Charging Inclined Furnaces.—Figs. 338 and 339 show two different types of machines used on the Continent to charge furnaces of this description. In the first, the small trolley is loaded with small ingots, which are laid carefully side by side, and is run on to the tipping cradle, *a*, carried on a frame, *b*, which is fastened to the upper end of a hydraulic plunger, *c*, working in the cylinder, *d*. When the piston rises, the chain, *e*, is tightened, and the cradle tipped into the position shown, so that the ingots roll into the furnace. In the second case (fig. 339), a species of fork, *a*, is inserted under the ingots, which are brought up on the trolley, *b*. This fork is

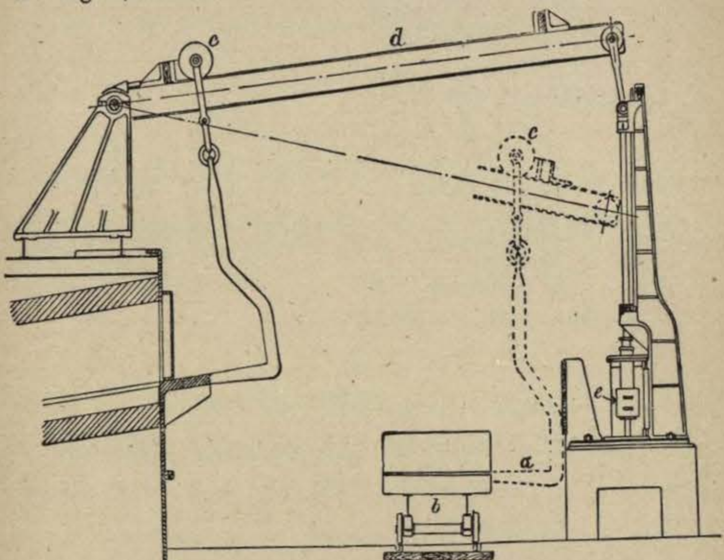

Fig. 339.—Charger for Inclined Furnaces.

fastened to the runner, *c*, which can travel along a rolled beam, *d*, one end of which is lifted by the steam cylinder, *e*. The fork then runs down the sloping beam, and strikes the fore plate at the furnace mouth, whereby the ingots are shot off into the furnace.

In other furnaces the ingots or billets are brought, one at a time on live rollers, or several at once on a bogie, opposite the doorway at one end of the long furnace, into which they are pushed by the piston-rod of a horizontal cylinder, worked by steam or hydraulic pressure, as explained in the previous chapter dealing with the furnaces.

CHAPTER XXIII.

DETAILS OF ROLLING MILLS.

The Rolls.—The rolling mill consists essentially of two rolls, mounted one over the other, both driven by some extraneous power in opposite directions, so that the upper side of the lower roll and the lower side of the upper roll travel at nearly the same speeds in the same direction. The piece to be rolled is put in between the two rolls which, by revolving, draw it forcibly through, and so reduce the section of the piece acted on. If plates or sheets are to be made, the rolls are plain cylinders; but if bars are wanted, grooves are formed in the rolls, which give the piece being rolled the section desired. The rolls are mostly made of good, tough cast iron, run into dried sand or loam moulds, except in those cases where it is desired to put a highly-finished surface on plates or sheets, when the rolls are "chilled."

When in the molten state cast iron holds in solution the Carbon it contains, which separates in the form of crystals of Graphite, distributed throughout the mass as the fluid cools, rendering the casting soft and grey. On the contrary, when cooled suddenly, there is not time enough for the Graphite to separate, its retention in solution rendering the chilled iron dense, white, intensely hard, and capable of receiving and retaining a high polish, which it can impart to materials pressed into intimate contact with it.

Chilling is effected by making the mould in sand as usual, except that portion destined to form the body or "barrel" of the roll, which is made up of heavy cast-iron rings, called "chills," which are carefully turned on the joints and bored out true inside. They are warmed to remove any moisture, and the insides washed with a coating of black lead, which dries upon them; when the iron is poured in through a passage or "git" running down to the bottom of the mould, as it rises it comes in contact with the chill, and is converted into white iron for a distance of 1½ to 1¼ inches inwards from the surface, while the central portion retains its grey tough character. As the chills employed are costly and are destroyed by frequent use, while the slightest defect on the surface of the roll will leave a mark on every sheet rolled by it, and, therefore, ensure its rejection, and the labour of turning so hard a material is considerable, such rolls cost from 50 to 100 per cent. more than those cast in sand, and known as "grain rolls." The operation of chilling causes the different parts of the roll to cool at different speeds, and puts the whole casting into a condition of initial tension, with a peculiarly brittle surface, so that such rolls are very easily broken, and, as they are very susceptible to sudden changes of temperature, require considerable care on the part of the men using them; they are consequently employed only for purposes where a high finish is required on the rolled material. A "part-chill" roll is one which is chilled only at the end where the finishing grooves are situated.

Any iron not too high in Silicon can be chilled, but to obtain satisfactory chilled rolls, possessing both the requisite strength and hardness—*i.e.*, two characteristics more or less antagonistic—is by no means an easy matter. The best rolls are made from mixtures of cold-blast pig-iron smelted from the argillaceous ores of Staffordshire, Shropshire, or from Blaenavon, in South Wales.

By driving the blast furnace with cold air its temperature is kept comparatively low, and consequently the total Carbon in the pig iron made is little more than 3 per cent., and the Silicon can be kept down to 1·0 or 1·25 per cent. without the Sulphur rising in inverse proportion to the reduction in Silicon, as usually occurs when hot blast is employed to smelt the ores. If such pigs are carefully remelted in a suitable furnace the Carbon need not fall below 2·8 per cent., while the Silicon is being reduced to the extent necessary.

The strength of the roll depends chiefly upon the proportions of Carbon and Phosphorus. If the total Carbon approaches 2 per cent. the iron becomes rotten and loose in texture. If the Phosphorus is present in excess, it makes the casting brittle; but if insufficient gives a chill which is too soft, and can be too easily dented. The depth of the chill depends on the amounts of Silicon and Sulphur present, the former tending to throw the Carbon out of solution (into the Graphitic form), while the Sulphur has the opposite effect, and increases the chilling capabilities of the iron. Manganese has some influence in preventing the cracking of the surface, improving the material much in the same way as it improves steel, and if deficient in quantity the chill is apt to peel off in patches when the roll gets hot, a condition called by the workmen "spawling."

The iron used for casting chilled rolls is melted in a reverberatory furnace, known as an "air furnace," the grate being fed with large coal; the South Staffordshire "thick coal" (now nearly exhausted) is peculiarly suitable for the purpose, as it gives a long smoky flame of high temperature, free from Sulphur, which would be readily absorbed by the iron, and would render the metal very brittle. The door for stoking is made as small as possible, and a deep bed of fuel is kept up to prevent the flame becoming too oxidising. When the furnace-tender considers the metal is about right for casting, the Silicon being sufficiently reduced to give a good chill, he ladles out a small quantity and casts with it a little block, about 6 inches square by 2 inches thick, set edgeways in a sand mould, the bottom of the mould being formed of a cast-iron chill plate about 12 inches square and 3 inches thick. By observing the depth of chill he can tell whether the metal is ready for casting.

The chemical composition of the iron, after treatment in the melting furnace, must lie within very narrow limits. Most good Staffordshire chilled rolls have a composition lying between the following limits:—

Total Carbon,	2·80 to 3·20	per cent.
(of which 0·8 to 1·0 per cent. is combined).		
Silicon,	0·75 to 1·00	,,
Sulphur,	0·06 to 0·12	,,
Phosphorus,	0·30 to 0·50	,,
Manganese,	0·40 to 0·80	,,

The above is an outline of the process, but there are many points to be observed, such as the heat at which to pour the metal, while the composition varies according to the purpose for which the roll is required, and whether it is intended for rolling hot or cold material. To a certain extent also the composition of the metal is varied according to the size of the roll to be cast. Some mill managers prefer a chill dying away gradually into the grey back, others as distinct a line of demarcation between the skin and the body as it is possible to obtain. A considerable amount of care, skill, and experience are needed to get really satisfactory results and to satisfy the varying requirements.

The first pair of rolls between which the ingot is put for reduction to sections suitable for finishing in other mills are known in England as "cogging," and in America as "blooming" rolls; these are now usually steel castings, which, having two or three times the strength of good iron castings, are almost unbreakable. Plate rolls, if of more than ordinary length for their diameter, are frequently made of forged steel, in spite of their extra cost, for if the diameter of the rolls is increased, every other part of the mill must be increased to correspond, so that it will often pay to use steel rolls rather than make the whole mill stronger throughout. Many old mills are now regularly turning out work of a size which they could not have attempted with cast-iron rolls, which would have broken almost as soon as started. The deflection of a steel roll under any given load is only half as much as that of a common cast-iron roll, and is an additional advantage. For small rolls turning out difficult small sections requiring sharp corners on the rolls, such sections being so thin that they cool very rapidly, and require finishing at a low heat, necessitating great pressure per unit

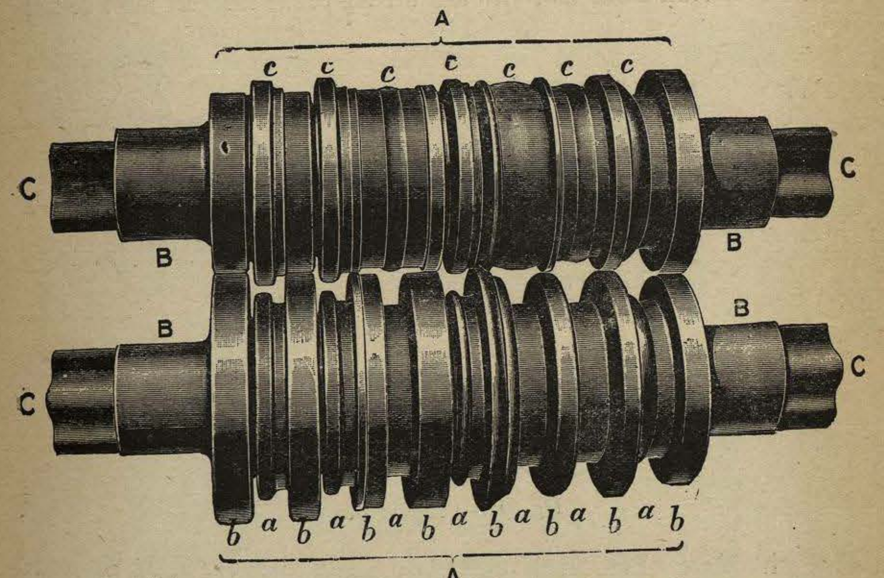

Fig. 340.—Pair of Rolls by Messrs. Akrill & Co., Ltd., West Bromwich, for Rolling Rails. A, A, bodies of the rolls; B, B, B, B, necks which revolve in bearings in the chocks; C, C, C, C, wobblers, by means of which the rolls are driven. The openings between the bodies of the rolls form the passes, consisting of the grooves, *a*, *a*, bounded on each side by a collar, *b*, *b*, and closed in at the top by the closers or formers, *c*, *c*.

of surface, high quality forged steel rolls soon pay for themselves, in spite of their high price (three or four times that of cast iron), because sharp corners in cast iron easily crumble under heavy pressures, and, therefore, the rolls continually require returning. It is as well to remember that steel rolls cannot be "chilled," and any hardening by quenching when hot is at once removed by the heat of the material being rolled, so that such hardness as may be required must be obtained by the use of suitable alloys in the steel. Soft steel rolls do not wear at all well, and much dissatisfaction has been caused where makers, for the sake of cheapness, have supplied such material for the purpose. All steel rolls are apt to develop surface roughness, if the material to be rolled is raised to too high a temperature, but they possess the advantage of being practically unbreakable.

The length of the body or barrel of the roll is rarely less than two, or more than four times the smallest diameter; if too long the roll will either bend or break, a plate roll always bending sufficiently to make the plate appreciably thicker at the middle than it is at the sides. At each end of the barrel is a journal or neck, as it is usually termed, about half the diameter of the body, and about as long as its own diameter, except in chilled sheet rolls, when the diameter is about three-fourths of the diameter of the body. There is, however, a marked tendency steadily to increase the diameter of all necks, thus reducing breakages, as well as wear and tear.

At the outer end of each neck forming part of the casting is a "wobbler," provided with either three or four prongs or corners, by means of which the roll is driven (see fig. 340, &c.). Some engineers contend that with three prongs a bearing is taken on all three from the start, while the hard skin of the casting not being broken, wear does not so soon occur. Others maintain, on the other hand, that with four driving points the wear must be less

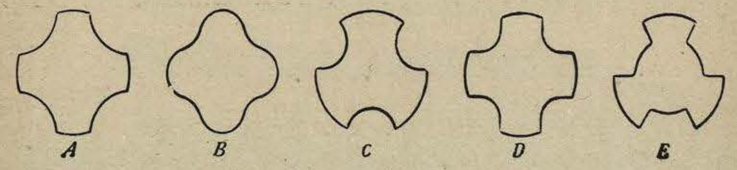

Fig. 341.—Various Forms of Wobblers.

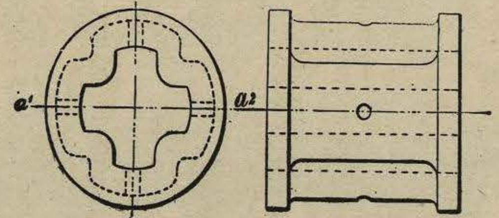

Fig. 342.—Coupling Box.

than with three. Both kinds work satisfactorily, but the forms A or B (fig. 341) are easily chipped down to a square when the corners are worn off, and are then capable of continuing their work for some time longer; indeed, small forged rolls are often made with square wobblers from the first. A and B show the usual English forms of wobbler, C is less often employed, D is typical of American practice, while E is known as the French wobbler. The diameter over the largest part of the wobbler is usually a little less than the neck, but in the case of C it is often equal, and in E occasionally more than the diameter of the neck. The size cannot be increased to any great extent, or the coupling box which fits over the wobbler, and connects it to the driving spindle, would be too much weakened, seeing the diameter over the couplings must obviously be less than the distance between the centres of the rolls, or the two boxes would not clear each other.

These coupling boxes are iron, or more often steel castings, with the central hole from one-eighth to one-half of an inch larger all round than the wobblers, on which they are thus a free fit, the length of the box being a little more than twice that of the wobbler: for small mills they are,

externally, plain cylinders, but for large mills they are generally lightened out (fig. 342), and have a hole cast in them at a_1 a_2, through which a bar can be passed to facilitate rapid handling.

Rolls may be divided into two classes—first, those having plain cylindrical bodies, which are used for rolling plates, such rolls being screwed down closer to each other every time the piece to be rolled is passed

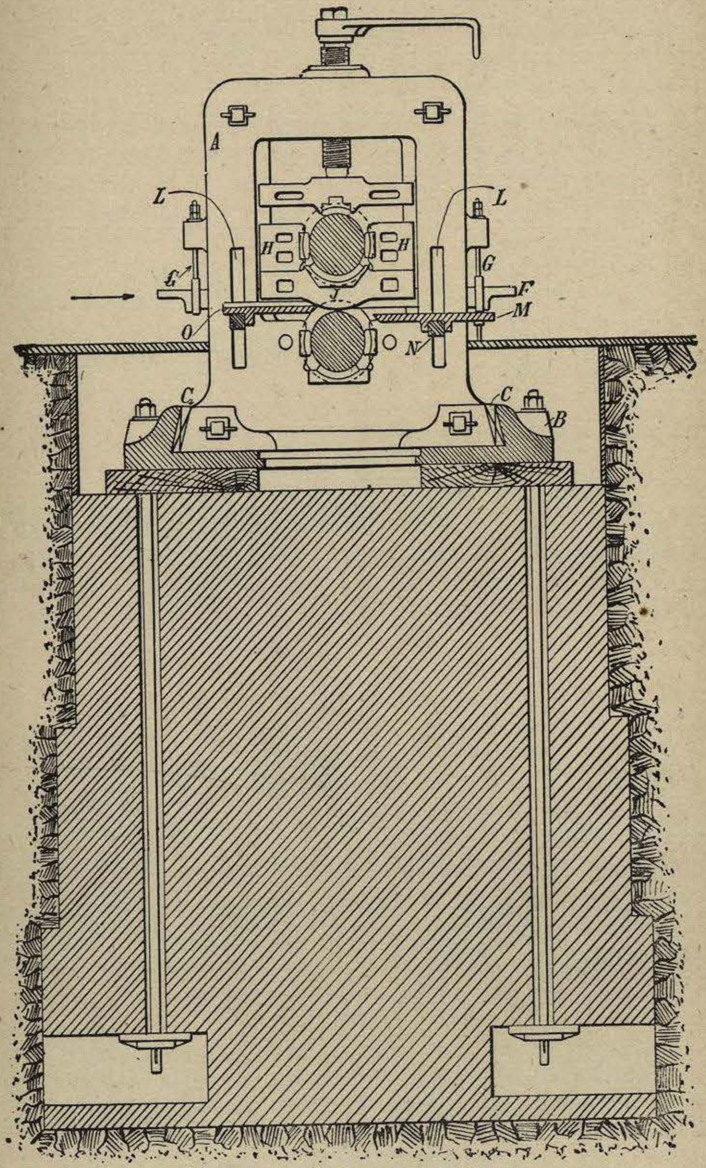

Fig. 343.—Typical Old English Housing.

Transverse section through the middle of the rolls, showing the inside face of the housing. A, Housing; B, bed-plate; C, C, wedges for securing housing in bed-plate; F, bar to support bottom chock, J; G, G, loops screwed at their upper ends, and provided with nuts, by which the height of F may be adjusted; L, L, recesses cast in the inner sides of the housings to receive the cramp-bars, N, which support the fore-plate, O, and the guard, M.

through to reduce the plate to the requisite thickness, and are known as movable or balanced rolls. The second class possess grooves turned in them, each groove being smaller than its predecessor. Such rolls while running are usually kept the same distance apart, and the reduction of the bar is effected by passing it through one after another of these grooves or "passes," as they are termed, each smaller than its predecessor, until the requisite

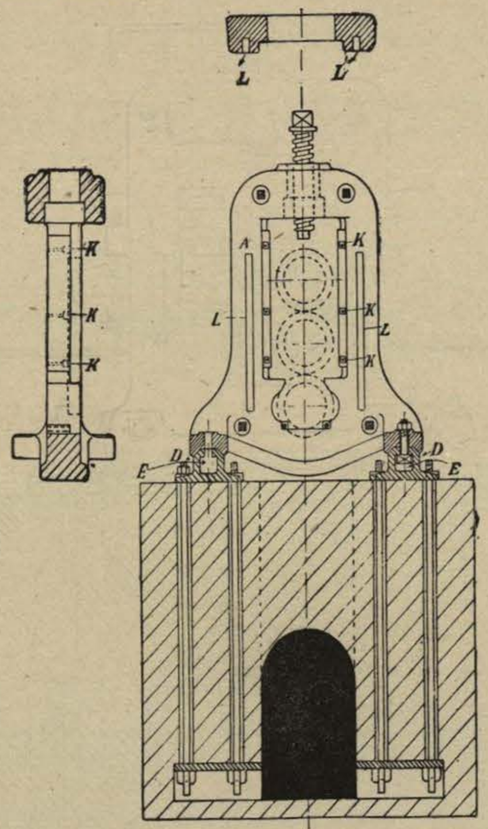

Fig. 344.—Typical American Housing.

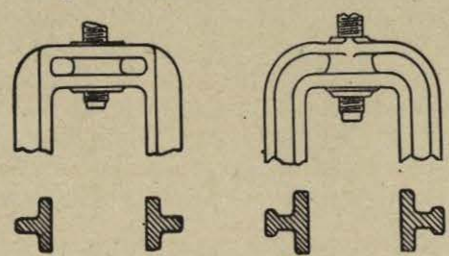

Fig. 345.—Sections of Steel Housings.

section is obtained. In most reversing cogging mills the reduction of the ingot is effected by a combination of the two methods, the ingot passing once through the first groove when the rolls are at some distance apart, and once more through the same groove after the rolls have been screwed down, before passing to the next groove.

The Housings.—The rolls are maintained in their correct relative positions when working by means of the "housings," "holsters," or "standards," as they are variously called, which are usually made of cast iron. Fig. 343 shows a typical old English housing with all details in position, and fig. 344 a typical modern American one without details. The housings are now frequently made of cast steel, in which case they are generally of the section A or B (fig. 345). The housings of the mill (fig. 343) are of cast steel. Housings made from good cast steel will sustain with safety stresses three or four times as great as those made in cast iron, so that a broken steel housing is almost unknown. It is not, however, advisable to take full advantage of the reduction in section which the additional strength of the newer material would allow, because more weight in a housing has its utility; the mass absorbs shocks, and reduces vibration; some light steel housings for three-high mills, though amply strong, have failed to give satisfaction by their want of rigidity.

The upright sides of all housings stretch very appreciably when the piece squeezed passes between the rolls; as the stretching under any given load per unit of sectional area is twice as great in the case of cast iron as in that of steel, steel housings of the full section, formerly used in cast iron, are now fitted, and with great advantages, in mills for rolling sheets and similar thin material. In such mills the springing of the housings plays a very considerable part in determining the reduction which can be effected at a single pass.

The housing of the old English mill (fig. 343) is carried on a flat bed and secured by wedges driven into the dovetail spaces, C, C. The first American three-high mills, having pins and boxes at both top and bottom of the housings, could not stand on the usual flat bed, but were carried instead by feet cast on the uprights of the housings, which rested on girders at front and back of the mill. Hence originated the American plan of planing grooves of an inverted V shape in the feet of the housing, which fit on to the separate planed girders, D, D (fig. 344), to which the housing is secured by T-headed bolts fitting freely into the grooves, E, E, made to receive them. This arrangement is distinctly superior to the old English plan, and is rapidly replacing it everywhere, because the mill is thus much more easily kept in line, and the housings can be rapidly shifted along the girders and secured in a fresh position to accommodate varying lengths of rolls, with the certainty that they are truly in line, without employing centre lines or similar devices in order to set them. Securing housings with wedges, which are very apt to work loose, and are inconvenient to get at when requiring to be tightened, is a clumsy survival from the days when planing machines were unknown, and screwed bolts costly luxuries. In the old mills the periodical "lining up of the mill" consumes much valuable time, and is an exercise in which a millwright of the old school delights in displaying his skill, but it is an operation which it is well to render unnecessary. The mills were formerly always bedded on timber sills, which stood on masonry foundations, in order to provide a cushion which was thought necessary to take up shock. This timber allowed the beds to work loose, and was a fruitful cause of the mills getting out of line, under which circumstances they need more power to drive them, and are much more liable to breakages. Timber is generally dispensed with now, and the beds are laid direct on the masonry foundations, and grouted in with liquid cement. In either case they are secured to the foundations by strong holding-down pins, fastened by cotters at the bottom end; the passage through the foundation in fig. 344 affords access to the cotters, by which means a broken holding-down pin can be replaced without it being necessary to dig holes in the mill floor.

In the inner sides of the housings are cast recesses, L, L (figs. 343 and 344), to receive square bars, which are laid from one housing to its fellow, and wedged firmly in place. These bars serve to carry the guides and guards, to be described later. In the larger mills, where the piece to be rolled runs up to the mill on loose rollers, recesses, B (fig. 346), are also cast on the inner faces of the housings to receive the brasses in which the spindles of these rollers may revolve. When these spindles are driven by power, they run through to the outer side of the housing, and the brasses are then situated in a hole cast through the housing as at A (fig. 346; see also fig. 353).

The housings are prevented from spreading or moving apart by two tie bars placed near the top and two near the bottom (see figs. 343, 357, &c.).

The section of the housing through the smallest part of each upright, when made of cast iron, is about one-half to three-quarters of the cross section of the body of the roll. The uprights should be placed at such a distance apart that the rolls can be drawn out endways when the chocks have been lifted off; if the "daylight" is not much more than the neck

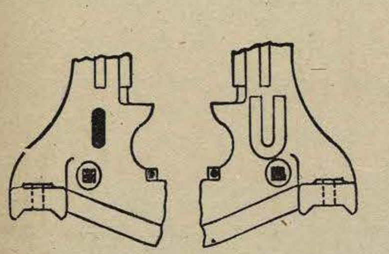

Fig. 346.—Recesses to carry Rollers.

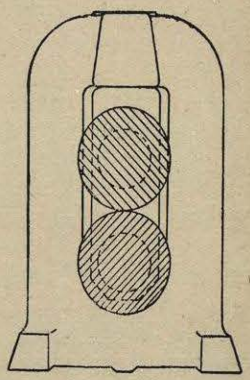

Fig. 347.—Bad Form of Housing.

of the roll, as in fig. 347—the whole housing has to be disconnected and moved aside along the bed plate before the rolls can be got out, an operation involving serious waste of time.

Seeing that salaries and other dead expenses have to be paid whether the mill is running or not, the ability to change rolls rapidly is a matter of considerable moment, yet such housings have even yet not entirely disappeared from English works. To facilitate the changing there is a growing disposition, particularly on the Continent, to make the housings with open tops, the cap being a separate casting, usually of steel for the sake of lightness, secured to the uprights by bolts (see fig. 348). By this means the width between the uprights need be little more than the diameter of the roll necks, and the whole housing may be smaller and lower. If, however, elaborate screwing gears need removal, no time is saved, and although for some purposes this form has its advantages, the housing is never as strong when made in this way.

The Chocks.—The necks of the rolls run in brass, bronze, or white metal bearings, which can be renewed when worn. The brasses for the lower roll are generally fitted into the housings direct, though sometimes, as in

fig. 348, they are carried in separate castings which are let into the housings. The necks of the bottom roll are very commonly left entirely exposed on their upper side, but some engineers cover them with a light cap to keep out the dirt. The bearing for supporting the neck of the upper roll is carried in a casting called the lower chock, which, if the upper roll is a fixed one not requiring to have its distance from its companion varied during the process of rolling, may be carried in any convenient way, the most common one being the arrangement shown in fig. 343. In this method a flat wrought-iron bar, F, passes through both sides of the housing, and is suspended from loops, G, G, provided with screws at their upper ends, by which the height of the chock can be regulated as the wear of the brasses or rolls requires. If the upper roll is movable during the process of rolling it must be supported at varying heights, and to accomplish this the chock below the roll in small mills is slung from a cross piece which rests freely on a shoulder formed on the screw, these bolts passing down through holes cast in the top of the housing (see fig. 349).

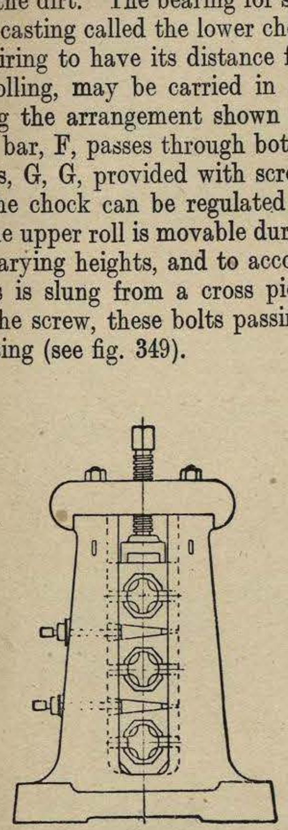

Fig. 348.—Open-topped Housing.

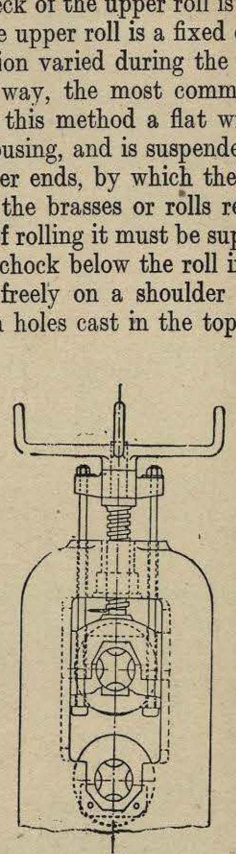

Fig. 349.—Method of supporting a Top Roll which needs to be adjusted during the process of rolling.

If the adjustment required is small, the cross piece may be dispensed with and the bolts supported on volute springs resting on the top of the housing. Where heavy rolls are employed, the power required to lift the roll by the screw is too great, and balance weights are fitted. These are generally situated below the mill floor, and, by means of levers, press upwards two rods which pass through holes cast in the bottom of the housing on either side of the neck of the lower roll, and support the chock on which the neck of the upper roll rests. In the best modern mills a hydraulic balance is now commonly used. It consists of a cylinder, A (fig. 350), turned mouth downwards, so that the scale may not fall into and destroy the packing; this cylinder moves on a fixed ram, B, through the centre of which water is admitted under constant pressure from the hydraulic supply of the works. The arrangement can also be used as a hydraulic jack to raise the roll when it has to be changed. The most recent practice is to place the balancing cylinders on the tops of the housings, where they are out of the way of falling scale, and the packing leathers are more accessible when they need renewal.

The balancing of the roll, besides rendering it easier to adjust the screws, keeps the neck of the upper roll always in contact with the brasses in the top chock, and thus prevents the blow which would occur if the roll were driven up against its bearings by the piece entering the mill, and the corresponding shock when the roll fell back again on the lower one, as the piece passed out. For this reason the only mills provided with movable rolls, which can dispense with the balancing of the upper roll, are sheet and strip mills, in which only very thin material is treated, so that the roll lifts very slightly when the piece enters the mill. The lower roll, resting by its own weight in its bearings, into which it is firmly pressed by the pressure of rolling, has little tendency to move in the direction in which the piece enters the mill,

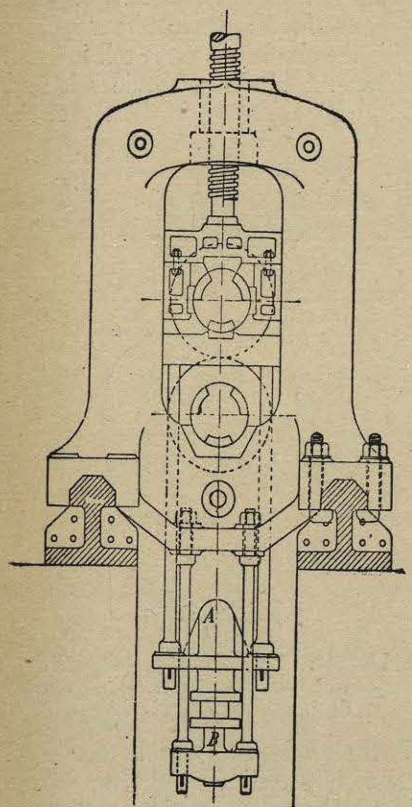

Fig. 350.—Hydraulic Balance for Plate Rolls.

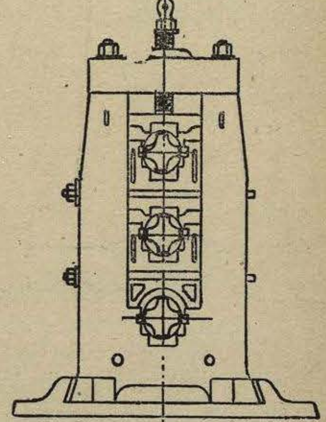

Fig. 351.—Small Open-topped Housing for Three-high Mill, provided with adjustments between the chocks.

but the upper one is easily displaced. If the top brass, therefore, does not cover a considerable portion of the neck (an arrangement conducive to a hot bearing), the top roll needs side brasses to steady it. Except in some English sheet mills, where the roll has so very little lift that these brasses can be secured in the housings, as is the case with the bottom roll in fig. 353, they are either carried in the chock supporting the roll, as in figs. 351 and 354, or in separate side chocks, H, H, in fig. 343, which may be secured and adjusted in any convenient manner (see figs. 350 and 353).

To reduce their weight, and so render the chocks more easy to lift out when the rolls have to be changed, they are cored out, and the large ones are steel castings, by which still more weight can be saved (see fig. 489).

The chocks get hot when in use, and expand more than the housings; they must, therefore, be a very free fit when cold, or they will become immovable when hot. If the shaking of the chock in the housing gives trouble, it is prevented by sheet packings inserted between the two.

The movement of a roll longitudinally is prevented by the inner ends of the brasses bearing against the shoulder formed by the junction of the necks and body of the roll, but as the ends of the brasses wear the roll gets end play. This is a matter of no moment in the case of the plain rolls used to produce plates or sheets, but in the case of grooved rolls for forming sections, it is essential that the groove in the upper roll shall be exactly above the corresponding portion in the lower roll, or the section will not be accurate.

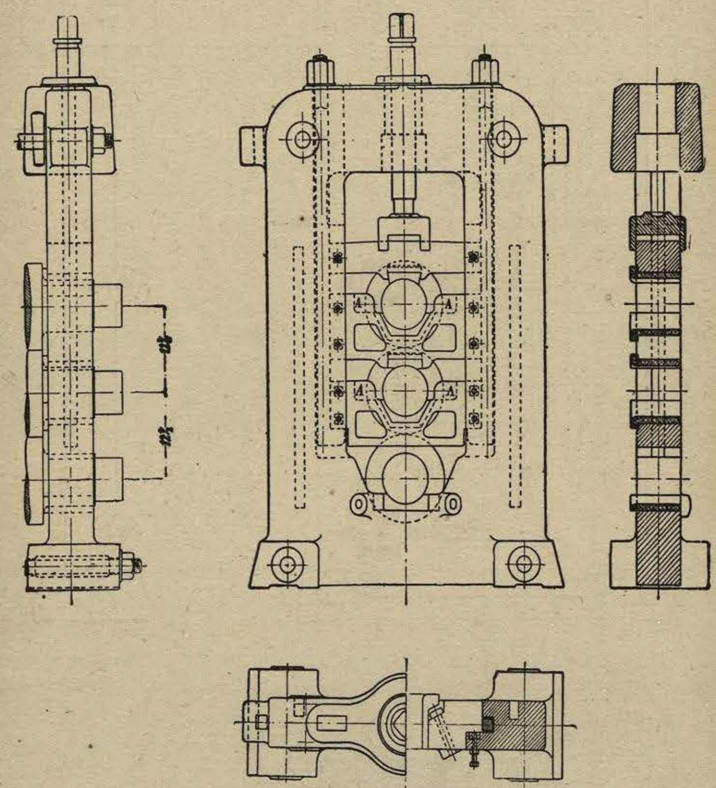

Fig. 352.—Housing for 12-inch Three-high Mill.

How the rolls are adjusted in this respect will be seen by examining the detailed drawings of the housing (fig. 352), made by Messrs. Thomas Perry & Son, Limited, of Bilston, for the 12-inch bar mill, shown in fig. 479, and the drawing (fig. 353) of a housing for a 28-inch mill for rolling tin plate bars, made by Messrs. J. & S. Roberts, Limited, of West Bromwich.

In both housings pins are fitted to bear on the flanges of the brasses of the bottom roll, so as to move the brasses inwards, and take up any end play caused by wear. The pins are clearly shown in the sectional plans (fig. 352), where they bear on the bottom brass, and in fig. 353, where they bear on the two side brasses. To enable the upper rolls to be adjusted to correspond with the bottom one, recesses are cast inside the housing at