K, K (fig. 344), to receive square nuts, in which work set pins, by means of which the position of the chocks can be adjusted horizontally, so as to bring the finishing groove in each roll in exact correspondence with that in its neighbour. These pins are shown clearly in the plan and elevation in fig. 352. In the case of the larger mill (fig. 353), the chocks themselves are not adjustable, but bear against the shoulders formed in the housing,

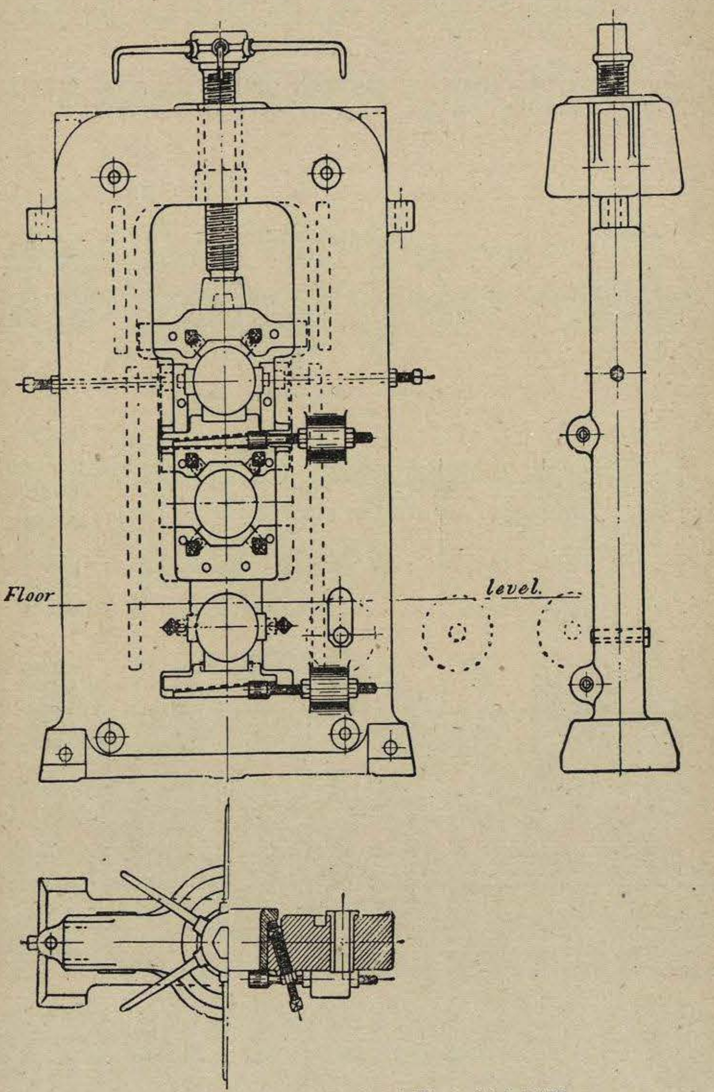

Fig. 353.—Housing for 28-inch Three-high Mill.

while the brasses are adjusted in the chocks in the same way that the bottom brass is adjusted in fig. 352. All the set pins are, it will be noticed, accessible from the outer side of the housings, and all are provided with lock nuts to prevent them slackening back under the vibration incidental to all running machinery.

The arrangements for carrying the rolls in three-high mills, where there are three rolls per pair of housings instead of two only, differ considerably.

The bottom roll usually rests on brasses let into the sole of the housing, as in two-high mills, and for small mills the simple plan is adopted of laying the chock carrying the middle roll direct on to the neck of the bottom roll, and that carrying the top roll direct on to the neck of the middle roll, the chocks being provided for this reason with brasses on their under as well as their upper sides. When so arranged, wear is allowed for by packings of thin sheet metal between the chocks and the brasses they carry, and when the rolls, which become smaller each time they are re-turned, finally become too small to meet each other, a thinner set of chocks is substituted, three or four sets of varying depth being kept in stock for the purpose. The changing of the chocks may be avoided by splitting the bottom and middle chocks in halves, and inserting between the halves a wedge set up by a screw, as in fig. 348.

Any arrangement of this nature which piles chock on neck, and neck on chock, throws the weight of all the rolls and chocks on the lowest brass, and when a piece is between any pair of rolls four brasses in each housing are subjected to the additional wear produced by the pressure, instead of only the two which are absolutely necessary to maintain the rolls in position, thus increasing the power required to drive the mill, and adding to the friction and wear and tear. This can be avoided by placing packings or adjustable wedges between each pair of chocks, and between the bottom chock and the sole of the housing.

In fig. 352 the bottom chock is hung on two hooked bolts, A, A, from the arch of the housing, an arrangement which is convenient for adjusting the distance between the bottom and middle roll, and has the further recommendation of taking the downward thrust exerted on the middle roll, when the piece being rolled is entered above it, thus relieving the neck of the bottom roll from this pressure. The upward thrust on the middle roll, however, is still transmitted through the brasses and neck of the top roll to the pin in the arch of the housing. In this mill the bottom roll is always fixed at one height, and the middle and top rolls are adjusted to it, by lowering them as they wear or become smaller each time they are freshly turned. In fig. 353 the middle chock lies on ledges cast in the housing to receive it, so that the middle roll is always at one height, and the bottom roll is raised as necessary by the wedge placed below its bottom brass, capable of adjustment by means of the screws and nuts provided for that purpose on the outside of the housing.

Retaining the middle roll at one invariable height and moving the other two to suit it is generally preferable to making the bottom roll the fixed one. The pinions which drive the rolls retain the same diameter until worn out, while the rolls are being continually reduced in diameter as they wear, and consequently the spindles which connect the rolls to the pinions are thrown less out of line, if the middle one retains its horizontal position, leaving the bottom one to slope up and the top one down, than is possible if the bottom spindle remains horizontal, and the top one has to slope downwards through twice the distance of the middle one. The more the spindles are out of line the faster they wear out, and the more power is required to drive the mill, both disadvantages becoming greater as the size of the mill increases.

A method of carrying each roll independently, and one much used on the Continent, is that introduced by Herr Erdman (fig. 354), in which the chocks for the top roll are slung from bolts in the top of the housing, while those for the centre roll are carried by four curved levers, *a a*, above, and *b b*, below, lying in slots cast through the sides of the housings for this purpose. The height of the roll is adjustable by means of the screws, *c c*, and *d d*, which are easily accessible from the front and back of the mill respectively. When the rolls become smaller by wear, the position of the levers is changed, *a a* being placed below and *b b* above the chocks.

In this housing, the rabbeted recess into which the chocks fit is made on the outside of the housing, and the chocks are kept in place by bolts passing through them horizontally, so that they can be drawn away outwards, whereas in most housings they are first lifted and then drawn away inwards. In figs. 506 and 507 the chocks are similarly removable from the outer side, an arrangement which saves lifting them, and is specially convenient when rolls are short. In some cases the chocks are retained in position by strips bolted on to the outside of the housing (see fig. 495). Fig. 355 shows a Continental design in which the middle roll is fixed, and the bottom roll is lifted by screws. In each of these (figs. 354 and 355), the pressure on the middle roll does not pass through the necks and brasses of the other rolls.

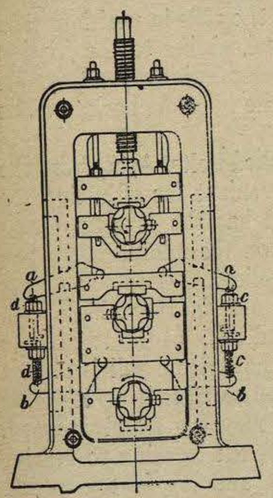

Fig. 354.—Erdman's Three-high Housing—Bottom Roll fixed.

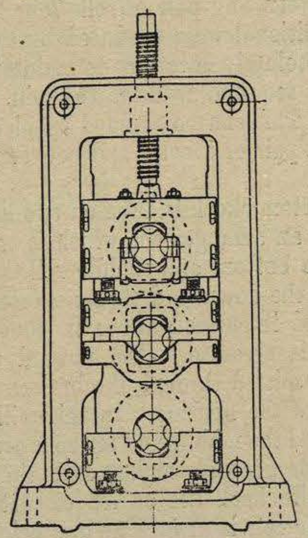

Fig. 355.—Three-High Housing—Middle Roll fixed.

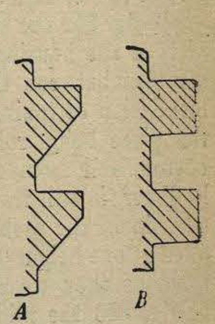

Fig. 356.—Sections of Threads of Housing Screws.

In all cases the top chock is held down by a strong screw about $\frac{1}{3}$ to $\frac{1}{4}$ of the nominal diameter of the roll, which works in a wrought-iron or cast-steel nut, let into the arch of the housing. In old mills the nut was hexagonal and tapered to fit a hole of similar shape cast in the housing, but in new mills the holes are bored, and the nuts turned with one or more shoulders to take the pressure. The screws and nuts, called by the workmen "pins and boxes," are cut with a common square thread, B (fig. 356), except for large mills where the stronger buttress form of thread, A, is now generally employed.

The pins must be made a very free fit in the boxes, or they will jam when the pressure comes on them. They are provided at their upper ends with spanners which have one handle only in the case of small mills, but, in the case of large mills, six or eight, disposed like the spokes of a wheel. To insure that both screws shall be set down by equal amounts, bevel wheels are sometimes fixed on the upper ends of the pins, into which gear similar wheels keyed on to a shaft running across the top of the housings.

Screwing Gears.—The adjustment of the pins, in the case of a large mill, requires the efforts of so many men, and is even then so slow an operation, that where the top roll requires adjustment during the rolling of the piece, power has to be supplied to work the screws. When first used about 1860, the power was taken from the main crank shaft of the engine up to a small shaft running across the top of the housing, the direction of rotation of this shaft, or a continuation of it, being capable of reversal at will by means of open and crossed belts, friction cones and bevel wheels, or similar devices. On the shaft were two worms, driving worm-wheels, which in turn were geared to the screws, and so actuated them; or the worm wheels may be keyed direct on to the nuts which turn in the housings, while the screws are prevented from turning, and so travel up and down through the nuts (see fig. 489). These devices serve well enough when the mill is not a reversible one, and the engine consequently runs continuously in one direction, but are not suitable for a reversing mill, for use with which a great diversity of arrangements have been contrived, such, for instance, as gearing the two screws together in various ways, and on part of the gearing which connects them together, fixing a barrel having a chain wound round it, either

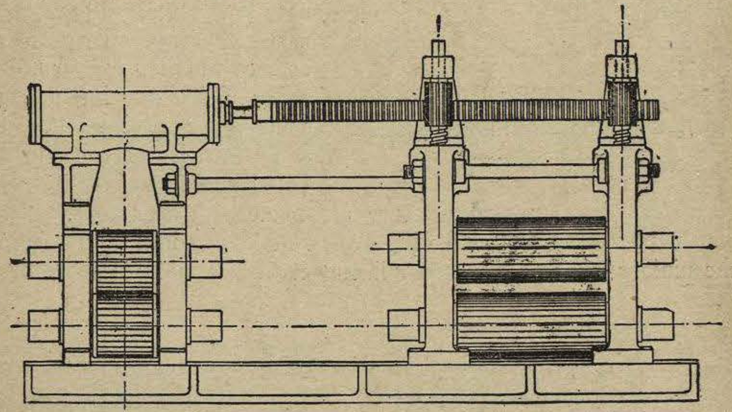

Fig. 357.—Hydraulic Screwing Gear.

end of which may be hauled over as required, by means of stream or hydraulic cylinders. Almost the only two methods now used, are either to key a pinion on each screw, with a width of face equal to the rise of the top roll, + the width of a rack which gears into both pinions, this rack being moved to and fro by a direct-acting hydraulic cylinder, situated horizontally either on the top of the housings themselves, as in fig. 465, or of the housings of the driving pinions adjacent to it (see fig. 357); or the revolving shaft previously described, with its worms and worm wheels, is driven direct by a small pair of reversing engines coupled to one end of it (see figs. 417, 490), or frequently of late by an electro-motor (see figs. 489, 494).

Adjusting Wedges.—The pins shorten materially under the upward thrust which comes upon them where the piece is being rolled. If anyone will calculate the possible additional opening between rolls due to the stretching of the housings and the shortening of the pins, if both are stressed to near the elastic limit, he will be surprised at its extent, and how large a proportion is due to the "upsetting" of the pins. That these are often strained beyond the elastic limit of the material of which they are composed is evident from the fact that unless originally made a very free fit in the boxes, they will set up sufficiently to jam themselves, and become immovable in the boxes.

The yielding due to shortening of the pins can be avoided by replacing them with wedges, as shown in fig. 358, which represents a French sheet mill housing.

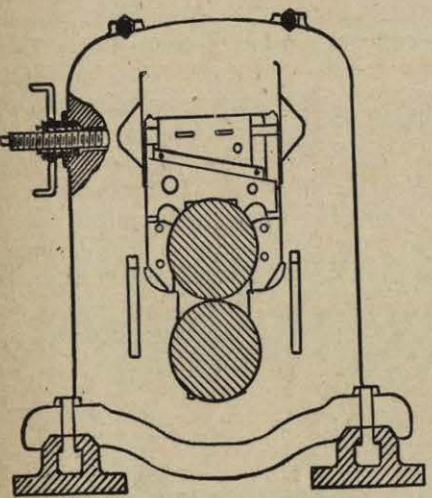

Fig. 358.—Roll Housing, with wedge instead of pins and boxes.

Some discretion is necessary when employing this method of adjustment not to reduce the yielding beyond safe limits, or the necks of the rolls will be sheared off.

Pinions.—Each roll is coupled by means of a short spindle of the same section as the wobbler on the roll, having at each end, as previously described, a loose coupling connecting it with one of a set of "neck-pinions," which are practically short rolls whose surfaces are covered with teeth, so that the pinions gear into each other and turn together. The pinions are carried much in the same way as the rolls, in a pair of "pinion housings," which, as there is very little upward pressure, are made with open tops. Fig. 359 shows the pinion housing used with Messrs. Perry's 12-inch mill. The necks of the pinions run in solid chocks lined with white metal. These bearings

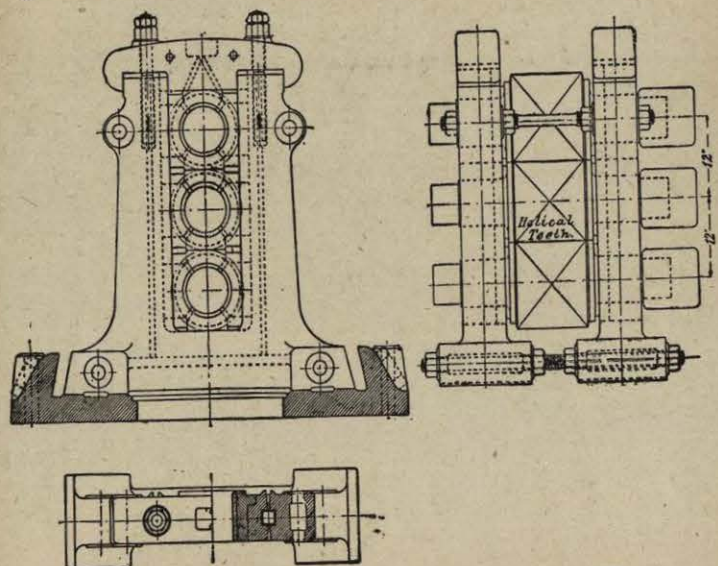

Fig. 359.—Pinion Housing for 12-inch Three-high Mill.

are not adjustable, as there is little pressure on them, and they are merely required to steady the pinions; when worn the white metal is melted out and the chock re-lined. The simplicity of the plan and the absence of any

need for adjustment has led to its adoption for small mills—of 12-inch or less in this country—but in America this method is employed for mills of large size.

Fig. 360 shows the pinion housing employed with Messrs. Roberts' 28-inch mill. The necks run in brasses carried in chocks which are adjustable by means of carrier bars and wedges, in the same way as the chocks used for carrying the rolls, and there are side brasses to prevent shaking.

The pinions are usually cased in to protect them from dust, and to catch grease which would otherwise be thrown about the mill. Fig. 496 shows the top and bottom of this casing in place and the side removed to enable the teeth to be examined. Sometimes the two housings are cast in one so as to form an oil-bath, but often the teeth are merely dressed occasionally with a mixture of black lead and tallow, or some other thick grease, so as to prevent the teeth from cutting and wearing out rapidly.

The pinions are now usually steel castings, which seldom wear less than three, and often as much as ten, times as long as iron ones, and are far less liable to be broken by any accidental shocks at the rolls.

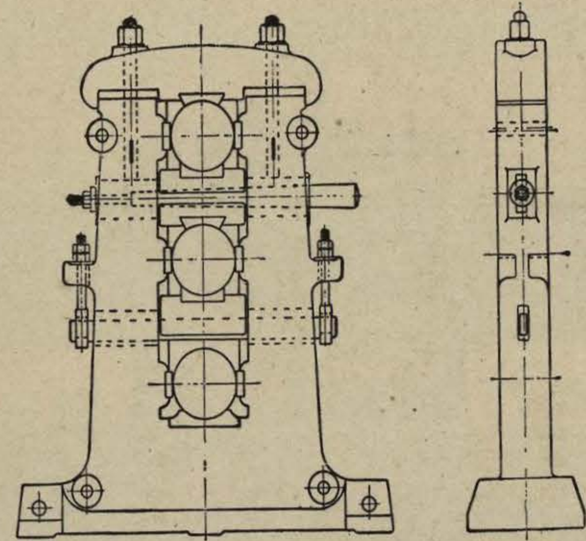

Fig. 360.—Pinion Housing for 28-inch Three-high Mill.

The pinions originally had straight teeth running right across the full width of the face, but as the teeth must be few to obtain sufficient strength (from 9 to 18 in number, and most frequently 13), they do not work with the smoothness of wheels possessing many teeth. To obtain greater smoothness of running the face was split up into two portions, the teeth on the one half being in line with the spaces on the other, thus obtaining the equivalent of a wheel with double the number of teeth. Fig. 494 shows pinions whose teeth are split up into three separate sections across their faces. These stepped teeth have now been displaced by helical teeth, which were introduced about fifteen years ago, and are now practically universal. Messrs. F. H. Lloyd & Co. (Limited), of Wednesbury, find that 99 per cent. of the steel pinions they make are now demanded of this shape. Fig. 361 shows a pinion of this kind. The rolling motion is continuous, and no shock occurs as the teeth in turn come into action, as was the case with the older form. Indeed, strip or cold-rolled sheets will often show marks answering to each tooth, where the rolls are driven by straight teeth pinions, such marks being absent when helical pinions are employed.

Some years ago Krupp, of Essen, cut helical pinions out of steel forgings, but such things were too costly for general use. Those for the mill (fig. 495) are not only machine cut, but also oil-tempered. Now that automatic machinery has been devised for cutting helical teeth in steel forgings, the cost has been so much reduced that the use of forged steel helical pinions for high-speed mills is certain to extend, as the saving in power and smoothness of running where they are employed are very marked, and when run in an oil bath they are remarkably durable.

The object of these pinions is to ensure that the two rolls shall revolve together regularly. They are placed between the engine and the rolls, the engine in the case of a two-high mill being coupled to the lower, and in a three-high to the middle pinion, by means of a spindle generally similar to those connecting the rolls and pinions together, this spindle being known as "the leading spindle." Its section was reduced somewhat in the centre to form a "breaking spindle," so that if a dangerous strain were put on any part of the mill this spindle would break in preference to the rolls or other more costly portions of the machinery, spare spindles being kept in stock

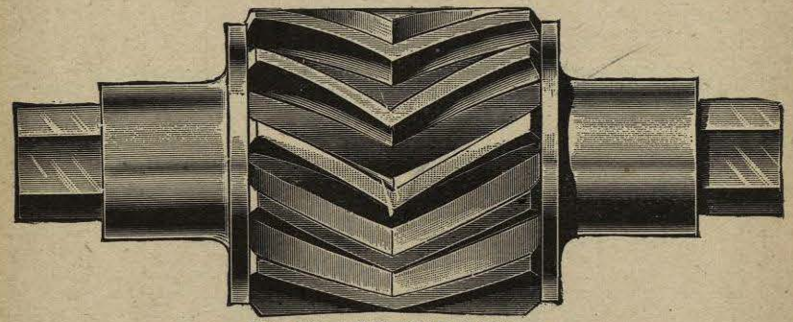

Fig. 361.—Helical Neck Pinion.

which can be rapidly substituted for the one broken. The spindles and coupling boxes throughout are, in modern mills, usually steel castings, except one of the couplings, which is still made of common cast iron to serve as a safety valve. In mills where the top roll is not movable, an even simpler and cheaper plan is frequently employed, a "breaker" being placed on the top chock, on which the screw of the housing bears (see figs. 348, 352, 353, 354, 355, 479, &c.). If a careless workman puts too large or too cold a piece in the rolls, this small casting gives way and allows the roll to lift, when the piece passes through without damage. For small mills the breaker can be replaced by hand in a few seconds, and the work proceeds with scarcely a moment's interruption. Unless the leading spindle is very short, it should have either one or two bearings in its length to carry its weight; if unsupported, it will cause considerable additional wear on the boxes and wobblers.

A spindle must always be a little longer than the two coupling boxes which connect it to the wobblers at each end, so that it may be lifted into position with the two boxes on it. These are then slid on to the wobblers to right and left, and to prevent their working back there are laid between the boxes, and outside the spindle, strips of timber, which are held together

by hoop iron and nails, by leather belts buckled on, or even by wrapping with rope. The timber is quickly removed if the spindle or couplings break, or when a roll has to be changed, and, primitive though the arrangements may appear, they are quite satisfactory in practice. In fig. 496 the timber is shown in position.

When the upper roll needs considerable adjustment during the process of rolling, the upper spindle, coupling the roll to the pinion, is necessarily

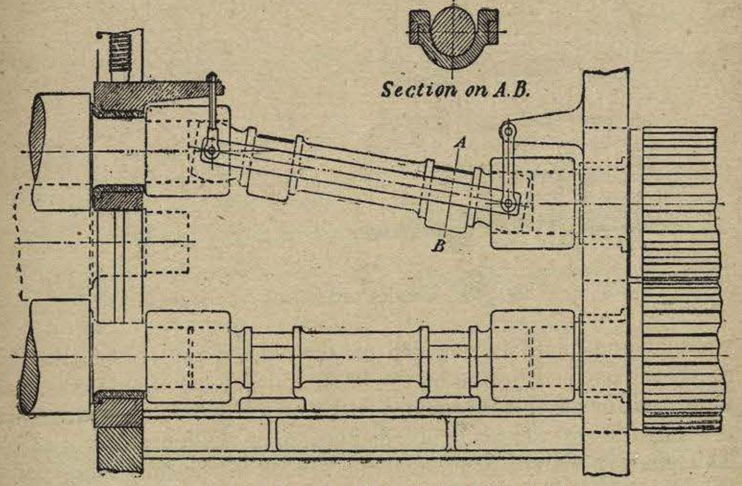

Fig. 362.—Leading Spindle for Plate Mill.

much out of line, and to reduce the stresses thus set up, the distance between the pinion and roll housings, in such cases, must be considerable, so that the spindle may never be more than about 15° out of line. The ends of the spindle are formed into a species of spherical wobbler, to allow of their want of alignment. The weight of the spindle and the shape of the ends necessitate some form of bearing, which must follow the spindle up and down as

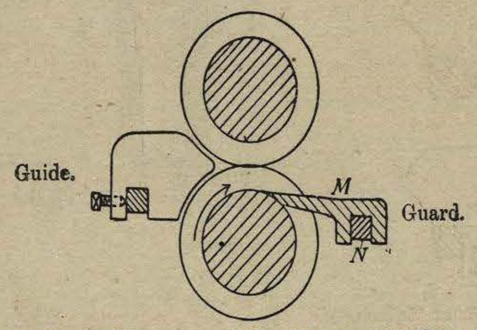

Fig. 363.—Guide and Guard for Small Mills.

the rolls open and close, and the difficulty is got over by placing a wrought-iron bar or bars beneath or on each side of the spindle, carrying one or more bearings, one end of the bar being suspended by a link from the chock carrying the roll, and the other end hung from the pinion housings (see fig. 362, also 493 and 494), or the spindle can be supported by weighted levers, or by hydraulic cylinders, in the same way as rolls are balanced.

Guards.—If the piece in passing between the rolls is wedged sufficiently fast into the grooves of one of them, instead of the bar passing straight away from the mill, in continuation of the direction in which it entered, it will be carried round by the roll and wrapped round it. As will be explained later, to prevent this occurring, the two rolls are so formed, in relation to each other, that if there is any tendency to adhere it shall be to the lower and not to the upper roll of the pair, and to clear the bar out of the lower roll, a

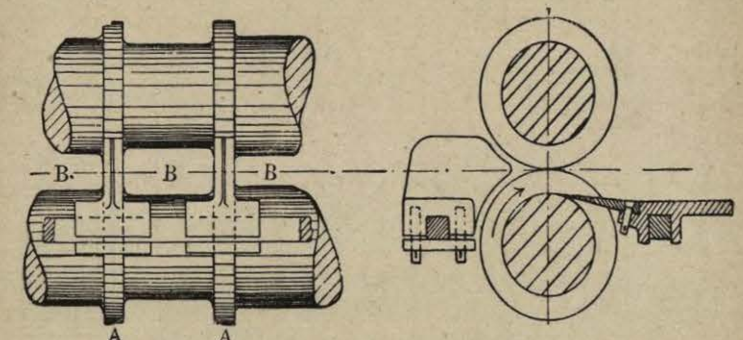

Fig. 364.—Guides and Guard for Larger Mills.

wrought-iron guard is provided on the side of the rolls furthest from the roller, the one end resting on the lower roll and pointing towards the workman, and the other end provided with a notch resting on a square bar, which is secured in recesses made for the purpose on the inner face of each housing. This guard peels the bar out of the groove in the lower roll, and allows it to glide away along the floor as it leaves the mill. The guard is marked M, and the bar on which it rests N, in figs. 363 and 343. In place of the

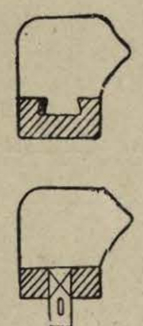
Fig. 365.—Other Methods of Securing Guides.

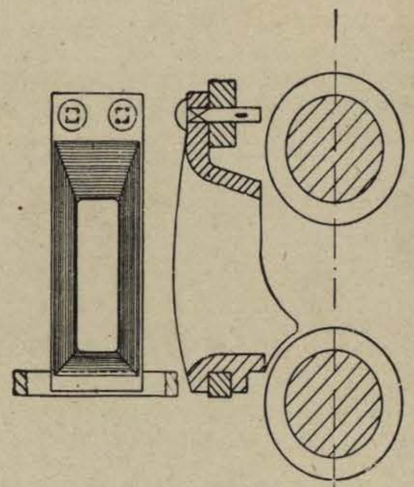
Fig. 366.—Guide for Edging Slabs.

square bar a flat plate is sometimes employed, as in fig. 364, having an approximately horizontal surface, with recesses cast in it to receive the heels of the guards, which are secured by bolts with heads countersunk into their upper surface. In a reversing mill, guards must be provided on each side of the mill.

Guides.—In mills fitted with grooved rolls, if the piece to be rolled were inadvertently presented opposite the collars, A, A (fig. 364), instead of opposite the grooves, B, B, B, it would be spoiled, and the rolls probably broken, and to assist the roller in entering the piece correctly a "fore plate," O (fig. 343), is provided on the roller's side of the mill; this is a flat plate of cast iron or steel, shaped to fit up closely to the roll, and bolted securely to bars held in the housings, much in the same way as the guards are secured. The edge of the plate is shaped to suit the contour of the roll, and projects into the grooves, so that the piece to be rolled can slide along the fore plate tangentially to the roll, until it is just on the bottom of the groove. The fore plate is usually provided with ribs opposite the collars of the roll (see fig. 343), on each side of the pass, forming troughs leading to the passes, thus enabling the roller to see that the piece is presented square with the axis of the rolls, and central in the pass. If the mill is a small one the fore plate is usually raised somewhat above the surface of the mill floor, but in larger mills it is merely a continuation of the cast-iron floor plates, both being on the same level to facilitate dragging the piece along the floor without having to lift it.

In mills rolling heavy pieces, the power required to push the piece along the fore plate into the rolls is too great, and, instead of the plate, rollers, on which the piece can run, are placed level with the floor in front of the housing. For cogging mills which deal with the raw ingots, the form of which is constant, two or more of the rollers in the floor nearest the mill can be grooved to correspond with the main rolls and lead the ingot in fair: but for mills which have to deal with varying sections, the cost of numerous rollers to match each pair of rolls in the housings would be too great, and the time lost while changing them too serious, and, therefore, the rollers are made as plain cylinders of uniform diameter. To prevent the pieces being rolled getting in between the collars, flat division plates are placed opposite the collars, forming a set of pigeon-holes leading to the grooves, one hole opposite each pass (see fig. 363). These guides are either bolted on to a single bar (see figs. 363, 364, and 365) or are fastened top and bottom to bars running from housing to housing (see fig. 366) similar to those used to support the guards; or a single large bar having a trough running the length of its upper side may be employed, into which feet cast on the guides may be wedged, as in fig. 365.

The arrangement of these parts differs very greatly, according to the nature of the work being produced and the practice of the rollers, every one of whom considers the plan he follows superior to every other, so that no two works have these contrivances precisely alike.

The guides and guards are shown in position in fig. 507.

Guide Mills.—Small sections cool so rapidly that to finish them hot they must make as few passes as possible, and the only way of getting few passes is to effect a heavy reduction in each pass. As it is not generally practicable to reduce the sections more than 15 to 25 per cent. in one pass unless the piece is brought to a section having a sharpish edge and wider than it is thick, such as a diamond or oval, these forms must be employed if a reduction of 30 to 50 per cent. is to be effected, and the piece must be turned on edge when presented to the following pass. If not entered quite vertically the bar, instead of being flattened right down by the pressure of the rolls, is liable to be tilted over to one side and spoiled, or the rolls are broken. Heavy sections are more easily held true by the men's tongs, but small sections running at high speeds are easily twisted between the tongs and 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).

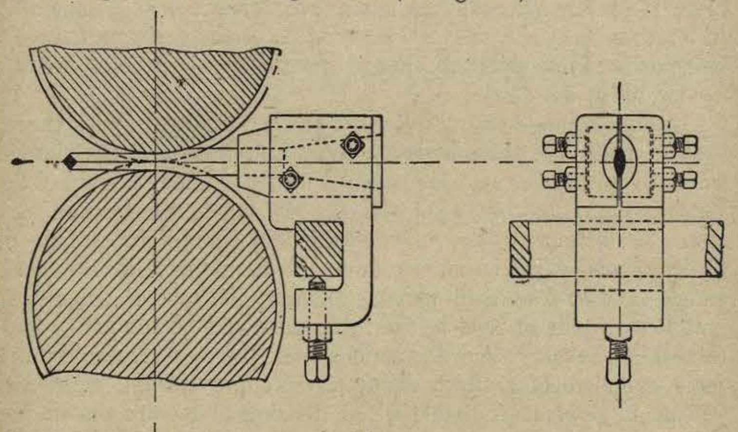

Fig. 367.—Guide for Guide Mills intended to produce Light Sections.

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.