the rolls, and to prevent this guides are provided as close up to the rolls as possible. These guides fit the bar closely, and prevent it turning over on its side. They consist of two small castings, which lie side by side and form an oval pipe, with a bell-mouthed opening for convenience of entering the bar; they are held in a socket carried on a bar crossing from one housing to the other, and the two halves forming the tube are adjustable towards each other to allow for wear (see fig. 367). As has been explained before, some form of guide is usually necessary to protect the mill against the carelessness of the workmen, or to enable the men to work with greater speed, because less care is needed in entering the piece when guides are used, but the term "guide-mill" is reserved for mills in which the bar could not be properly entered with the workmen's tongs, and must have a guide to hold the bar on edge when it is being entered (see fig. 507).

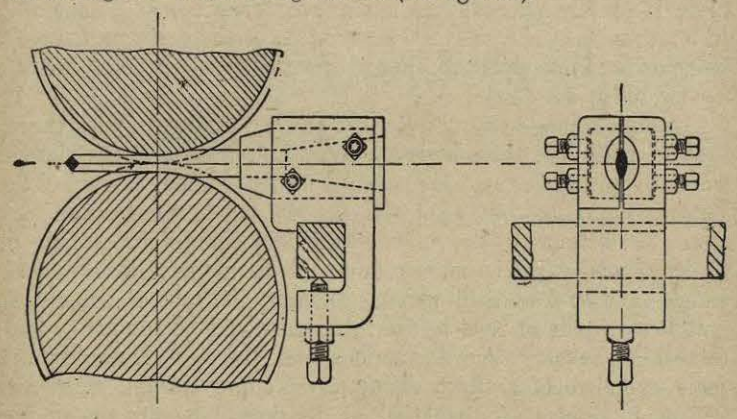

Fig. 367.—Guide for Guide Mills intended to produce Light Sections.

Mills of this description are made up to 16 inches, but are almost always under 12 inches, 9- and 10-inch mills being the most usual sizes, and are used for the production of small rounds, squares, and similar sections. When bars are rolled by guide, they only go once through the last pass, and not two or three times as is usual with large rounds and squares, and consequently any trifling inaccuracy in the final pass cannot be corrected. It is, therefore, seldom that bars over 1 to $1\frac{1}{4}$ inches diameter are rolled by guide, $1\frac{1}{2}$ inches being the maximum size so treated. One works rolls bars up to $1\frac{3}{4}$ inches diameter in this way, which enables them to get a larger output, because the bars need pass once only through the last groove in the rolls. They also maintain that the heavy reduction in the final pass increases the tensile strength of the bars, which, however, can hardly be as truly round as they would be if rolled in the usual way.

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CHAPTER XXIV.

THE FIVE LEADING TYPES OF MILL.

THERE are five distinct methods of conducting rolling operations, viz., by means of:—

1. The old two-high "Pull-over" mill, in which the bar is rolled as it goes forward, and is passed back over the top of the rolls to be rolled in the next pass, no work being done on the bar during its return journey.
2. The "Three-high" mill, in which instead of only two rolls there are three, mounted one over the other. The bar is rolled as it goes forward between the middle and bottom roll, and rolled as it returns between the middle and upper roll.
3. The two-high "Reversing mill" in which the bar is rolled on the forward journey exactly as in the pull-over, but in which, when the bar has passed through, the direction of rotation of the rolls is reversed, and the bar is run back in the opposite direction through the next pass, and so brought back to the side from which it started, work being done on the bar during both journeys.
4. The "Continuous" mill, where several pairs of rolls are placed one before the other in a straight line, and the bar to be rolled travels forward continuously through them in a straight line, until it emerges finished from the last pair.
5. The "Looping" mill, which is a three-high mill with several stands of rolls coupled up together in a straight line end to end, instead of one in front of the other as in the continuous mill; the mill is, nevertheless, used so as to give a continuous action by working it in the following manner:—The catcher, who stands at the back of the mill, does not wait, as at the ordinary three-high mill, until the whole length of the bar has passed through the mill, but as soon as he sees the end of the bar appear through the first pass between the bottom and middle roll, he seizes it with his tongs, bends it round to point in the opposite direction, and returns it through the next pass between the middle and top roll; immediately the end appears on the other side the roller seizes it in the same way and puts it into the next lower pass, and so on, until the bar may be in six or eight passes at the same time, forming a series of loops on each side of the mill alternately, the bar running on continuously, not in one straight line as in the continuous mill, but in a series of S curves (see fig. 501). Of course this mill, often called the Belgian wire mill, can only be used for rolling sections which are light enough to be readily turned into loops, and is chiefly employed for the production of wire intended to be used for telegraphic or fencing purposes, which is required in long lengths, and being very thin cools too fast to admit of its being rolled by ordinary methods.

All rolling mills work on one or other of these five systems, though there are various modifications used for special purposes, and a description of those most used will be found in Chapter xxvii. dealing with this branch of the subject.

The "Pull-over" Mill.—The rolling mill, as used by Cort, consisted, as was shown above, of two rolls only, set one above the other. The roller, standing on the front or "roller's side" of the mill, takes hold with his tongs of one end of the piece to be rolled, and thrusts the other end in between the rolls, while the catcher standing at the back or "catcher's side," as soon as the bar has passed through the mill, lifts it on to the top of the upper roll, which, travelling towards the roller, carries the bar in his direction, and immediately the free end is sufficiently over the centre of the roll, the roller seizes it with his tongs, and pulls it over towards him, the catcher releasing his end when the roller has fairly gripped the other. The piece is thus passed to and fro between the men as many times as are necessary to complete the rolling, the roller and catcher always holding each his own end of the bar.

The expression "roller's side" is still used for that side of any mill where the bar first enters, and where the heating furnaces are situated, while the term "catcher's side" is used for the other side, from which the bar passes when finished to the hot bed or shears.

In this form of mill the lower roll is in a line with the crank-shaft of the engine which drives it, the upper roll being driven by the pinions, or in the case of a sheet mill by merely resting on the lower roll. It is still used, chiefly for rolling light and short pieces, and for sections where special accuracy of adjustment is needed, such, for instance, as rolling pen steel, thin strip and cotton ties, or for small sections, to produce which the grooves cut in the top roll must be exactly over the corresponding ones cut in the lower roll. In such mills the first few stands of rolls may be arranged three-high, but the last stand or two two-high, because it is much easier to get two rolls correctly adjusted together than three (see fig. 479).

Except for work of this kind the pull-over mill is now rarely used, owing to the loss of time and the labour involved in lifting the piece over the roll. Sheet mills, however, without exception, are still made on this plan, for special reasons, which are detailed in the section on sheet mills in Chapter xxxiv.

The Three-high Mill.—When watching a pull-over mill running in 1857 at the Cambria Iron Company's Works, of which he was then manager, it occurred to Mr. John Fritz that if a third roll were mounted above the upper one, a bar could be rolled between the existing top roll and the new one above it, and that thus, instead of passing the bar back to the roller idly, useful work might be done on it during the return journey, whereby the output of the mill might be at once doubled, and the object he had more immediately in view—namely, the finishing of his iron rails at a high heat—might be easily accomplished. He mentioned his ideas to various persons conversant with the working of rolling mills, but strangely enough the idea was pronounced by them all to be impracticable. Nothing daunted, after a long fight, he obtained the permission of the proprietors of the works to make the experiment; and immediately it was known what he was arranging to do, he was pronounced hopelessly mad by all the self-styled "practical men" around. The mill was completed, and tried successfully, unknown to the workmen, who, it would seem, took alarm at the possible loss of their employment, for the works were mysteriously burned down one Saturday night. The old hands were got rid of, the works rebuilt, and the mill was restarted in July, 1857, and at once ran with perfect success. The use of the new style of mill spread rapidly, particularly in the States and on the Continent, and in ten years it had become common practice. In England

it was not taken to kindly for large mills, but most of our smaller mills have long been of this description.

In the States, its original home, the three-high mill has been brought to the highest state of perfection, and is used for very heavy work, mills with rolls 40 inches in diameter having been constructed and successfully worked on this plan. Of late years, since ingots over 3 tons each in weight have been cast, even the Americans have taken to the use of reversing mills for their heaviest work, the disadvantages of having to lift and lower such great weights in the process of rolling becoming daily more obvious, and necessitating the employment of ponderous and complicated lifting tables to manipulate them.

In a three-high mill the engine crank-shaft is in line with, and is coupled to, the centre neck pinion, the middle roll being thus driven direct, and the upper and lower rolls by teeth on the opposite sides of the centre pinion, the thrust being thus balanced, and no teeth having to transmit greater power than is required to drive one line of rolls. The double wear on the centre pinion is equalised by changing the position of the pinion when too much worn, and placing one of the less worn ones in the centre.

As originally constructed, the bearings for the centre roll were secured in one fixed position in the housing, the top and bottom roll being carried in movable chocks which were adjustable towards the centre roll by pins and boxes both at top and bottom of the housing, whose two ends were practically identical. The housings were carried by feet cast on the back and front edges, and resting on girders instead of on the original flat bed plates. The screws were geared together so that the top and bottom screws were actuated simultaneously when the workman made any adjustments.

To protect the lower screws, which were liable to injury by hot scale from the piece being rolled falling upon them, they were provided with telescopic guards.

Three-high mills have also been constructed in which the top and bottom rolls were fixed in position, and the middle roll was moved up and down during the rolling by four screws driven by friction reversing gear from the engine, the Lauth mill (Chapter xxvii.) having developed from this arrangement. Three-high mills, however, as a rule, have the bottom roll fixed, and the two others are held down by a single screw through the top of the housing, the rolls being maintained in their correct relative positions by set pins or other means of adjustment between the various chocks, small mills being invariably constructed in this way.

Except in the case of the Lauth plate mill, the employment in a three-high mill of rolls which have to be adjusted between each pass has been abandoned; even in America all three-high mills are now provided with fixed rolls, the grooves of which are so proportioned as to give the reduction needed.

In a two-high mill the bottom roll rests by its own weight on the lower brass, and the upper roll may rest and run freely on the lower, rising slightly to bear against the brass above it when a piece enters the rolls. In a three-high mill the middle roll has to be prevented from moving up when a piece enters below it, or down when it enters above it, and to prevent this play the brasses must be held closely to the necks both above and below. In most designs of three-high mills this can only be accomplished by screwing down the top pin, thus forcing all the necks against their respective brasses. In any case there is much wear and tear, and considerably more power is absorbed in driving a three-high than a two-high mill. As previously men-

tioned, there is much more difficulty in adjusting three rolls to each other than in adjusting only two, and the fitting in place of the guides and guards takes much longer, so that it requires three times as long to change a stand of three-high as to change a stand of two-high rolls. For these reasons, where rolls have to be frequently changed, much of the advantage of the three-high mill disappears. But for this it would be used for all small work.

The Reversing Mill.—Mr. Ramsbottom, the manager of the Crewe works of the London and North-Western Railway Company, being desirous of making the frame plates for his locomotive engines in one piece, and finding such large plates difficult to pull back over the top of the rolls, was considering what other arrangement to adopt for handling them, when Nasmyth, of steam hammer fame, suggested to him the reversal of the engines as soon as the plate had passed through the rolls, and the running of the mill in the opposite direction to take the plate straight back again through the rolls, rolling it on the way, and thus avoiding having to lift it at all, with the further advantage that the output of the mill would at the same time be more than doubled. Mr. Ramsbottom, in order to test the idea, took a spare locomotive and secured to the driving axle a pinion which he geared into a large spur-wheel fastened on a shaft coupled to the rolls; the engine was run "at 60 miles an hour," and a plate successfully rolled. Mr. Ramsbottom then had a pair of large reversing engines constructed, and although the forgemen all prophesied that he could never roll plates without a flywheel, the engines, which were started early in 1866, worked with perfect success from the first. The use of the reversing mill spread rapidly in this country, and six years later the Dowlais Company were cogging 1,000 tons of ingots a week by its means.*

It is now used almost everywhere for dealing with heavy masses, though in America the three-high mill is still used for work which would in this country be considered much too heavy for it. A comparison of the advantages and disadvantages of the two systems will be found in Chapter xxxviii.

The Continuous Mill.—The first mill constructed on this principle was patented by Charles While of Pontypridd in 1861. Only iron rails were then made, and there was considerable difficulty in putting sufficient work on the piles before they became too cold to ensure good welds, on which the wearing properties of the rail depended. To avoid the time lost while the bar was passed backwards and forwards through pass after pass and turned on edge after each pass, Mr. While mounted a series of pairs of rolls so close together that while the pile was still between the first pair, the end, which had passed, entered between a second pair, both pairs of rolls thus operating on the piece at the same time. Actually three pairs of rolls were employed, the pile being in all three pairs at one time, and to ensure the proper welding in all directions, the first and third pair were mounted horizontally in the ordinary way, while the second pair placed between them stood vertically. About 20 of these mills were in use in South Wales alone in 1872. Bedson's mill, described in Chapter xxxv., is a development of this idea.

In the ordinary mill one pair of rolls has cut in them a series of grooves diminishing in size, through which the bar passes in succession, as many grooves being required as there are passes; but in the continuous mill, as the bar passes once only between each pair of rolls, there must be as many pairs of rolls as there are passes, the bar travelling forward continuously in one straight line.

* *Iron and Steel Inst. Journ.*, vol. i ., 1872, p. 68.

Seeing that the bar increases in length in proportion as its sectional area is reduced in each pass, the surface of the second pair of rolls must travel as much faster than that of the first, as the length of the bar has been increased by its passage through the first pair of rolls. Otherwise the bar, accumulating between the first and second pairs, would not feed straight into the latter, and the result would be disastrous. As it is practically impossible to hit off the precise relative speeds, the second pair is driven rather faster than is necessary to take up the slack, thus keeping the bar always under a slight tension. Where several pairs of rolls are employed each pair must be slightly over-speeded, as compared with the preceding pair.

In a continuous mill the piece to be rolled is entered between the first pair of rolls and travels right through the series, issuing from the other end a finished bar, without being touched after it has entered the first stand. The output of such a mill is, therefore, very high, and the labour cost very low, but the first cost of so many stands of rolls is a serious matter. The cost of the numerous rolls which are needed is very large, and much time is wasted in changing them, so that it is only practicable to use a mill of this kind where a continuous demand exists for one special section. It is chiefly applicable to the manufacture of wire rods (see Chapter xxxv.), or for billets, and to a limited extent for bars (see Chapter xxxvi.).

Looping Mill.—A description of this will be found in Chapter xxxv.