CHAPTER XXXIV.

COMMON MILLS, THEIR USES AND OUTPUTS (*Continued*).

II. PLATE AND SHEET MILLS.

Early Reversing Plate Mills.—Plates being the heaviest rolled masses commonly required, and the most awkward to handle at the rolls, more benefit was to be anticipated by reversing the mills used for this purpose than for any other, and therefore they were the first to which reversing was applied. After 1868 most existing pull-over plate mills were made reversible by adding gearing between the engine and rolls, by which the direction of rotation of the latter could be changed, while the former continued running in one direction. One of the best known of these devices is the "five-wheel" reversing gear shown in fig. 487. The shaft, A, connected to the engine,

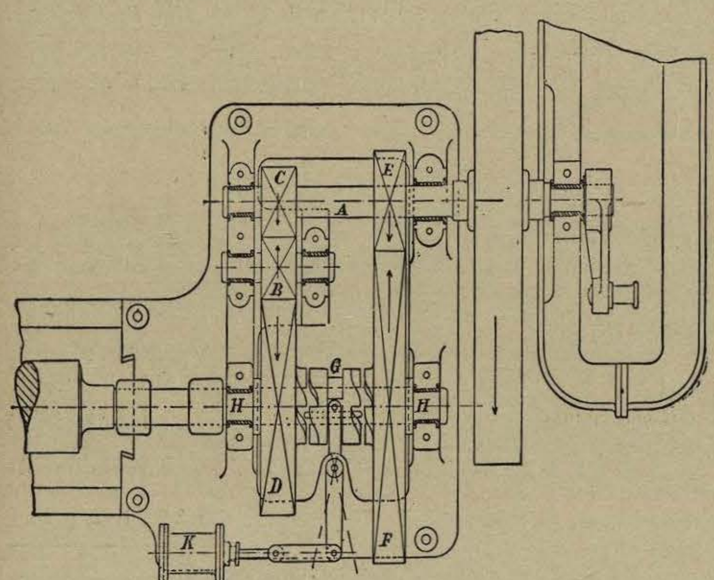

Fig. 487.—Five-wheel Reversing Gear for Rolling Plates.

runs always in one direction. The idle wheel, B, running between the pair of toothed wheels, C, D, causes D to run in the direction contrary to F. By throwing one or other face of the clutch, G, which slides on feathers on the shaft, H, by which it is driven, into gear with the corresponding clutch teeth on F or D, the direction of rotation of the shaft, H, can be changed, although the shaft, A, runs constantly in one direction.

This simple, if somewhat crude, device, raised the output of the pull-over

plate mill from 8 or 10 tons per shift to more than double this amount, and by avoiding the need for lifting the plate, dispensed with several men, and made it possible to produce much larger plates at reasonable cost.

The clutches worked fairly well, while the rolls made only 25 to 35 revolutions per minute, but at higher speeds the throwing over of the clutch by hand was difficult, and dangerous to the man who reversed the mill. When the owners were obliged to speed up their mills to compete with the new mills, which were driven at much higher speeds by the new reversing engines, a steam or hydraulic cylinder, K, had to be provided to move the clutch lever.

The shock of reversing the direction of rotation of the line of spindles, pinions, and rolls in this sudden manner, caused constant breakages, and led to the introduction of a variety of friction clutches, which would permit of a small amount of slip when the resistance was excessive, and yet possessed enough holding power to perform the rolling. By this means speeds of 50 or 60 revolutions per minute, and outputs of 25 tons per shift, or 250 tons per week were obtained in clutch-driven mills. The late Mr. Jeremiah Head * refers to a mill of this kind which turned out as much as 750 tons per week. The rapid wear and constant need for renewing the frictional surfaces of the clutches, which required unremitting attention, and the much greater speed and handiness of the mills driven by reversing engines, have brought about the gradual disuse of such appliances, which, nevertheless, were very useful in their day, and possessed the advantage that two mills could be driven by one engine, and each reversed independently, whenever the length of the plate being rolled required it.†

Recently the coil clutch, a new form of friction clutch, has been introduced, which is free from some of the objections incidental to the older forms of friction clutches. This clutch depends for its action on the fact that if a rope or flexible band be coiled several times round a body, a very slight check upon the end last removed from the loaded end of the rope, will cause the coils which precede it each to tighten upon the body round which it is coiled with rapidly increasing force. A familiar application of the principle is seen when a ship is leaving a quay side. By holding or slackening the last turn of rope round the mooring post, by which the ship is made fast to the quay, a man can control at will the movement of the largest vessel.

Fig. 488 shows a pair of such clutches, the part of the mooring post being taken by two chilled castings keyed on the shaft driving the mill. Around these revolve, in opposite directions, two coiled steel bands, which are secured to their respective driving wheels, and are bored slightly larger than the chills. When the hand-wheel is turned so as to move the centre spool on the driving shaft towards one of the coils, it moves a lever which causes the coil to slightly grip the chill, and the coils immediately tighten so firmly on it as to form practically one piece, until the pressure is released. So firm is the grip that the chill and coil may be greased, thus preventing any cutting of the surfaces. Several mills requiring as much as 1,000 H.P. each to drive them are successfully working with this appliance; some up to 6,000 H.P. maximum.

* *Inst. M.E.*, No. 3, 1893, p. 243.

† The addition of a reversing engine to the plate mill, at the Bowesfield Ironworks, raised the output from 300 tons to 570 tons per week. *Inst. M.E.*, No. 3, 1893, p. 244.

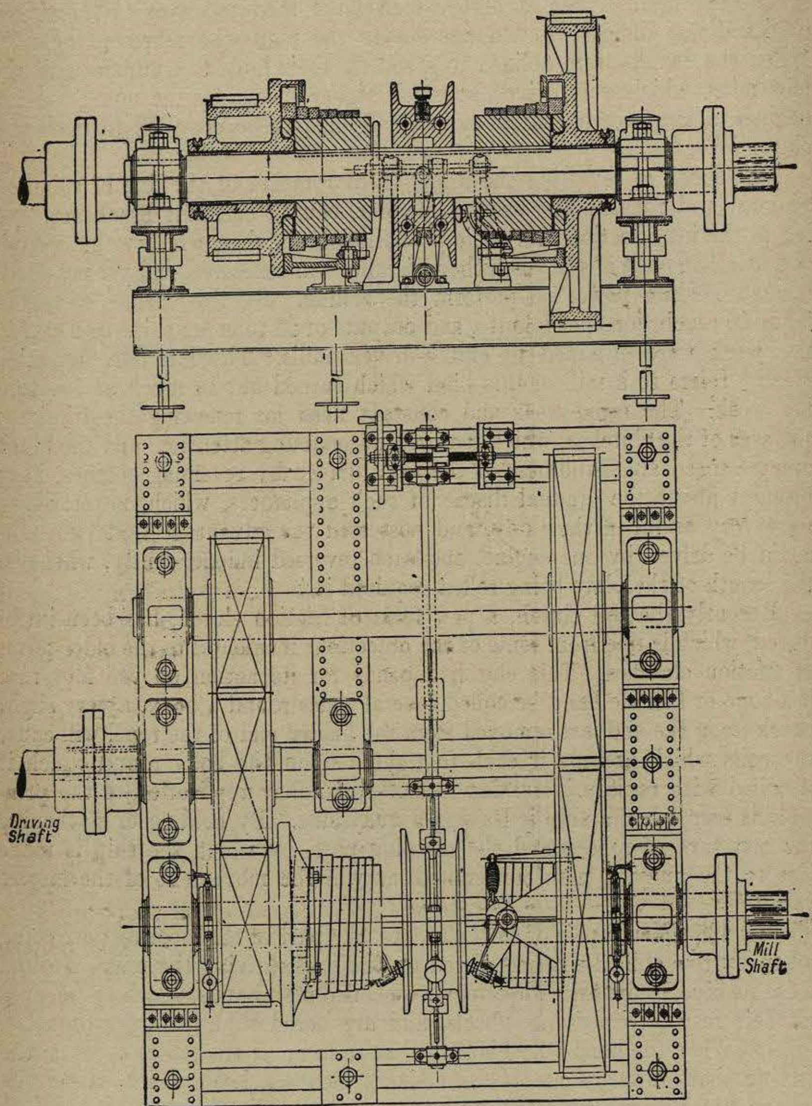

Fig. 488.—Coil-clutch Reversing Gear.

Modern English Plate Mills.—These are all driven by reversing engines, and consist of two stands of rolls from 26 to 36 inches in diameter, by 8 to 12 feet long in the barrel, the latter dimension of course determining the width of plate which can be rolled in the mill. The stands are coupled end to end, the pair of rolls next the engines are either iron grain rolls or steel rolls, and are used for roughing, the last pair, which are generally longer in the barrel than the others, are chilled iron, so as to give a good finished surface to the plate; the engines are geared to the mill in the proportion of 2¼ or 2½ to 1.

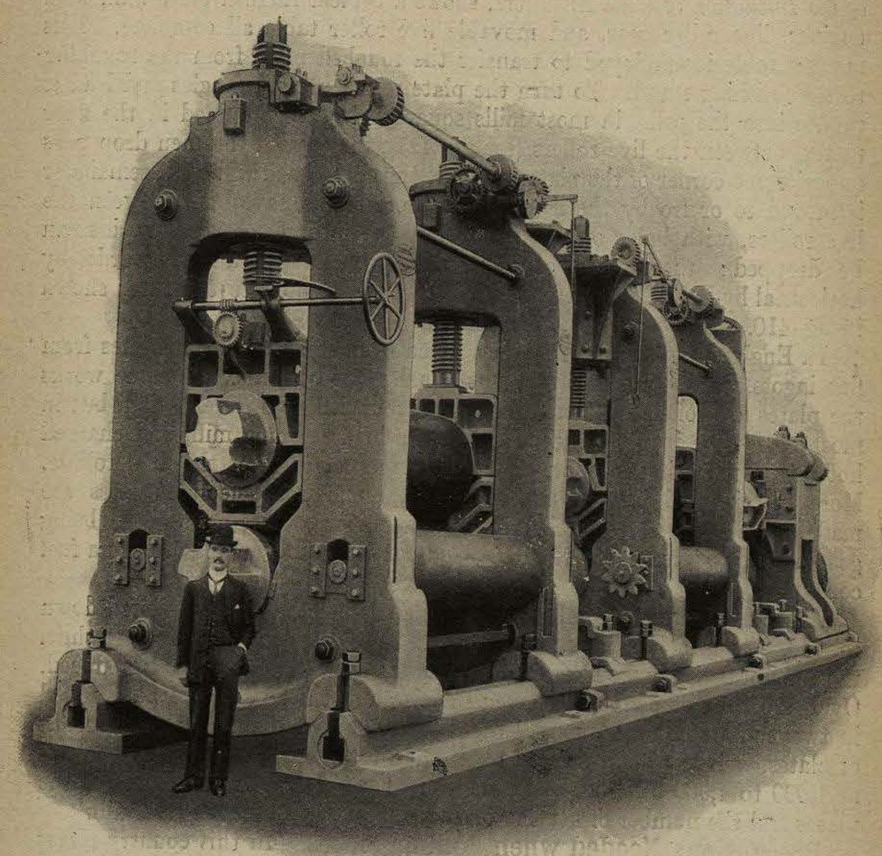

Fig. 489.—English Plate Mill and Pinions.

Fig. 489 is prepared from a photograph of a plate mill with rolls 36 inches in diameter, by 9 feet long in the barrel, made by Messrs. J. & S. Roberts, Limited, of West Bromwich, for a well-known French works. The screwing gears will be worked by electric motors, not shown in the drawing, but which will stand on brackets bolted to the housings. To produce plates having an equal thickness on each side, the top roll of a plate mill must, whatever be its height above the bottom roll, always remain parallel with it. The screwing gear lowers both ends of the roll equally and simultaneously, but as the bearings at one end wear faster than those at the other, the parallelism of the rolls is not long maintained, and to correct this error there is inserted between the screw and chock, at one end of the finishing stand, a tapered wedge, movable horizontally by a screw, actuated by the hand-wheel in front of the picture, through the intervention of a worm and wheel.

The balance cylinders, which are suspended from the underside of the housings, in a pit in the foundations, are not shown in position in the cut.

Fig. 490, Plate xliv., reproduced by permission from the *Proceedings of the Institution of Civil Engineers*, shows a typical English plate mill, with engines, live roller gear, and movable live roller table all complete. This moving table is employed to transfer the roughed plate from the roughing to the finishing stand. To turn the plate round at right angles and lead it square into the rolls, in most mills square holes are provided in the floor plates, between the live rollers (see fig. 417), into which the men drop pegs opposite one corner of the plate, which it thus held back while the remainder is moved to or fro by the live rollers. Some mills have bars between the live rollers, with holes on their upper sides, into which similar pins can be dropped; these bars can be moved backwards and forwards by horizontal hydraulic cylinders, in a manner very similar to the tilter shown in fig. 410.

In England plates are sometimes rolled from square and sometimes from flat ingots, both plans giving about equally good results. In some works the plates are rolled right out from the ingot without any reheating, but in most places the ingots are cogged to slabs in a slabbing mill, and charged hot into a reheating furnace, to raise the temperature for the final rolling. More fuel is used by the latter method, but fewer defective plates are made, and there is less strain on the machinery, these advantages being generally considered more than a set-off for the small amount of extra fuel consumed.

A good modern plate mill, fed with slabs which have been cogged down to, say, 3 or 4 inches thick, will turn out 50 to 100 tons of plates per shift, the amount depending on the thickness to which the plates have to be reduced. Over 400 tons of plates of convenient size and thickness have been rolled in twenty-four hours on special occasions, but an ordinary average output of plates, weighed when sheared to size and ready for despatch, may be put at 1,000 to 1,500 tons per week, dependent largely on the thickness of the plates and the number of heating furnaces available for serving the mill.

Precautions Needed when Rolling Plates.—In this country plates for boilers are ordered to be so many sixteenths of an inch thick, and plates for ships either sixteenths or twentieths, but many shipyards order their plates to weigh so many pounds per square foot, rejecting plates below the weight specified, and declining to pay for any weight beyond that ordered.

All rolls expand in diameter when in contact with heated metal, the centre of the barrel becoming hotter, and therefore expanding more than the ends, from which much heat escapes through the wobblers and necks, which often have to be cooled by jets of water. The variation in expansion at different points of the barrel is not of much consequence in the case of section rolls, but causes considerable trouble with plate rolls. If plate rolls were turned to exactly the same diameter throughout their length when

[To face p. 778.

], with Engines and Live Rollers.

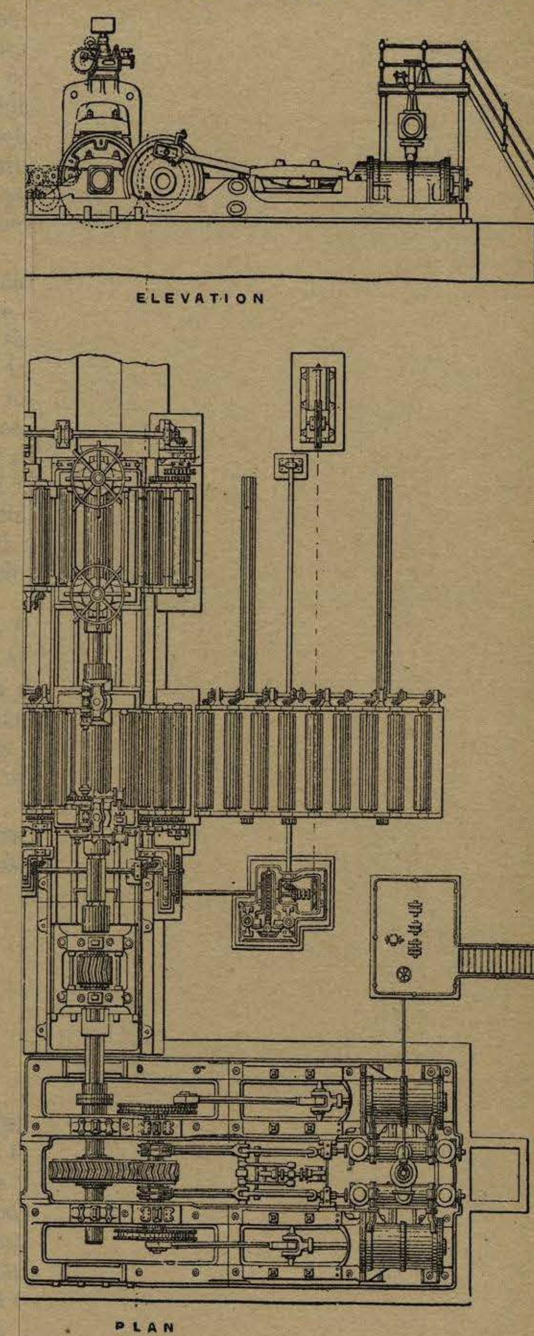

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PLATE XLIV.—English Plate Mill, with Engines and Live Rollers.

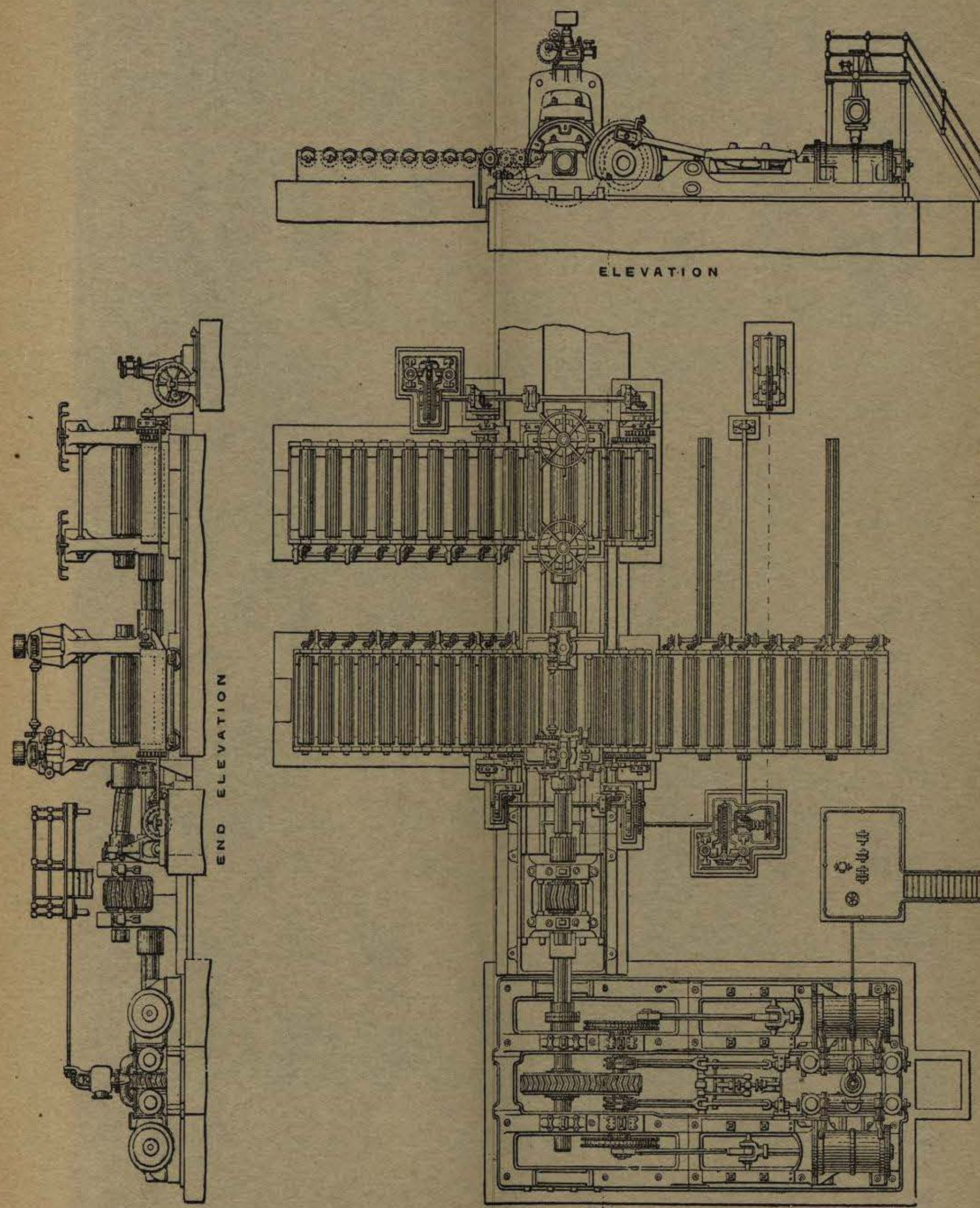

Fig. 490.

cold, the centre would increase in diameter when heated so disproportionately to the ends, that the centre of the plate would be unduly stretched, and would stand up as a rounded mound when the finished plate was laid on a flat surface. This buckling is most difficult to get rid of, except by re-rolling to a less thickness between parallel rolls, which will stretch out the sides as much as the centre. Consequently plate rolls must be turned slightly smaller in the middle, as much as $\frac{1}{32}$ of an inch in 8 feet, and during the first turn or two in each week only narrow plates are turned out, which can be worked in the centre of the rolls, and later in the week, when the middle of the rolls have attained their normal temperature and diameter, those plates are rolled which need the full length of the rolls for their production.

On the other hand, rolls 12 feet long spring very appreciably, particularly if heavy draughts are employed, so much so that very wide plates are usually from $\frac{1}{16}$ to $\frac{1}{8}$ inch thicker in the middle than on the sides.

The effect of variation in the diameter of the rolls at different points, or of their springing in the middle, are most noticeable when thin plates or sheets are rolled from pieces of flat bar which have been sheared square at the ends, so that all four sides are perfectly straight. The sides and ends of the resulting sheet will not be straight, but curved, convex or concave, according to the relative diameter of the rolls at the middle and ends at the time of rolling. The skill of the roll turner and roller are shown by the production of plates which have neither horns on the corners, nor bellies on their ends.

Increase in Tensile Strength due to Rolling.—The work put on a plate during the process of rolling increases its tensile strength appreciably, so that a thin plate has a considerably higher breaking point than a thick one rolled out of the same ingot. The following table is derived from a comparison of a very large number of acid open-hearth steel plates, made in a great many different works :—

CARBON REQUIRED IN STEEL PLATES TO PASS THE BOARD OF TRADE OR LLOYDS' TESTS FOR BOILER PLATES.

Thickness of Plate in Inches.	Carbon Required.
$\frac{5}{16}$	·12 to ·14
$\frac{7}{16}$	·14 „ ·16
$\frac{1}{2}$	·15 „ ·18
$\frac{3}{4}$	·16 „ ·18
$\frac{13}{16}$ to 1	·17 „ ·19
$1\frac{1}{8}$	·17 „ ·20
$1\frac{5}{16}$ to $1\frac{1}{2}$	·18 „ ·20

Handling, Straightening, and Shearing.—The old system of handling the hot plates as they came from the mill was to catch the smaller ones on a small bogie, on which they were run away and tipped down to cool on any convenient spot on the floor, while the larger ones were seized by a pair of self-acting tongs attached to a chain leading to a steam winch, by which the plate was dragged away along the floor, and left to cool off.

The floor soon becomes as hot as the plates, which can give off their heat only from the upper side, and such floors are now usually constructed of perforated plates, with a pit below, through which air can circulate. In modern plants the plates are received on live rollers, on which they cool much more rapidly, the rollers being moved slightly, as needed, to prevent any tendency of the hot plates to sag.

The thinner plates used to be straightened as they lay on the floor by blows from a wooden mallet, and the thicker ones by a heavy roll which was lifted on to them by a crane and rolled to and fro by hand or power, but it is usual now to use a plate-straightening machine. These machines consist of a set of seven forged steel rollers, four above and three below; the upper rollers are raised simultaneously by gearing to suit the varying thicknesses of plates which pass between the upper and lower set. The machine is driven by a belt or direct from a small steam engine or electric motor. Fig. 491 shows a machine of this kind, made by Messrs. Hugh Smith & Co., of Glasgow.

Plates used to be lifted by several men, standing round the plate, each furnished with a two-pronged fork. They placed one prong above and the other below the edge of the plate, and thus carried it to the shears,

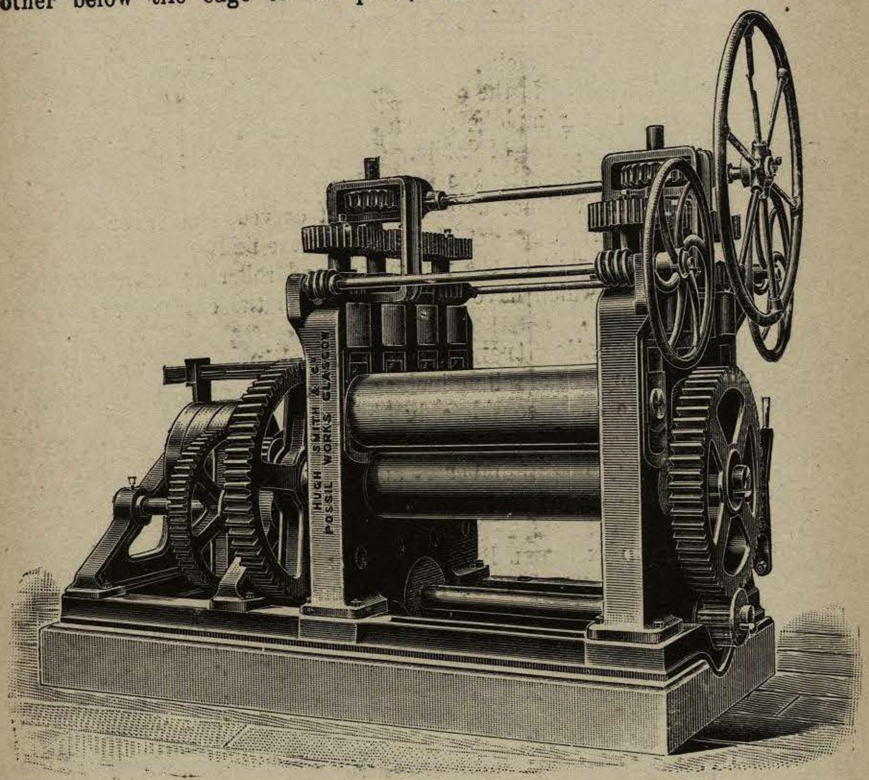

Fig. 491.—Plate-straightening Machine.

where it was marked and cut to size, and they then removed it in the same way to the railway truck for despatch. As plates grew in size and weight, this method of handling became too laborious, and they are now conveyed by overhead cranes, which carry sling chains provided with hooks to slip under the plates, and thus suspended, they are sheared and loaded into trucks. Electro-magnets are occasionally used for the purpose, and might be supposed to be an ideal method of lifting, but they have the disadvantage that if the plate is sufficiently thin to bend to any great extent, so that it is not kept in close metallic contact with the whole surface of the magnet, it is liable to drop off without warning; while if not lifted almost exactly in its centre of gravity, it inclines and slides along the face of the magnet. Another disadvantage is, that where a magnet is applied to a stack of plates

more than one plate is picked up at a time, and the man must drop the others one by one by reducing the strength of his current, and even then is not quite sure how many he may have attached to his magnet. Pneumatic power has also been tried; a cylinder with an indiarubber lip is lowered on to the plate and a connection opened through a flexible pipe to an exhaust pump, when the pressure of the atmosphere holds the plate up to the cylinder. Obviously such an appliance is only applicable to comparatively thin plates.

Fig. 492 shows a large pair of plate shears, made by Messrs. Lamberton, of Coatbridge, to cut plates up to 2 inches thick, and to cut through the middle of a plate of any length, if not over 6 feet wide. The strain of shearing is taken by two large steel bolts 13 inches in diameter, passing from top to bottom of the machine. Rams are provided to hold the plate down firmly on the bolster during the shearing.

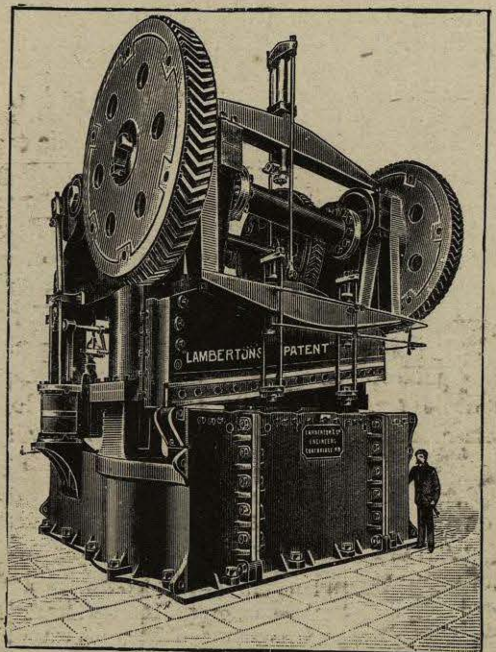

Fig. 492.—Plate Shears.

The late Mr. Jeremiah Head* stated that 100 tons of ingots could be made to produce, on an average, 69 tons of saleable plates, and 26 tons of scrap sheared from the edges, 5 tons being lost in the reheating. From other figures given by him it would seem that cogged and reheated slabs averaged 70 per cent. of good plates, while ingots rolled off direct without cogging averaged 67½ per cent. of saleable plate. During the discussion of a paper read at Glasgow,† he stated, however, that the yield of plates rolled direct from the ingot, in America, was 65 to 66 per cent., but that at works where the ingots were first cogged, the yield of saleable ingots was 68 per cent. of the weight of the ingots.

Reduction in the Cost of Plates.—The enormous reduction in the cost of plates, which has been effected since the introduction of cheap steel and the present methods of handling large masses at the rolls, which the new

* *Min. Proc. Inst. C.E.*, vol. cxxvi., p. 21.
† *Inst. M.E.*, 1865, vol. iii., p. 453.

methods of manufacture necessitate, may be best appreciated by comparing the extras for boiler plates demanded by Mr. John Bagnall, the leading Staffordshire maker, and by the Bowling Iron Company in Yorkshire, in 1873, with the prices and extras on large steel boiler plates paid to-day (1901). The prices ruling in 1873 were, of course, exceptionally high, this being the period of the "boom" immediately following the Franco-German War, but the "extras" were those usual, both before and for some years after 1873, and will give an idea of what were considered heavy plates thirty years or so ago.

Iron plates must necessarily be more costly to produce than steel, because the loss from the iron pile to the finished plate made from it, caused by oxidation in the furnace, and by the loss of material which must be sheared from the edges, is about 45 per cent., whereas the loss from the same cause in the case of a steel slab is only about 30 per cent. Nevertheless the difference is mainly due to the improvements which have been made during the last forty years in the methods of handling large masses of heated metal.

TABLE CXVII.—PRICES OF IRON BOILER PLATES IN 1873, AND OF STEEL BOILER PLATES IN MARCH, 1901.

	Iron Boiler Plates, 1873.		Steel Boiler Plates, March, 1901. Leeds Forge.
	John Bagnall, Staffordshire.	Bowling Iron Co., Yorkshire.	
Base price per ton,	£16 10 0	£29 0 0	£7 10 0
$2\frac{1}{2}$ to 3 cwts. each plate,	16 10 0	30 0 0	7 10 0
3 ,, $3\frac{1}{2}$,, ,,	16 10 0	32 0 0	7 10 0
$3\frac{1}{2}$,, 4 ,, ,,	16 10 0	34 0 0	7 10 0
4 ,, 5 ,, ,,	17 10 0	37 0 0	7 10 0
5 ,, 6 ,, ,,	19 0 0	40 0 0	7 10 0
6 ,, $6\frac{1}{2}$,, ,,	20 0 0	-3 0 0	7 10 0
$6\frac{1}{2}$,, 7 ,, ,,	21 0 0	43 0 0	7 10 0
7 ,, $7\frac{1}{2}$,, ,,	22 0 0	46 0 0	7 10 0
$7\frac{1}{2}$,, 8 ,, ,,	23 0 0	46 0 0	7 10 0
	Plates 15 feet long or over 4 feet wide £2 per ton extra.	Plates over 6 feet wide £2 per ton extra.	Plates over 8 feet wide 2s. 6d. per ton extra for each additional 3 inches. Plates over 4 tons each 2s. 6d. per ton extra for every additional 5 cwts.

That the cost per cwt. of a Yorkshire iron plate in 1873 was more than six times that of a Siemens steel one ten times as heavy in 1901, is the more noteworthy, if we consider that the latter has the higher tensile strength, and is far less liable to "blister" on exposure to the fire.

Instead of demanding extras on plates weighing a few cwts., they are now rolled as large as possible, and cut up to form the smaller sizes, whereby less material need be sheared from the edges, and more weight can be got through the mill, than would be possible were every small plate rolled individually.

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PLATE XLV.—American Three-high Plate Mill.

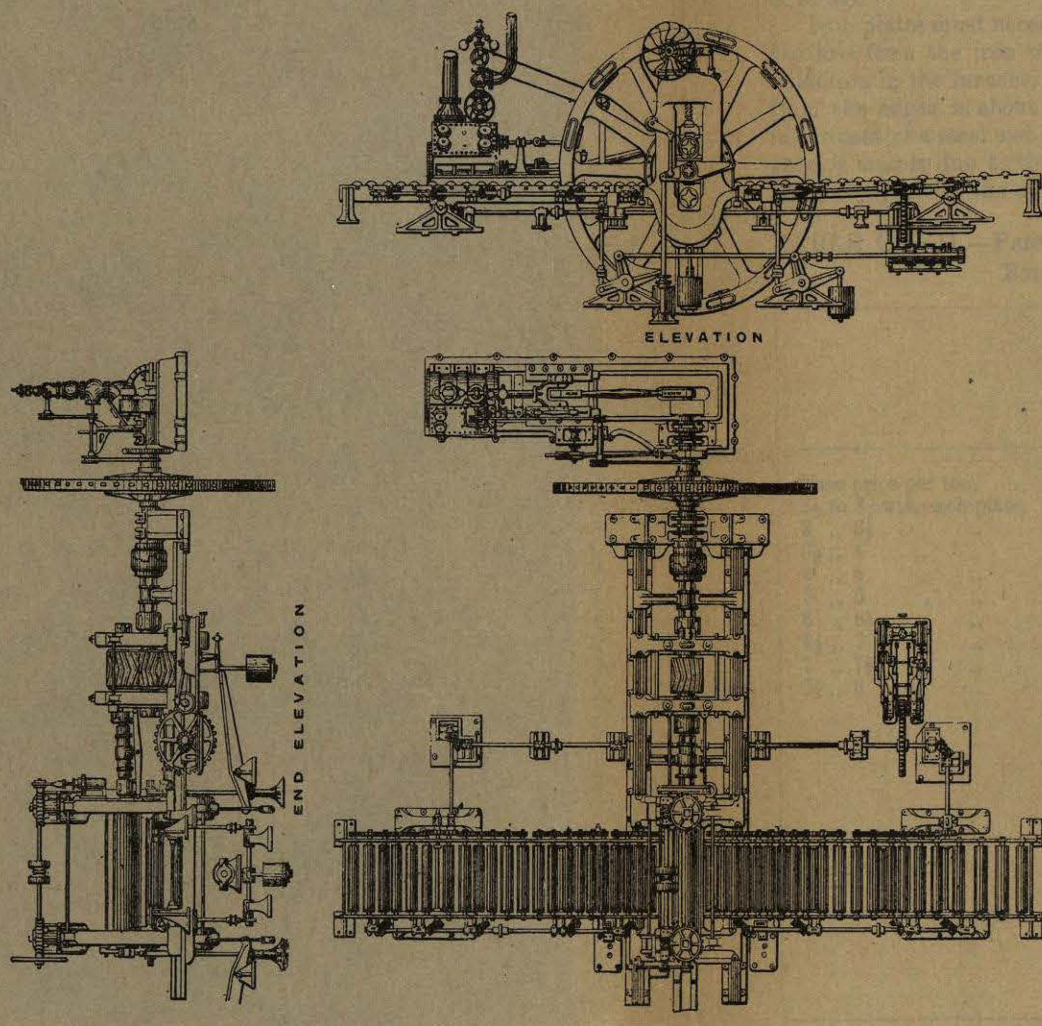

Fig. 493.

The real limit of size now is the dimension which the railway companies can carry, this restricting the width to 10 feet, if plates are to be carried in ordinary trucks, and to about 13 feet where special trucks are employed.

The possibility of obtaining large plates at reasonable cost is most advantageous to the constructor. In shipyards plates 30 feet long and $3\frac{1}{2}$ feet wide are not uncommon to-day, while the standard plate used for the shell of a Lancashire boiler is 22 feet long, by $4\frac{1}{2}$ or 5 feet wide. The reduction in the number of rivetted joints, and the possibility of arranging such joints as there are in positions where they are readily accessible, are considerations of the greatest value.

The Central Marine Engine Works, of West Hartlepool, have for some years* constructed the shells of their boilers, 15 feet 6 inches diameter by 10 feet long, out of two plates only, each of which when sent from the mills measures 25 feet 6 inches long, 10 feet 10 inches wide, and $1\frac{1}{4}$ inches thick.

American Plate Mills.—Fig. 493, Plate xlv., showing the construction of the American plate mill, is reproduced, by permission of the Council of the Institution of Civil Engineers, from a paper on "The Manufacture of Steel Plate," from which much of the following information is also extracted.

The regular American practice differs entirely from the English methods of working, the standard American plate mill being a three-high mill of the Lauth type, with one stand of rolls only. The top and bottom rolls, which are 34 inches in diameter, are both driven, while the middle roll, which is 24 inches in diameter, runs loose, but is raised or lowered by a hydraulic cylinder, to enable the plate to enter the mill alternately above and below it. All three rolls are chilled, and are kept cool by a continuous stream of water running over them, a proceeding which does not cool the plate as much as might be anticipated, because the heat of the plate suffices to maintain the water most of the time in the spheroidal state, thus preventing any close contact between the two. In English practice the rolls were not usually wetted.

The engine driving the mill has a single cylinder about 54 inches in diameter by 6 feet stroke, and is provided with a 50-ton flywheel; the crank-shaft is coupled direct to the centre pinion, and the rolls to the top and bottom pinions, which, being larger than the centre one, give a small reduction in speed between the engine and mill without the employment of any other gearing.

The power developed by one such American engine exceeds that developed by the pair of ordinary English mill engines, the extra power being needed to give the additional speed, which must be maintained where the slab or flat ingot is rolled off direct, without any reheating, and in wetted rolls.

The slabs must, of course, be tapered to permit of the removal of the ingot mould in which they are cast, and as there are no means of "edging" the slab, the top roll not lifting sufficiently for the purpose, it would naturally roll out into a plate wider at one end than at the other, did not the roller take advantage of the fact that in rolling, the piece rolled is extended in length, but not appreciably in width. The slab goes through the mill for the first pass with the thin end first, but is returned with one corner of the wide end leading, is put through the next time with the narrow end facing square, and is returned with the other corner of the wide end leading. By presenting first one and then the other corner of the wide end alternately, but causing the narrow end to enter square with the rolls, the narrow end becomes as wide as the other, and the rolling can be finished in the ordinary way.

In the American plate mills the plates are cooled as they travel forward

* *Engineering*, January 7th, 1898, vol. lxv., p. 11.