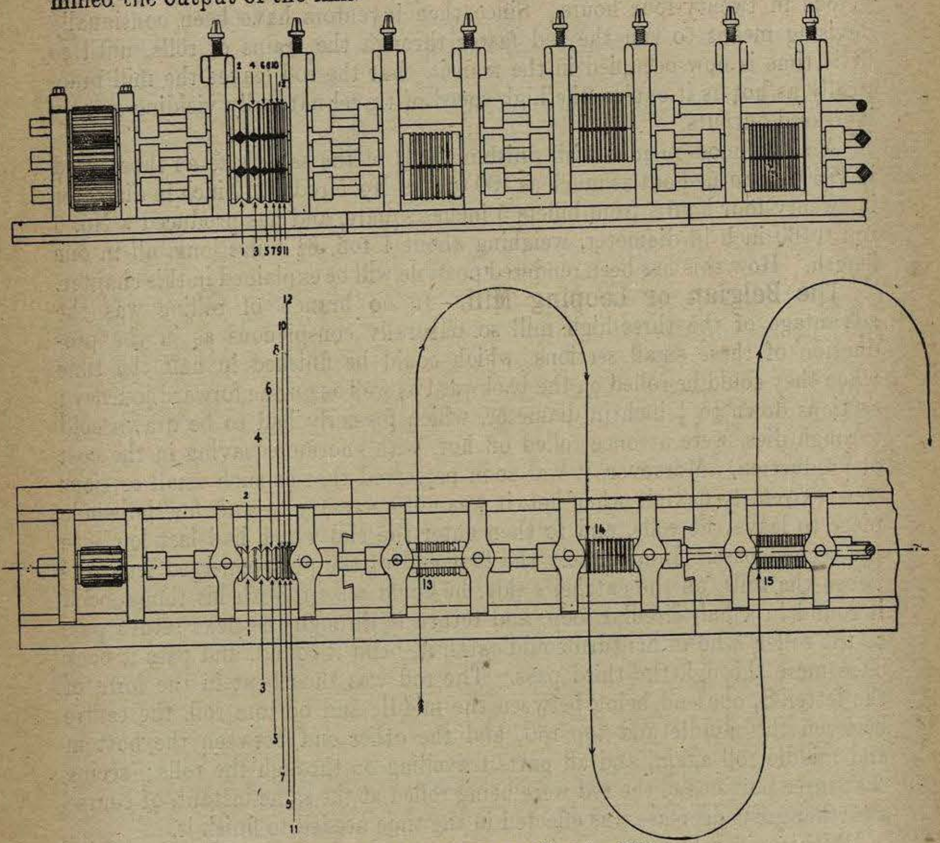

Fig. 501.—The Belgian or Looping Mill.

From what has been said earlier in this work, it will have been understood that whenever a piece of metal is rolled, its length is increased at every pass in proportion to the reduction effected in its cross-section, so that it always passes away from the mill at a speed greater than it entered in exact proportion to its increased length. In the Belgian mill, all the rolls being coupled up in one line, make the same number of revolutions in a given time; their peripheries necessarily travel at the same speed, and accordingly every pair of rolls take in the rod at the same speed, which is always less than the rate at which it left the previous pair, with the result that the loops, which are formed when turning the rod from one pair of rolls into the next, gradually increase in length from the first. To prevent

these loops getting entangled or twisted round the men's legs, a boy placed a hook in each loop, and, walking away from the mill, kept it stretched out along the mill floor, while the end, as it left the last pass, was seized by a boy who ran along with it, thus stretching the rod out along the floor to cool. The speed of rolling was determined by the rate at which the boy could drag it out, and the length rolled was limited by the length of floor available on which it could be laid.

To watch the progress of the fiery serpent, with its life-like wriggles in its course through the mill, is a fascinating sight, but, for an unwary sightseer, a dangerous one. It is easy to be caught in the toils, and seriously if not fatally injured, and in the event of a serious breakage in the mills, the workmen, to avoid being lassoed by the hot loops, usually clear out till the mill has stopped.

By sloping the mill floor away from the rolls, the loops are kept stretched out by their own weight, and most of the hook boys are dispensed with; but the most convenient arrangement is to keep a flat floor on which the workmen can stand, and to provide sloping surfaces below it on which the hoops can lie.

With the advent of the electric telegraph a demand arose for great lengths of wire without a joint, to produce which with the minimum labour and room, a boy was employed to slip the end of the rod between the staves of a reel about 2 feet in diameter, which another boy turned by means of a winch handle, and so wound up the rod (or thick wire as it was then) while hot into a coil, which was slipped off the reel and bound round with two or more short pieces twisted up to secure it. Fig. 510 shows a reel of this kind, but driven by a belt.

This arrangement of stands of rolls all coupled in one line, having a set of three-high breaking-down rolls to begin with, with the rod turned backwards and forwards through the stands, and a reel to wind it on, constituted the well-known Belgian wire mill, which was a vast improvement on any existing methods, and enabled much greater lengths and smaller sizes to be rolled than had ever been possible before.

Beard & Thomas, of Bilston, in 1867, were running a 9-inch mill of this kind at 550 revolutions per minute, and were producing iron rods by this means in lengths up to 130 feet.

Many such mills are still in use doing excellent work, and can turn out rods of small size where the lengths needed are not excessive; the output of such a mill is now 20 to 30 tons per turn of No. 1 rod = 0·300 inch diameter, and a proportionate quantity of No. 7 = 0·176-inch.

In Germany the Dowlais, or "double-duo" mill is now generally employed instead of a three-high mill for rolling rods. Fig. 502 shows a mill of this kind made for the Krefeld Steel Works by the Duisberg Machine Company (formerly Beohem & Keetman), of Duisberg. It consists of a three-high roughing stand, not easily distinguished in the cut, directly coupled to a tandem compound steam engine, having cylinders 18 × 30 inches in diameter × 34 inches stroke, provided with a flywheel of 24 tons weight, 22 feet in diameter, and grooved to take six ropes. These drive the pulley of 4·7 tons weight directly coupled to the intermediate double-duo mill shown in the foreground. This mill has five stands, each containing four rolls 13 inches in diameter, one stand 50 inches, three 40 inches, and one 24 inches long in the barrel, and runs at 225 to 250 revolutions per minute. From this intermediate mill the rod passes to a double-duo finishing mill (not shown in the cut), having five stands of 9-inch rolls running at 350 revolutions per minute, driven by a continuous current motor of 300 H.P., for which is provided a cast-steel flywheel 10 feet diameter by 10 tons weight.

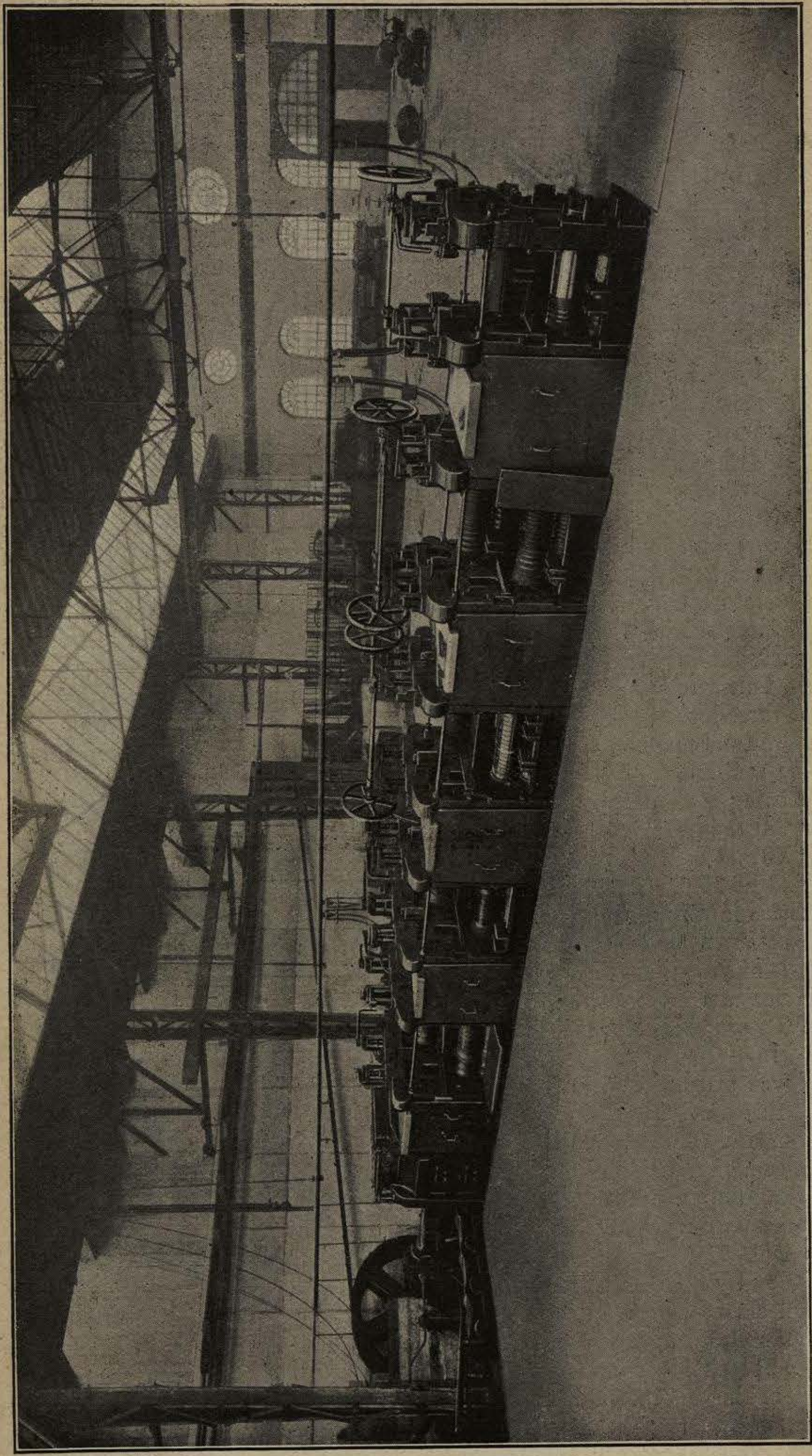

Fig. 502.—Four-high or "Double-duo" Rod Mill.

The drawback to the system was the unmanagable length to which the loop grew when long lengths were required, and the large surface they expose to the air, which causes much loss from scaling, and also limits the diameter and length of the piece which it is possible to get through the mill before it is cold; though the whole length of the billet has run through the first pass in a time so short as to be practically instantaneous, it nevertheless is so long in travelling through the final one, that the end of the thin rod has so much additional time to cool, and is inevitably finished at a much lower heat than the beginning, which, when cold, is therefore of a smaller diameter, a difference which may be still further increased if the final length is almost cold, and therefore so hard as to spring the rolls appreciably.

To increase the speed of the peripheries of the rolls in regular proportion to the increase in length of rod produced by the previous pass, would avoid the growth of the loop, and enable the rod to be finished in less time. To do this, by running each succeeding pair of rolls at the greater number of revolutions needed, would involve considerable difficulties in the matter of gearing, while to accomplish the same result by simply increasing the diameters of the rolls, and continuing to run them all at the same number of revolutions, would require a final pair of impracticable diameter. The two methods may, however, be combined by coupling together two stands of rolls of different diameters, and running every two stands at an increasing speed from a line shaft, which runs at such a speed (say 250 revolutions per minute), that some of the pairs of stands can be speeded down, and others speeded up, without an undue difference in the sizes of the driving and driven wheels respectively. The Cambria Iron Company, of Johnston, U.S.A., using stands of 8- and 10-inch rolls, coupled end to end in pairs (thus giving a reduction of 25 per cent. in each pass, about the limit possible for iron), every two pairs being speeded up or down as required, were getting an output of 25 to 30 tons of No. 7 wire rod = 0·162 inch in diameter, from billets $1\frac{1}{8}$ inches square, in 12 passes, in 1878, and had succeeded occasionally in rolling No. 9 wire rod = 0·114 inch in diameter.*

Bedson's Mill.—Mr. George Bedson, who was born at Sutton, near Birmingham, approached the problem of rod rolling from a different direction altogether, and, to avoid the trouble of looping, patented in 1862 a continuous mill. This consisted of a series of pairs of rolls arranged horizontally and vertically alternately, and placed as close together as possible, through which the billet travelled in a straight line. By varying the proportions of the gearing wheels driving them, as shown in fig. 503, each succeeding pair of rolls was driven at the increased speed necessitated by the increased length of the rod.

By this arrangement, which flattened the rod horizontally and vertically alternately, Bedson avoided the need for giving the rod a quarter turn at each pass; and, by placing the rolls as closely together as possible, reduced to the lowest possible limit the time from the billet leaving the furnace until it could be wound up on the reel, one end of the billet being actually on the reel before the other end had left the furnace. Messrs. Richard Johnson & Nephew, of Manchester, soon after erecting his mill, were making with it 100 tons of $\frac{1}{4}$-inch wire per week, and at the Paris Exhibition, in 1878, exhibited a No. 3 rod (0·261 in diameter) 530 yards long, which they had rolled from a billet weighing 281 lbs., at that time a wonderful performance. To enable the work to be done, so long a billet had to be employed that it required to be folded up to get it into the heating furnace.

The chief objection to Bedson's mill has been that the scale and water from the rolls fall upon the bottom bearings of the vertical rolls, and on the bearings and gearing on the horizontal line shaft below the floor, which

* *Engineering*, July 19th, 1878, vol. xxvi., p. 41.

are difficult to get at, and so cause excessive wear, and trouble in repairs. This has been obviated in some mills of this type, by putting the line shaft above the mill, or by arranging all the rolls at an angle of 45° with the vertical, to the right and left alternately, so that all the gearing is now above ground where it can be readily oiled and examined, or repaired.

It is well known that, by rapidly hammering a small rod on the smith's anvil, it can be made too hot to touch with the bare hand; the energy expended in rolling, which is very much greater in amount, is likewise accompanied by the development of heat, though the conditions are usually such that the generation of heat by this means cannot be recognised. In a continuous rod mill running at such high speeds, and developing power so great in comparison to the section operated on, and with the successive squeezes following each other at such short intervals of time, the heat generated by the rolling more than compensates for the small loss by radiation, and there is often a positive rise in the temperature of the rod being rolled, notwithstanding the fact that the rolls are kept flooded with water.

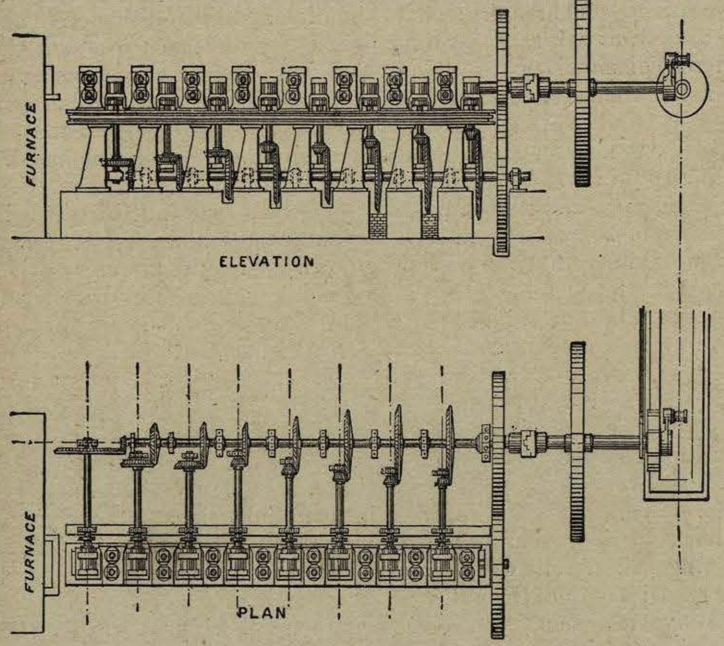

Fig. 503.—Bedson's Continuous Mill.

The average output of the Bedson mill, originally 11 tons per diem, on billets of 80 to 100 lbs. weight, has been raised to 150 tons in twenty-four hours.

Morgan's Mill.—The Washburn & Moen Manufacturing Company, of Worcester, Massachusetts, of which company Mr. Morgan was then the general manager, in 1869, purchased one of Mr. Bedson's mills, which did indeed all that was promised, but failed to produce more than 7 tons per day, until the power reel—to be afterwards referred to—was devised by Mr. Morgan. After a few years experience with them the alternate vertical rolls were abandoned by Mr. Morgan, and a mill was built having horizontal rolls only, which, as will be understood from what has been said as to the methods of reduction in rolling, necessitated turning the rod on its axis through a quarter of a circle after every pass; to accomplish this twisted guides were

employed, consisting essentially of tubes cut with a spiral groove, which rotated the rod in the same way as a rifle barrel spins a bullet (see figs. 515 and 516).

It was necessary to arrange that the speed of the surface of each pair of rolls should be such as to take in the rod at precisely the speed at which it left the previous pair, the speed of every pair of rolls being increased by exactly the same percentage as the rod had been lengthened in the previous pass. When all the rolls were new this was not very difficult to accomplish, but when the rolls needed re-turning to compensate for wear, and a different amount was turned off each roll, great practical difficulties were encountered. The revolutions of each stand of rolls were fixed by the gearing provided to drive it, but with a trifling error in the areas of the passes, or in the circumference of any roll compared with those before or behind it, trouble arose. If any pair of rolls took in the rod slower than the previous pair fed it into them, a loop formed between the two stands which broke or displaced the guides; while if the same rolls took in the rod faster than the previous pair were supplying it, a scraping action occurred in one or both stands, which caused rapid wearing of the grooves. Though the lengthening of the rod in any one pair of rolls could be readily controlled by slackening or tightening the housing screws, the adjustment which would suit the stand in front might aggravate the difficulty in the one behind, and *vice versâ*. However, by persistent work the difficulties were finally overcome; each pair of rolls were deliberately calculated to run a very small percentage faster than the rod was intended to be fed to them, putting a slight tension on the length of rod between every stand, and twisted guides were devised which permitted a small amount of gathering between the rolls in case of any miscalculation. Mills of this description require great care in adjustment, which takes considerable time to effect correctly, and are therefore suitable for the continual production of one or two sizes rather than for a miscellaneous class of work.

A great number of improvements have since been made in minor details, and mechanical perfections introduced, which permit of running at speeds as high as 1,200 revolutions per minute. As a result, over 800 tons of No. 5 wire have been finished *in one groove* in a week at the American Steel and Wire Company's Works at Cleveland, Ohio, which is at the rate of over 70 tons per shift, or ten times the product of the Bedson mill of thirty years ago.

Bedson's mill, with its alternate vertical and horizontal rolls, admits of only one rod being rolled at a time, but in continuous mills having all the rolls horizontal any number of rods may be rolled side by side at the same time; as much as 260,000 lbs., or 116 tons, have been finished in a single shift in a continuous mill of this description at Waukegan, Illinois, and 400 tons, when running four parallel lines, have been turned out in one day of two ten-hour shifts.

These figures seem impossible unless we remember that a 10-inch roll has a circumference of over $2\frac{1}{2}$ feet, and that 1,000 lineal feet of No. 5 (Stubbs' gauge) wire rod weighs 122·3 lbs. If the finishing roll runs at 1,200 revolutions per minute, it could theoretically discharge $\frac{1,200 \times 2\frac{1}{2} \times 122\cdot3}{1,000} = 366\cdot9$ lbs. of material per minute, equivalent to 22,014 lbs., or 11 American tons of 2,000 lbs. per hour. Under these circumstances, a finishing roll producing 50 tons per groove per ten-hour shift could be running empty for more than half its time, and yet allow four hours out of every twenty-four for changing the rolls or guides.

The Garrett Mill.—While the Bedson and Morgan mills, constructed to deal with billets of small section, were being perfected by their respective inventors, Mr. William Garrett, a Scotchman settled in the States, perceived advantages in starting with a larger billet. A billet 5 inches square and 1 foot long is the same weight as one $1\frac{1}{4}$ inches square and 16 feet long, but the surface of the former subjected to scaling in the heating furnace is only about one-fourth as great, and its handier shape much facilitates the charging and drawing of the furnace, which can, moreover, be much reduced in size; the compact form of the piece makes it easier to bring it to a uniform heat throughout, and prevents its cooling appreciably while being "broken down" to $1\frac{1}{4}$ inches square in an ordinary three-high mill, from which it may pass to any form of finishing mill.

So great in any case is the length of the finished rod compared with that of the original billet, that in any form of mill the rod can always be roughed down much faster than it can be finished, whether the looping or the continuous plan is adopted. The essential difference between the two methods is that in the looping mill, the roughing being done at the same high linear velocity as the finishing, the former is completed so soon that the rod is kept

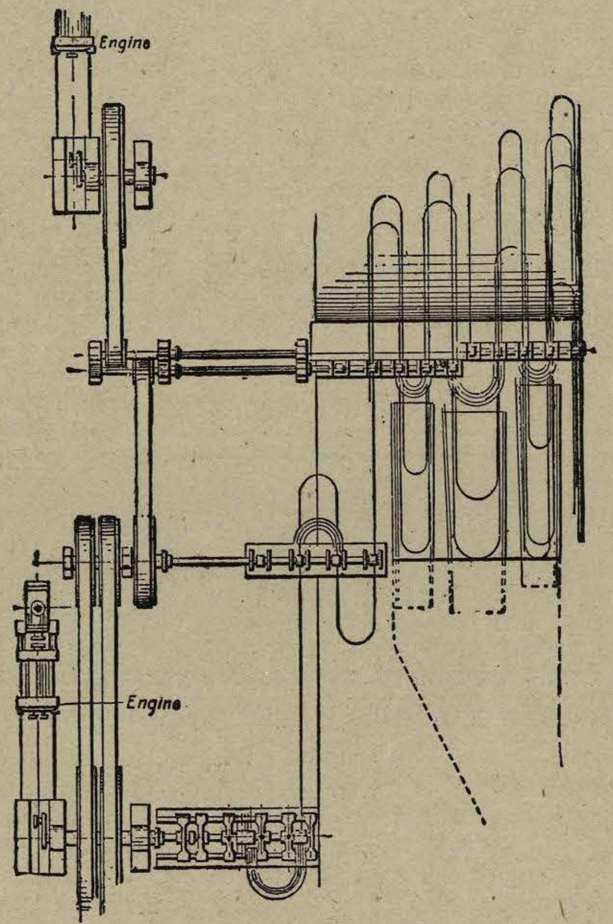

Fig. 504.—Garrett's Mill.

for the larger part of its time at its smallest diameters; while in the continuous mill it is roughed out at the lowest possible speed, and so retained as long as is possible at its largest size, thus, Mr. Garrett claims saving the extra cooling and scaling due to the smaller section in the looping mill.

The holders of the Bedson and Morgan patents being more desirous of

retaining for themselves the profits obtainable from the use of their mills than of granting licenses to competitors, Mr. Garrett turned his attention to improving the Belgian looping system, so as to rough at low speeds and finish at high ones. By splitting up the mill into three or four independent sections arranged in echelon, and driven at different speeds, or by entirely distinct engines, he succeeded in retaining the rod as long as possible at its largest diameters, so reducing cooling and scaling.

Fig. 504 shows one of Garrett's mills. He started with billets of 4 or 5 inches square, which were roughed down in the ordinary three-high mill until sufficiently small to be looped in in the Belgian manner; and instead of employing a man at every pass to catch the rod and return it, he used trough-shaped guides bent round in a semicircle in a horizontal plane, known as "repeaters," around which the rod, as it issued from the rolls, ran, until it entered itself into the next pass, the loop as it gathered freeing itself by rising bodily out of the trough-shaped guide. These repeaters work most satisfactorily with the bars from the square passes, but are not so easily arranged to turn the flat ovals which alternate with the squares, and must be turned on edge during the journey from pass to pass; indeed, it is a moot point whether the increased scrap they cause by their occasional failure with the ovals pays for the saving in wages they effect by dispensing with the men. The looping mill fitted with them becomes almost as automatic in its action as either of the continuous systems. The first idea of the repeater would seem to have been derived from a patent taken out by Mr. Bleckly, of Pearson & Knowles' works at Warrington, in 1872, in which he proposed to employ one pair of rolls mounted directly above a second pair, and to lead the rod, as it issued from the upper pair, down between the lower pair, by means of a guide bent into a semicircle in a vertical plane, thus returning it to the roller's side of the mill.

The first Garrett mill was put down by the Cleveland Rolling Mill Company in 1882, and at once turned out 72 tons a day, or double what was made in the old mills. Owing to the short length of the billet during the first roughing passes, the roughing down can be completed much faster than it is possible to roll the great length of the finished rod, and one roughing mill can therefore be made to serve for two finishing mills. When rolling six rods at once nearly 400 tons of No. 5 (0·212 inch) in diameter has been obtained from such mills.

At the Joliet Works of the Illinois Steel Company one of Garrett's mills, four years ago, turned out in one week 3,273 tons of No. 5 rods, and since then has turned out 728 tons in twenty-four hours.

The extraordinary result has thus been obtained of turning out these rods at a cost of only 16s. per ton for fuel, labour, stores, repairs, and every incident above the cost of the billet used, and of this 6s. is the cost of the labour.*

Boecker's Mill (fig. 505) consists of two lines of stands of two-high rolls, set in pairs opposite each other, on either side of a horizontal driving shaft. The axes of all the rolls are parallel with each other and with the shaft; the first two stands of rolls—one stand on each side of the shaft—revolve in one direction, the next two stands in the opposite direction, and so on alternately. The requisite variation in the speed of rolls is obtained in a manner very similar to that employed in the Cambria Company's mill previously described. The bar, as it leaves the first stand, passes in a straight line through the second stand on the other side of the driving shaft, which runs in the same direction, but with the requisite difference in speed. It is then bent round into a loop, and entered into the third stand, placed on the same side of the shaft as the second stand, and end to end with it, but

* E. P. Martin, *Iron and Steel Inst. Journ.*, 1897, vol. i., p. 27.

running in the opposite direction; and from this third stand it passes in a straight line into the fourth stand on the opposite side of the shaft running in the same direction as the third stand, the fourth stand being situated end to end with the first stand, but running in the opposite direction to it. The

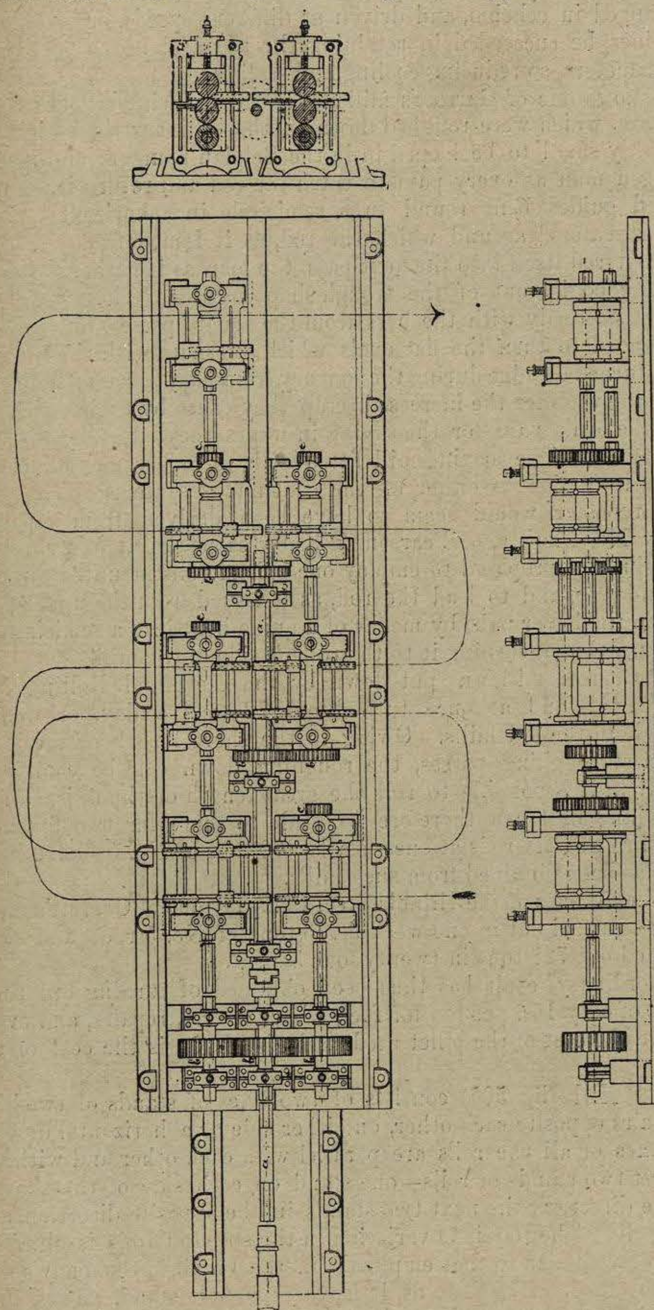

Fig. 505.—Boecker's Wire Mill.

process is repeated as often as may be necessary, the rod passing backwards and forwards across the centre line of the mill, as in the Belgian mill, except that it goes through two pairs of rolls each time it crosses the centre instead of through one pair only. Boecker's mill, therefore, acts alternately as a continuous and a looping mill every time the rod passes the centre.

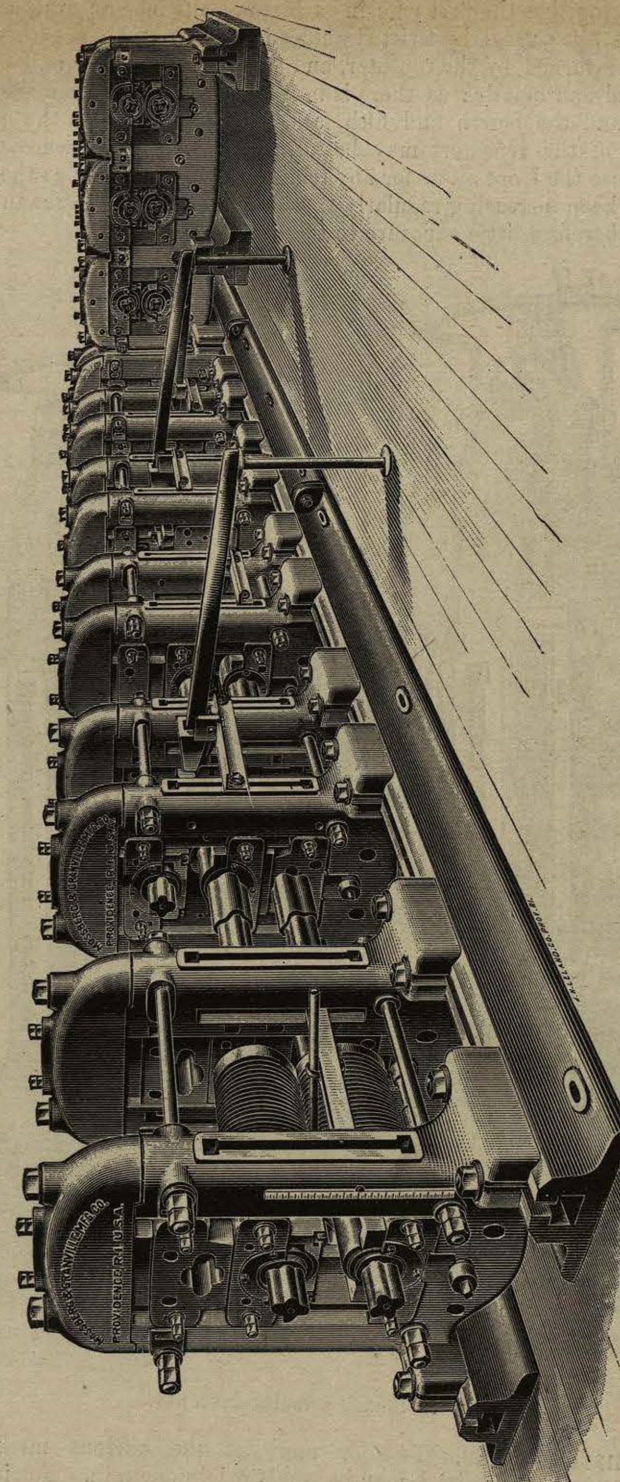

Fig. 506.—Belgian Mill combined with Three Stands of Continuous Rolls.

By arranging that the first pass in each stand shall be an oval, and that this oval shall be turned by twisted guides into the square pass, there is no oval to be returned by the repeater, and the mill can, therefore, be readily made entirely automatic: as there is no twisted guide between the second and third, and the fourth and fifth, and other like stands, the rolls on either side of the repeaters may be adjusted without reference to each other, because the loops allow for any trifling irregularity, and as the speeds of the rolls keep increasing regularly there is practically no growth of the loops, and therefore little exposure to the air.

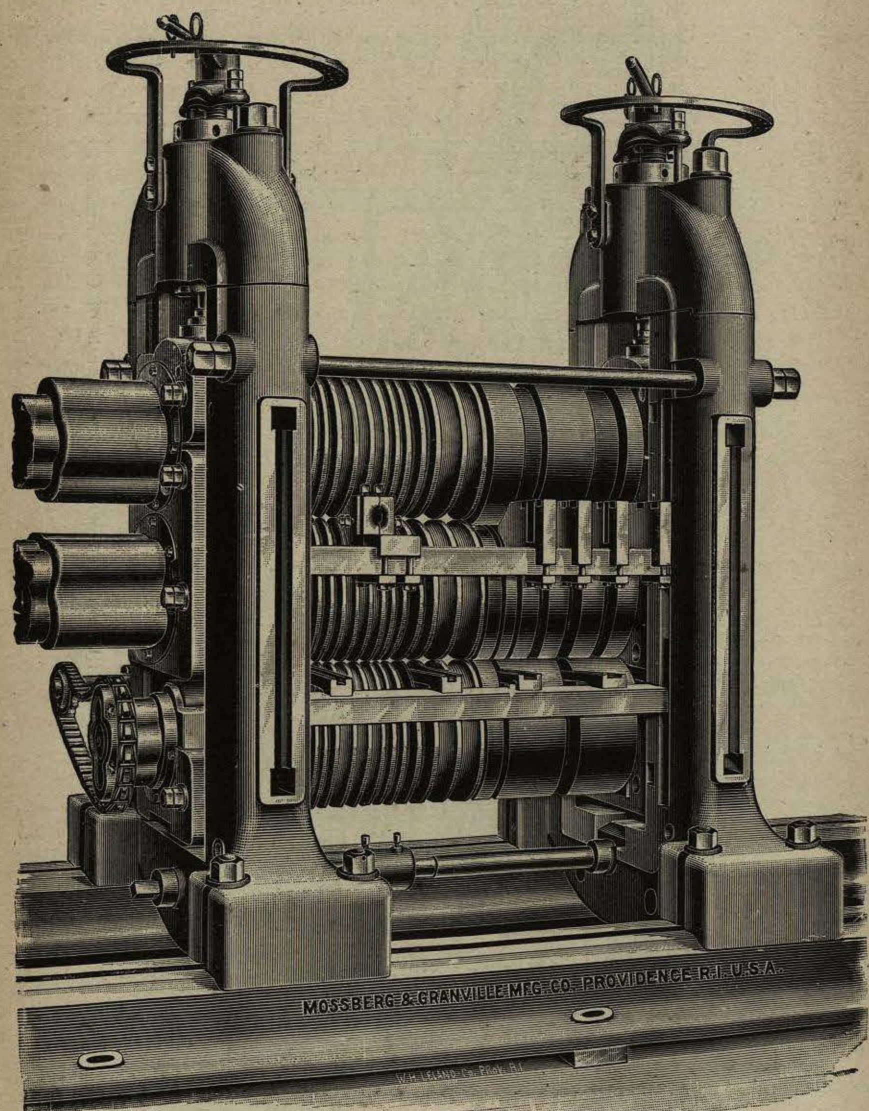

Fig. 507.—16-inch Breaking-down Stand.

Combination Mills.—Two or more of the various methods of working previously described, may be combined in one mill. For instance, the woodcut (fig. 506) shows a 9-inch Belgian mill constructed by the

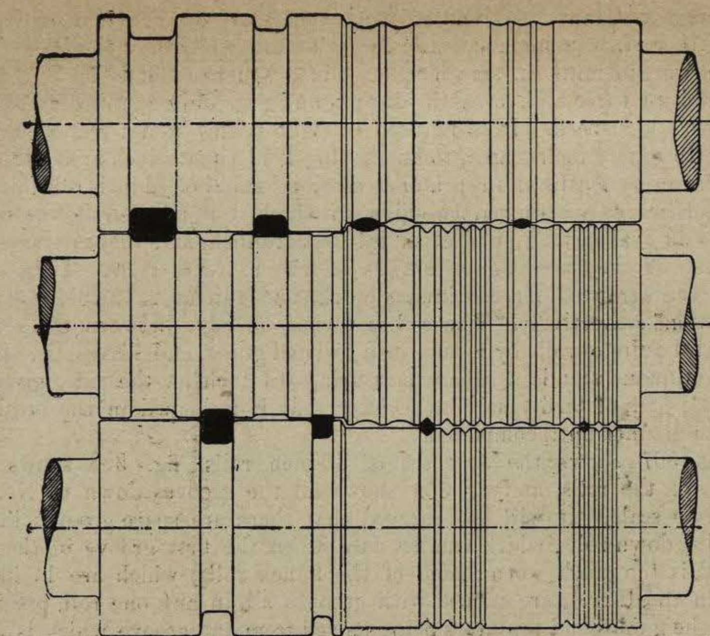

Fig. 508.—Breaking-down Rolls of the Mossberg Mill.

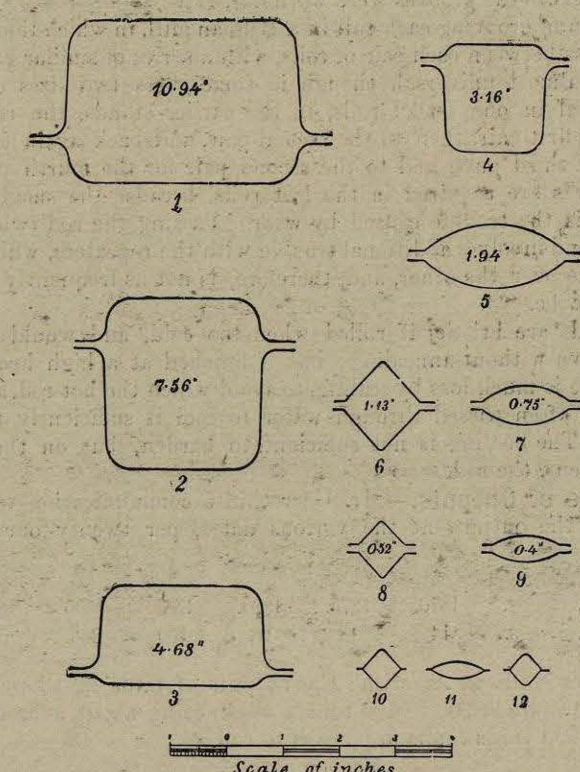

Fig. 509.—Passes in the Breaking-down Rolls of the Mossberg Mill.

Mossberg & Granville Manufacturing Company of Providence, Rhode Island, U.S.A., which embodies some of the features both of the Garret and of the Morgan mills, inasmuch as the 4-inch square billet is broken down in a 16-inch three-high breaking-down stand (fig. 507) running at a comparatively low speed. It is reduced in eight passes from a section having nearly 16 square inches area, to one having 0·52 square inch area; the rod then passes by means of a repeater to a second stand of 16-inch rolls, which, however, are only arranged two-high, in which it is reduced in the ninth pass to an oval having an area of 0·40 square inch, and thence travels to the first of the three 9-inch stands on the extreme right of fig. 506, which are arranged for continuous work, and run at 221, 264, and 315 revolutions respectively. The rod is turned on edge between the second and third pairs of rolls by means of a twisted guide, and leaves the last of the continuous stands a square measuring 0·4 inch on the side, giving a sectional area of 0·16 square inch: after that it is looped in the ordinary Belgian manner until completed.

Fig. 507 shows the first set of 16-inch rolls, fig. 508 shows the details of the rolls, and fig. 509 shows all the grooves down to No. 12, drawn to scale. It will be observed that there are spare grooves in the breaking-down rolls, which can be used when the first groove of the size needed is too much worn; each of the 9-inch rolls, which are 14 inches long in the barrel, are turned with grooves all, in any one roll, precisely alike, the guides and repeaters being moved from any groove which is worn to a fresh one; by this means the rods can be finished to accurate sizes without the delay which would be inevitable, if the rolls had to be frequently changed, because the grooves were worn out.

This plan of grooving each roll in a Belgian mill, in which the rod makes only one pass between each pair of rolls, with a series of similar grooves side by side, is almost universal, though in some cases two sizes of grooves are contained in one set of rolls, in the earlier stands, the rod passing through the first pair, then to the second pair, and back again to the first pair for the third pass, and to the second pair for the fourth pass; additional grooves are required in the last rolls, because the smaller the rod the greater is the trouble caused by wear. Passing the rod twice through the same stand involves additional trouble with the repeaters, which have to be placed one over the other, and, therefore, is not as frequently performed as it used to be.

Steel rods are brittle, if rolled when too cold, and would not stand drawing down without annealing; but if finished at a high heat and left to cool, there is much loss by scaling, to avoid which the hot rod, as it leaves the rolls, is often passed through water to cool it sufficiently to prevent oxidation. The cooling is not sufficient to harden, but on the contrary slightly softens, the rod.

Increase of Outputs.—Mr. Garret, in a communication to the *Iron Age*,* gives the outputs at the various dates, per twenty-four hours, as follows:—

Year,	1870.	1875.	1880.	1885.	1890.	1895.
Tons,	14	18	28	100	200	280

These are for mills in America: the outputs of mills in this country are nothing like so high, 200 to 400 tons a week being about average outputs, and 200 to 600 yards common lengths to roll.

* *Iron Age*, 1896.

Advantages of the Different Systems.—With regard to the advantages of the rival systems, Mr. N. K. Turnbull, in an excellent paper on rod rolling,* says:—"The only drawback to the continuous mill is the inferior quality of the rods produced as regards section, the various sections are not so completely under control as in an open mill, there is always a fin of a yard or two on both ends of a coil of rod, from a continuous mill, which has to be cut off, before the rods can be drawn, and becomes scrap; it is not, however, a heavy percentage of the total length; this class of mill is also not so well adapted for easy and quick changes to roll different gauges or sections. Undoubtedly, for quick roughing down, nothing can compare with the continuous mill, and as long as the section is large—say to ½ inch square—there is little trouble, but after that it is preferable, especially if frequent changes of gauge are required, and an absolutely regular satisfactory product is wanted, to revert to looping. The continuous mill ought to have a great deal more extended use in this country for quick roughing down."

It appears to be the practically unanimous opinion of those best able to judge, that the errors introduced by trifling inaccuracies in turning the rolls, and by the expansion of the rolls when heated, prevent the production of rods—when several rods are finished simultaneously in one pair of rolls—of sufficient accuracy in size, for anything except fencing wire. According to Mr. Garrett,† wire rod is accepted in the United States which measures No. 5 in one direction and No. 7 in the other. It is doubtful what market such material could find on this side of the Atlantic; certainly it would not be accepted for drawing down into wire.

The larger part of the wire rod rolled in the States is made in mills of the Garrett type. Mr. J. P. Bedson ‡ gave the following as the estimated amounts made per annum in America by the various systems:—

	Gross Tons.
Garrett System, running at maximum capacity,	650,000
Continuous,	250,000
Other forms of mill,	100,000
Total,	1,000,000

The actual output of wire rod in America was, in—

	Tons.		Tons.
1900,	846,291	1905,	1,808,688
1901,	1,365,934	1906,	1,871,614
1902,	1,574,293	1907,	2,017,583
1903,	1,503,455	1908,	1,816,949
1904,	1,699,028	1909,	2,335,685

Wire Rod Reels.—The enormous output of the present rod mills, which finish the rod at speeds as high in some cases as 3,000 feet per minute, would be impossible, had not the reels been perfected along with the mill. In the original Belgian mill, a boy, with a winch handle, could turn the reel (generally similar to fig. 510) sufficiently fast to take up the rod as it came from the mill; but soon the speed needed rose beyond the powers of a hand-worked multiplying gear, and reels were used driven by belts (as fig. 510), or better, by a small engine direct, the appliance being provided with a sensitive and powerful brake, by which the speed of the reel could be accu-

* "Notes on Rod Rolling and its Development," *Journal of the West of Scotland Iron and Steel Institute*, vol. vi., No. 7, p. 163, April, 1899.
† *Iron and Coal Trades Review*, 24th January, 1902.
‡ "Iron and Steel Wire, and the Development of its Manufacture," *Iron and Steel Inst. Journ.*, 1893, vol. ii., p. 95.

rately controlled. When the output exceeded the capacity of two reels—*i.e.*, from 40 to 45 tons per shift—an "automatic reel"—that is, one driven at a fixed rate corresponding to that of the speed of rolling—had to be employed.

The Morgan Pouring Reel, devised by Mr. Morgan, was the first automatic reel; the rod as it leaves the rolls is received by a receptacle re-

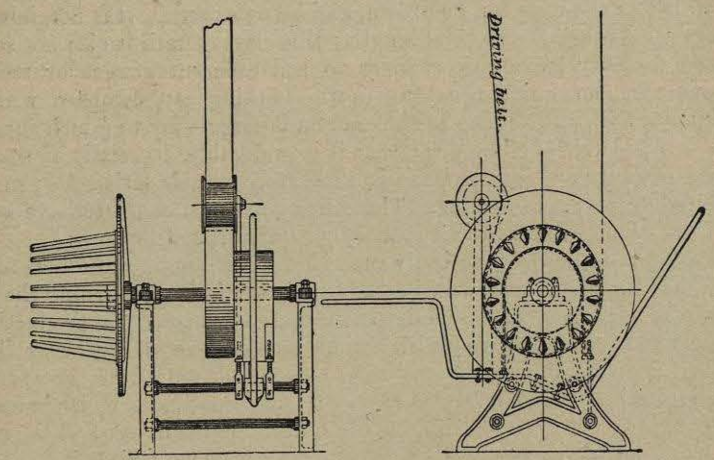

Fig. 510.—Traction Reel.

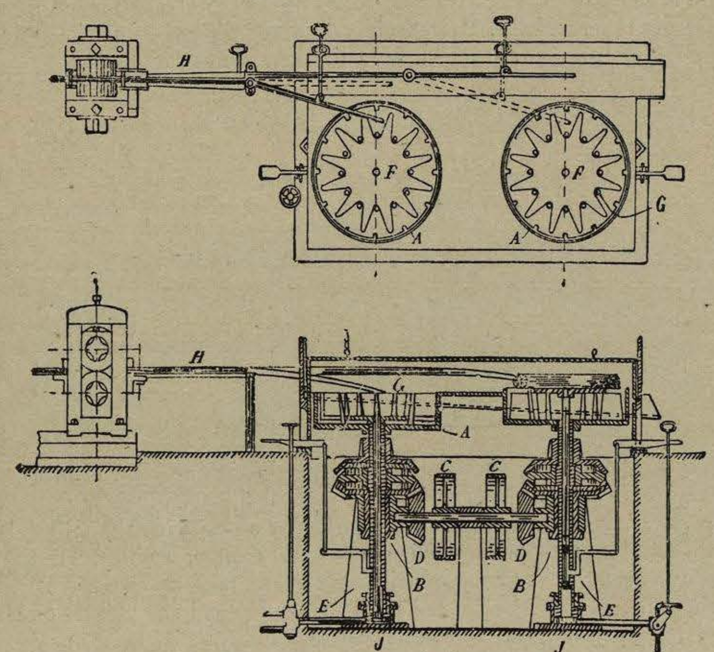

Fig. 511.—The Morgan Pouring Reel.

volving at the proper speed, on a vertical spindle, and it is still used in England, the United States, and the Continent. The flying pipe reel, also invented by Mr. Morgan, is in general use in the American mills; it consists of a pipe, one end of which revolves in a circle, and thus lays the wire on a stationary table, in the same way that a sailor coils a rope on the

deck; it is suitable for ordinary work, but is not available for winding up sections other than rounds, because with each turn it puts a twist on the metal, and therefore a pouring reel, in which the rod as it comes from the mill is poured out of a stationary spout on to a revolving table, is used for fine or special work.

The cut (fig. 511), prepared from a drawing, kindly supplied by the Morgan Construction Company, shows a pair of their pouring reels.

The reel on the left is empty ready for receiving the rod, while the star in that on the right has lifted up the completed coil ready for removal. The reel consists of a revolving pan, A, carried on a vertical hollow spindle, B, which is driven at the required speed by the pulley, C, through the pair of mitre wheels, D. Inside the hollow spindle is a second one, E, which carries on its upper end a star, F, the points of which lie between pegs, G, which project upwards in a circular row from the face of the pan.

The finished rod, flowing from the rolls through the pipe, H, pours into the revolving pan, which is driven at the same speed as the rod which pours into it, and the rod, therefore, lays itself in a circular coil on the upper face of the points of the star, F, outside the ring of pegs, G. When the whole length is delivered, the star is raised by admitting fluid under pressure to the cylinder, J, at the foot of the spindle, by which means the coil is lifted above the ends of the pegs, and can then be removed. The pans are filled and emptied alternately.

A variety of other reels have been constructed, but this and the revolving pipe reel are those most commonly used, and in both of these any slight variation between the speed of the mill and that of the coiling appliance, simply causes a slight increase or decrease in the diameter of the coil formed.

BIBLIOGRAPHY.

"On Iron and Steel Wire and the Development of its Manufacture." By J. P. Bedson.' *Iron and Steel Inst. Journ.*, 1893, vol. ii., p. 77.

"Rod Rolling Mills in America." By F. H. Daniels. Paper read at the Chicago Meeting of the American Soc. of Mech. E. in 1893.

"Notes on Rod Rolling and its Development." By N. K. Turnbull, *West of Scot. Inst. Journ.*, 1899, vol. vi., p. 151.

"Automatic Wire Reels." *Iron and Coal Trades Review*, January 26th, 1900, p. 169.

"American Wire Rod Rolling." *The Iron Age*, February 15th, 1900, p. 17.

"The Alabama Steel and Wire Company." *The Iron Age*, May 2nd, 1901, p. 12.

"The Passing of the Belgian Rod Mill." *The Iron Age*, May 23rd, 1901, p. 4.

"Efficiency Test of a Continuous Rod Mill." *The Iron Age*, September 12th, 1901, p. 8.

"Modern Practice and its Results in the Drawing of Wire Rods into Wire." Wm. Garrett. *Iron and Coal Trades Review*, April 11th, 1902, p. 880.