in order to meet these requirements, as well as some other details, the production of these housings was a work involving no little skill and anxiety.

Screwing-down gear for the horizontal rolls is placed in the usual way on the top of the housings. On the housing and side frame of the mill is arranged screwing gear for setting up the vertical roll transversely, and simultaneously for setting up the necessary guides for the slabs, these guides extending a considerable distance in front and at the back of the rolls. Both sets of gear are driven by a small pair of engines through gearing. They can be worked together; but the practice is not to work them simultaneously, but alternately as required, so that work can be put on the flat or edge of the slab at choice. To this end clutches are arranged on the shaft of the small driving engines.

The horizontal rolls are 28 inches diameter, and the vertical rolls about 21 inches. The latter are driven by bevel wheels on a horizontal shaft, which extends to the pinion housings and receives its motion through a pair of wheels, one on its extreme end, and which works into another keyed on the shaft of one of the mill pinions. This outer end of the driving shaft is carried in bearings formed in the pinion housings. As one of the vertical rolls has a traversing motion, the bevel wheel driving it must necessarily slide along the shaft. In order to keep it in gear with the crown wheel on the roll, a special form of yoke and thrust bearing was designed, which is carried on the projecting end of the vertical roll above the crown wheel. The driving wheel on the horizontal shaft has a long boss or sleeve, on which are formed collars; these fit into and run in the thrust bearing on the top end of the vertical roll. The spindles for driving the horizontal rolls are both supported in bearings, the upper one in a manner similar to that already described for the cogging mill at Wishaw.

At the front and back of the rolls are dead rollers, carried in brass bearings on side frames, and extending a considerable distance from the rolls. At each extremity are special carriages, similar though not identical in design, for bringing the ingot to the mill at one end, and removing the slab to the shears at the other. These carriages were adopted in place of the long series of live rollers commonly used. They are actuated by hydraulic rams, whose stroke is multiplied by the intervention of chains and pulleys. The rams and cylinders are placed on the ground, a little away from the centre line of the mill. The carriage for bringing up the ingot was a necessity under the special circumstances, inasmuch as the crane carrying the ingot is fixed, and can deliver it only at a certain point some distance from the mill. At this point is placed the ingot cradle, now so commonly used, but first designed and used at these works.

At the front and back of the mill, and in line with the roll housing at one side of it, are special appliances for moving the ingots or slabs. These consist of long piston rods, having a piston at about the middle of their length, on which work long pushing cylinders, carrying arms that extend across the centre line of the mill. The arm in front of the mill is made to rotate in a vertical plane upon the pushing cylinder by means of a small hydraulic cylinder and ram, which can take hold of a small projection on the back of the arm, when by the longitudinal movement of the pushing cylinder it is moved out to a certain distance from the rolls. The piston rods are hollow from each side of the piston, and through apertures in them the water pressure is admitted by which the cylinders are moved. The action of the parts is as follows: The ingot carriage is moved up to the cradle, which has received the ingot from the crane. The cradle is turned down, and deposits the ingot on the carriage, which is then moved forward to the end of the mill, the pushing arm having been tilted up for allowing the ingot to pass under it. The arm is then lowered behind the ingot and water pressure is admitted into the pushing cylinder, which moves forward and pushes the ingot over the rollers up to the horizontal rolls of the mill; these seize upon it and pass it through. Then the corresponding pusher on the other side of the mill comes into action, and pushes the ingot back again into the rolls, and this alternate action is continued until the slab is finished to the required width and thickness. All these operations are controlled by one lad at the screwing gear, one man at the pushers and carriages, one man at the mill engines with his assistant to do the necessary oiling, etc., and the roller in charge of the mill. When the slab is finished, the back pusher slides forward, takes hold of the near end of the slab, and pushes it off the rollers and upon the carriage which conveys it to the shears. The carriage is long enough to accommodate long slabs; it is supported and travels on a frame-work of girders, one end of which is pivoted, and the other rests on a hydraulic ram of short stroke, which by raising the end of the girder frame and the carriage resting thereon enables the slab to pass forward through the shear blades without contact with the lower blade until the shearing actually begins.

Hydraulic Slab-shears.—In connection with the first cogging-mill the author adopted hydraulic power for cutting the slabs; and when the second mill just described was constructed shears of the same kind but much more powerful were erected. They were made by Messrs. Tannett Walker & Co., Leeds. On the four corners of a massive bed-plate are placed columns supporting the cast-steel entablature, in which are formed three cylinders, the centre one 31 inches diameter, and the two side ones each 22 inches diameter. Four strong steel bolts, passing through base-plate, columns and entablature, bind the whole together into a firm strong structure. The rams for the two side cylinders are made sufficiently long to extend for some distance into the base-plate; they thus act as guides to the bolster of the upper shear-blade. The bolster is a strong steel casting; its upper centre part forms the ram of the large centre cylinder, while the two side rams pass through and are attached to it by strong tap-bolts or screws. The lower bolster is fixed on the base-plate; for resisting the lateral pressure when shearing, it is supported by two strong steel castings, which are placed on the base-plate under the columns, the main binding bolts passing through them. These castings are also strengthened by a strong bolt fastened through them, transversely to the shears. Provision is made for holding down the after end of the slab during shearing, by a cylinder fixed on the entablature, in which works a ram acting through a cross-head upon two rods; the latter are attached to a second cross-head, which presses down on the slab. All the rams are designed to work against constant pressure from the accumulator, and thus the return stroke is obtained. The accumulator is loaded to give a pressure of 1 ton per square inch. The pipes or tubes are all led to a convenient position, where all the movements are controlled by one man at the valves. On two of the columns brackets are provided, which support sliding brackets carrying the table that receives the slab when sheared. This table has hydraulic cylinders and rams under it, by which it is raised or lowered to suit the stroke of the shears when cutting off the slab. By the action of another ram the table after receiving the sheared slab is made to slide outwards, away from the shear-blade, and into range of the hydraulic crane, which lifts the slab and loads it upon the carriage, where it is weighed and stamped, preparatory to being passed forward to the plate-mill. In shears of this kind, it is important that the cut should be made as rapidly as possible; otherwise the hot slab is so long in contact with the blades that they become softened, the edges fail and they are soon rendered useless. Hence the areas of all apertures leading to the hydraulic cylinders should be as large as possible.

Slab-cutting shears of great power were made by Messrs. Buckton & Co., to work in connection with the cogging-mill at Wishaw steel works. The machine will cut a hot slab up to 42 inches wide and 12 inches thick. It is driven by coupled engines, with cylinders 26 inches diameter and 30 inches stroke, through gearing with a multiplying power of thirty to one. The eccentric shaft is 20 inches diameter in the necks; the caps of the eccentric shafts are held down by four bolts of 10½ inches diameter, passing through the uprights from top to bottom. While a slab is being cut off, it is held down on the anvil of the machine by a self-acting hydraulic-pressure foot, giving a load of twenty tons; this prevents the slab from tilting upwards under the action of the cut. The remaining portion of the bloom rests on a roller cradle, which is supported by a hydraulic cylinder loaded to a constant pressure of 20 tons, so that the bloom is upheld and prevented from tilting downwards under the action of the cut. Thus both parts of bloom are compelled to remain approximately horizontal; in consequence the severed ends are cut square, and are not sensibly scarfed. The cradle of live rollers which supports the bloom becomes depressed under the pressure of the shear slide, and recovers its position when the slide goes up again. The cradle is arranged to feed the blooms into the machine, and the cut slabs are delivered over the anvil. The object of this arrangement is that the live rollers which feed the bloom in may be brought as close to the knives as possible. At the delivery side of the machine there is a hydraulic measuring stop, for gauging the cut slabs to measured lengths from 6 inches to 8 feet long. It has a pointer and graduated scale for measuring; and is made with a hydraulic tilting cylinder, to swing the top free above the travelling bloom. With this gauging stop, the bloom can be stopped while travelling on the live rollers, and can also be pushed back into exact position for cutting, and be regulated easily to a fraction of an inch.

Plate Mills.—In this country it is almost the universal practice for plates of, say, ¼-inch thickness and upwards to be rolled in reversing mills, especially if they are of considerable area and weight; the difficulty in handling heavy slabs and plates no doubt conduces to this practice. Whether it is the most economical method of manufacture, especially for what may be described as plates of medium thickness and weight, may, perhaps, be open to discussion; but for handling the heavy plates now produced it is undoubtedly the safest, and, perhaps, also the most economical. The plate mills supplied to the Wishaw works by Messrs. Lamberton & Co. are excellent illustrations of present practice. For general use in producing plates of medium width, the mill is provided with two stands of rolls, the fi[illegible]ing pair being chilled, as is customary. The rolls are 8 feet long and 30 inches diameter. Both top rolls are supported on hydraulic balances, and have a lift of 18 inches. Mechanical screwing-gear is applied to the roughing rolls, and is driven by a pair of small horizontal engines geared to give the required speed. The chilled roll is screwed down by hand in this case; but there is no satisfactory reason why the screwing should not be done mechanically at both rolls. Arrangements exist which admit of accuracy of gauge being obtained with certainty when mechanical screwing is applied to the finishing as well as to the roughing rolls. One simple method which may be mentioned is the insertion of what may be termed a short screw-jack between the chock and screw in one of the housings; a slight alteration of this, made by the roller when necessary, will at once correct any small inaccuracy in the setting or position of the main screws. Live rollers are fitted in the front and at the back of the rolls, and are driven by a pair of vertical engines conveniently placed so that the driver can see the operations at the mill. The live rollers extend a considerable distance in front of the rolls, but only a short distance at the back; here they are supplemented by live rollers fitted into a table, which traverses the two sets of rolls, carrying the slab or plate across from the roughing to the finishing rolls. The table and rollers are actuated by a pair of vertical engines in the usual manner. The table travels in a pit; and its rollers being on a level with the mill floor, the finished plate is rapidly and readily delivered upon it. In a line with this mill is a stand of rolls for handling plates of the greatest weight and width. The rolls are 12 feet long and 40 inches diameter, the top one supported on hydraulic balances. The chocks are all of steel with heavy brasses.

This mill is fitted with mechanical screwing gear, driven by horizontal engines which are fixed on the top of one of the housings; and it is so arranged that either of the screws can be moved alone. Hence, the roller has full control, and can modify the screwing at pleasure, even to the extent of rolling plates of taper cross section if required. The arrangement is as follows:—On the crankshaft of the engine is keyed a pinion, which through a spur wheel drives the main shaft that extends over both housings; and on each of the main screws is a worm wheel, which is driven by a worm on the main shaft. These worms are loose on the shaft, and run in collar bearings in pillow blocks. They have three-pronged clutches on their outer ends, into which can engage corresponding clutches sliding on keys or feathers on the shaft; either or both of the clutches can be thrown in or out of gear, and either of the main screws can thereby be moved or stopped at pleasure by the screwer, who stands on a platform near at hand, and obeys the instructions of the roller. The pinions for driving both mills are placed between them. The spindles for driving the large rolls are of considerable length, so as to reduce the angle at which they drive. They, as well as their coupling boxes, are of steel. In front and at back of this mill are complete sets of live rollers, driven by a pair of vertical engines, which are conveniently placed for driving either these or the live rollers of the 8-feet roughing rolls, as may be required. A useful appliance is here provided for adjusting the position of the plate in front of the rolls so that it shall pass through them as nearly square as possible, and at equal distances from the housings. Such an appliance was first designed by Mr. Duff for the large plate-mill at Blochairn works, but has been modified for use here by Mr. Williamson. A long pusher-bar is connected to a hydraulic ram and cylinder fixed at one side of the live-roller frames; it is moved to and fro across the front of the rolls in grooves between the live rollers; holes are provided in it, into which pegs can be temporarily put, for moving the plate sideways or otherwise adjusting it. These mills are driven by a massive and powerful pair of reversing engines, constructed by Messrs. Duncan Stewart and Co., of Glasgow; they have cylinders 52 inches diameter by 60 inches stroke, and the gearing is in the ratio of two to one.

Three-high Plate Mills.—Although mills of this kind have not been adopted to any great extent in this country, it is known that they are largely employed in America; and in the author's opinion they are worthy of much more consideration than they appear to have received here. When well designed in all parts and details, the three-high mills used in the United States, which have two larger rolls and one smaller, are capable of doing more work in a given time, and probably at less cost, than the reversing mills so commonly used here. The grounds of this opinion are:—Firstly, that for driving three-high mills engines can be used which are highly economical in steam consumption, and if sufficient water can be obtained, they may be of triple-expansion with automatic valve gear; secondly, the mills can be driven at a higher speed; thirdly, the loss of time due to reversing can be saved; fourthly, plates can therefore be finished more quickly, and thin plate of large area can be rolled and finished with greater accuracy of gauge and in better condition for testing; fifthly, a larger output is obtained in a given time. These are advantages of considerable importance. The disadvantages are:—Firstly, that the cost of the three-high mill and its tables, &c., is, perhaps, somewhat greater than that of the ordinary reversing mill; and, secondly that the cost of maintenance is slightly greater. But it may be repeated that, if the details were carefully designed, it is doubtful if these disadvantages would exist at all, or, if they did, whether they would be worth much consideration. It is a pleasure to see one of the three-high mills at work, when in good order; and the contrast with an ordinary reversing-mill is somewhat striking. With proper appliances few men are required, and there is little, if any, larger demand on their skill. The use of the three-high mills, however, should be limited to the production of plates of light or medium weight and of medium width.