DESCRIPTION OF AN IMPROVED REVERSING ROLLING MILL.

By Mr. JOHN RAMSBOTTOM, of Crewe.

The improved Reversing Rolling Mill described in the present paper has been in operation for seven months at the Steel Works of the London and North Western Railway at Crewe, having been designed and laid down by the writer. The special point in the arrangement is that the rolls are driven direct by the engine, without the intervention of a flywheel; and the engine and rolls together are reversed each time that a heat is passed through, the rolling being alternately in opposite directions. The idea of reversing a train of rolls by reversing the engine at each passage of the heat through the rolls was first suggested by Mr. Nasmyth, but has never to the writer's knowledge been carried out before.

A general plan of the rolling mill and engines is shown in Fig. 1, Plate 34, and an enlarged plan of the Engines in Fig. 2, Plate 35; Fig. 3, Plate 36, is a side elevation of the engines, and Fig. 4 a transverse section. They are a pair of direct-acting horizontal engines coupled at right angles, as shown in the plan, Fig. 2; and they are reversed, without shutting off steam, by hydraulic power, by means of the arrangement shown in plan in Fig. 2 and in elevation to a larger scale in Fig. 7, Plate 37. The reversing shaft A is connected by links to a piston working in a small cylinder B of 4 inches diameter and 10½ inches stroke, the water pressure being 300 lbs. per square inch. The admission of the water to the cylinder is regulated by a slide-valve worked by the shaft and hand lever CC. This shaft is prolonged and carried outside the engine house, as shown in the plan Fig. 2, in order to place the attendant in a position where he may be able more

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easily to seize the right moment for reversing. The shaft C is made hollow, as shown enlarged in Fig. 6; and through it runs a second shaft with hand lever DD, which regulates the main steam-valve E of the engines by the lever and connecting rod F. By this means the attendant standing outside the engine house at G and in full view of the rolls has complete command over the engines by the two handles C and D. A hand lever is also fixed on the reversing shaft A, as a provision for reversing the engines in the event of any accident occurring to the hydraulic gear or any deficiency in the water supply.

The engines make $3\frac{1}{4}$ revolutions for one revolution of the rolls, and the speed of piston is about 4 times (4·14) that of the circumference of the rolls. The cylinders H H, Fig. 2, are 28 inches diameter with 4 feet stroke. The expansion link K, Fig. 3, shown to a larger scale in Fig. 5, is the straight link devised by Mr. Alexander Allan, and is driven by three eccentrics and rods, two at one end and one at the other, so as to avoid the oblique thrust inevitable with only two eccentric rods.

The connection between the engines and the mill train is made, first by means of an ordinary clutch shown at JJ in Figs. 1 and 2, and secondly by a friction coupling designed by the writer, and shown in position at LL. This friction coupling is shown enlarged in Figs. 11 and 12, Plate 40. The disc M is keyed on the driver shaft N, and a smaller disc O is mounted wobbler-fashion on the mill shaft P, and tightly compressed between the driver disc and a loose ring I bolted to the driver disc. Annular segments of alder wood packing $\frac{3}{4}$ inch thick are interposed between the discs to increase the bite, and are placed so that the fibres run radially to the shaft. This friction coupling is capable of transmitting the whole power of the engines in regular work; but if from a sudden obstruction the motion of the rolls is arrested, the driver disc slips round the follower without moving it, and no injury is sustained by any part of the machinery. In ordinary roll trains it has sometimes happened that the "breaking spindle" has broken, and that the broken end has acted as a lever to shift the engines from their bed; but by the present arrangement the probability of such

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an occurrence is very much diminished, and many stoppages and breakages are avoided, whereby loss of capital is prevented.

The engines are of such power that there is no necessity to do more than just start them before the heat enters the rolls. Thus the heavy flywheel usually employed is not required, and consequently the engines are easily reversed; neither is there any expenditure of steam except at the very time of rolling. For the same reason the wear and tear of machinery and the necessary lubrication are reduced to a minimum in this mode of driving the rolls. Instead of the heavy flywheel employed in the ordinary arrangement of rolling mills as a reservoir of power, in which the power of the engine is previously accumulated ready to be concentrated upon the work at the time of rolling, the boiler is made to serve as the reservoir of power in the new rolling mill; and it has this great advantage, that whereas the flywheel contains only a limited store of power, which continues diminishing during the time of application, the boiler supply is practically unlimited, so that the rolling power continues constant throughout the time of operation.

In the rolling of puddled slabs for the frame plates of locomotive engines, which are reduced $3\frac{1}{2}$ inches in thickness at one heat in the rolls, about twenty-one reversals of the rolls are required. These are effected with great ease and almost instantaneously by the arrangement above described, the shock being transmitted to the elastic cushion of steam in the cylinders of the engines. This handiness allows of either iron or steel plates being passed through both the roughing-down rolls and the finishing rolls at one heat; and the work is thus done with a minimum expenditure of heat and waste of metal. It has been found on trial not at all difficult to reverse the engines together with the whole train of rolls as many as 73 times in one minute.

There are two pairs of Rolls, one for roughing down and the other for finishing. The roughing-down pair are 24 inches diameter by 6 feet length; they are shown in elevation and plan in Figs. 8 and 9, Plates 38 and 39, and Fig. 10, Plate 40, is an end elevation;

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Figs. 13 and 14, Plate 41, are transverse sections through the housing and through the rolls.

In these rolls a new description of tightening-down gear has been designed, in order to obtain greater facility and accuracy in tightening down the rolls, and to ensure the top roll being at all times perfectly parallel to the bottom roll. This gear is shown in Figs. 8, 9, and 14. It consists of a vertical wrought-iron shaft Q, carried by a cast-iron bed-plate and supported at the upper end by the wrought-iron standard S, between the housings, and in the centre of the length of the rolls. On the top of the shaft is keyed a spur wheel T, which drives the two spur wheels UU on the vertical holding-down screws of the top roll R. These screws work in steel nuts let into the housings, as shown in Fig. 13, and the top bearing of the centre shaft Q is also a corresponding screw working in a brass nut, so that the centre spur wheel T rises and descends simultaneously with the two outer spur wheels UU when the gear is in motion. A vertical hydraulic ram V, Figs. 8 and 10, is placed in a convenient position near the rolls; and a chain, shown by the thick dotted line, is fastened at one end to the barrel of the ram, carried thence over the pulley on the ram head V, down again to the fixed pulley below, and thence round a guide pulley X on the nearer roll housing to the spiral chain-barrel upon the lower end of the vertical centre shaft Q. The chain makes a few coils round the barrel, and the end is fastened to the barrel near the top. Another chain is fastened to the barrel near the bottom, and after a few coils round the barrel quits it in nearly the same horizontal plane as the first chain, and passes off on the opposite side and over a guide pulley on the further housing; a weight W is suspended at the end of this chain, heavy enough to overhaul the other chain and slack back the tightening-down screws of the top roll, when the water pressure is shut off from the hydraulic ram V.

When a slab has entered and passed once through the rolls, the engines are reversed, and the water valve being opened the ram V rises and hauls in the chain, driving the chain barrel and causing the tightening-down screws UU to descend and lower both ends of the top roll simultaneously to the required extent. This process is

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repeated after each passage of the slab through the rolls. When the rolling is completed, the water is released from the ram, and the ram falls, while the counterbalance weight W on the second chain winds up the tightening-down screws to their original position; and the usual counterbalance apparatus Y, Figs. 8 and 13, applied to the top roll R, causes it to rise with the upper chocks.

The head V of the hydraulic ram, Figs. 8 and 10, carries an index finger, which by means of graduations on the guides enables the attendant to give with accuracy the requisite amount of lowering of the top roll at each reversal, and thereby to reduce each slab with certainty to exactly the same thickness. As an additional precaution in rolling a set of slabs all to the same thickness, a chalk mark is made on one of the spur wheels U, after the final rolling of the first slab; and at the final rolling of each successive slab of the same set a stop is placed in the teeth of the spur wheel at this mark, stopping the screwing down always at the same point, and thus preventing the possibility of any mistake in the finished thickness of any slabs of that set. The total vertical motion given to the roll by the hydraulic ram is $3\frac{1}{2}$ inches, while the stroke of the ram is 6 feet $2\frac{1}{2}$ inches; consequently the movement of the ram is 21 times that of the roll, and the indication by which the tightening of the rolls is measured being thus magnified 21 times gives great accuracy in the adjustment.

By this system of gearing the two tightening-down screws together by means of the intermediate spur wheel, the top roll is made to move always truly parallel to the lower roll, and there is no possibility of one end of the roll descending more than the other. Thus the two surfaces of the slabs rolled are made perfectly parallel to each other, with a uniform thickness throughout the entire width of the slab.

In the finishing rolls the same tightening-down gear is employed. These rolls are of cast iron chilled on the circumference, 24 inches diameter by 7 feet length; and they differ in no important respect from the roughing-down rolls. As the finishing rolls require only a small vertical motion, no counterbalancing gear is applied to the top roll as in the previous pair, the bottom chocks of the top roll

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being supported by the ordinary transverse spring beams passed through the housings.

In order to facilitate the introduction of large slabs into the roughing-down rolls, a set of bent levers ZZ, Figs. 8 and 14, shown to a larger scale in Fig. 15, Plate 42, are attached to a horizontal shaft B running along the ground parallel to the rolls ; and by means of a hand lever H on the shaft all these levers are simultaneously brought up under the slab, and by a slight movement the slab is then lifted into the rolls. Each of the levers is attached to the shaft B by an arm and pin joint, so that it can yield to any inequality on the surface of the slab ; and it is brought up again by the overhanging counterbalance ball A.

From the fact that the train of rolls driven in this manner is only in motion while the heat is being passed through, it is not found necessary to use a stream of water for lubricating the roll bearings in the ordinary manner ; but all the journals are truly fitted in the bearings, and are lubricated with oil and tallow.

The President enquired what was the greatest length of bar that had been rolled in the new rolling mill.

Mr. Ramsbottom replied that the greatest length they had rolled at present was only plates 17½ feet long ; but any length that was desired, from the least to the greatest, could be rolled with equal facility by simply keeping the steam on long enough, the only limit being the amount of furnace accommodation available for heating the bloom, and the extent of shop room for rolling in. The chief feature in the new arrangement was the ease and rapidity with which the rolls could be reversed at full speed, allowing of the work being rolled down rapidly, by avoiding the cooling from the delay of passing the iron back over the top roll.

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Mr. R. Napier asked whether any break-downs or accidents had occurred since the mill was first started.

Mr. Ramsbottom replied that they had had no accidents of any sort during the seven months that the mill had now been at work.

Mr. W. Fairbairn enquired whether the rolling mill was employed for rolling down ingots of steel; and whether the same plan would not be applicable for rolling armour plates.

Mr. Ramsbottom said he had not used the mill for rolling down steel ingots, but it was employed chiefly in rolling the frame plates for locomotives. For armour plates he thought the reversing mill would be very suitable, and the only question was one of gearing and power for rolling any size of armour plate that might be required. He had had no difficulty at present in rolling anything that had been put into the mill. On one occasion he had rolled a circular steel saw-plate, 7 feet diameter, which was of course rolled in a single piece. It had been objected to the plan of keeping the rolls parallel, by gearing the tightening-down screws together, that the plates sometimes wanted humouring, by tightening the top roll down more at one side than the other, which could not be done when the screws were geared together; but in practice the utmost extent of the humouring required was so slight that he had found it was only necessary to pass the plate through nearer to one side or the other, as the rolls themselves were not turned truly cylindrical, but slightly larger in diameter in the centre to compensate for the springing under the strain in rolling.

Mr. R. Napier remarked that the levers employed for entering a slab into the rolls looked very light, and he enquired whether they were found strong enough for the purpose.

Mr. Ramsbottom replied that the levers were made of pieces of ordinary spring steel $\frac{1}{2}$ inch thick and $3\frac{1}{2}$ inches broad, and there were four of them on each side of the rolls, and though light in appearance they completely answered the purpose of lifting the slabs into the rolls; and with this arrangement one man at the hand lever could do more than four or five men by the old plan of running a truck at the slab to force it into the rolls.

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Mr. B. Fothergill remarked that in ordinary ironworks where there were a number of furnaces in connection with the same set of rolls, the heats to be rolled would be of different thicknesses, so that it would be necessary to lower the rolls immediately from a bar or slab of say 3 inches thickness to a plate only 1 inch or $\frac{3}{4}$ inch thick; and he enquired how quickly the tightening-down gear could be altered in the new rolling mill, for changing the gauge of the rolls to suit such requirements, and whether this was done as quickly as in the usual mode by hand.

Mr. Ramsbottom replied that the top roll in the new rolling mill had a motion of $3\frac{1}{2}$ inches, and from the full width of opening it could be brought down in a few moments through the whole range of $3\frac{1}{2}$ inches by means of the hydraulic tightening-down gear, nor had any inconvenience or delay been experienced from this cause. The alteration was effected quite as quickly as with the ordinary tightening-down screws worked by hand and independent of each other; and the adjustment was made with much greater accuracy by the hydraulic apparatus, the $3\frac{1}{2}$ inches range of motion of the top roll being magnified 21 times on the scale of the hydraulic ram, which was constructed according to the arrangement of Sir Wm. Armstrong's hydraulic cranes. The range of the top roll could be further increased if desired, by altering the proportion of the gearing.

Mr. S. Lloyd observed that the old plan of reversing the rolls had never come into general use, because the process of reversing had been so slow, that, except in heavy work, it had been found quicker to pass a plate or bar back over the top roll and re-enter it than to reverse the rolls. From the description given in the paper of the new rolling mill however, it appeared that the reversing was now done so quickly and so easily that the rolls could be reversed quicker than the plate or bar could be passed over the top roll, even when working at a considerable speed. He enquired whether with very short pieces of metal the rolls were always reversed, instead of passing the work back over the top roll.

Mr. H. Maudslay observed that the case appeared similar to that of the planing machine, in which it was desirable to reverse the

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tool half round for cutting during the return stroke, when the length of travel was anything considerable; but with a very short travel this was of less consequence, and the return motion might be made without cutting.

Mr. Ramsbottom replied that one of the best illustrations of the facility of reversing the rolls was the mode adopted for rolling down the crop ends of plates into small sheets 1-16th inch thick, to be used as covers for the moulds in casting the Bessemer steel ingots. The men were left to themselves as to the mode of working, and they preferred to reverse the rolls for these small pieces of metal instead of passing the work over the top roll, as they found they could get on much quicker by reversing.

Mr. F. J. Bramwell remarked that as the engine drove the rolls direct in the new mill, without the use of a heavy flywheel, the engine itself must be of greater power, and he asked for some information respecting the comparative cost; he thought it probable the saving effected by avoiding the expense of the heavy flywheel would compensate for the cost of the larger engine.

Mr. Ramsbottom considered the engine working direct on the rolls to be certainly more economical in first cost than the ordinary plan of using a flywheel. In the present instance the engine employed was larger than was actually needed, having been put down originally for driving the tyre mill, and it had afterwards been applied to the rolling mill for the purpose of testing the plan of reversing, because it was not possible to reverse with a flywheel. In putting down a new rolling mill for the same class of work, it would not be necessary to have so large an engine as that shown in the drawings. It was of course requisite to have a second cylinder working at right angles, when the flywheel was dispensed with; but even with a flywheel two cylinders were not unfrequently employed.

Mr. R. Napier enquired whether the work was done with less expenditure of steam by dispensing with the flywheel.

Mr. Ramsbottom had no doubt that the expenditure of steam was not greater than with a flywheel, and there was certainly less wear and tear, and a great saving in time. The flywheel involved the

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defect in principle of going twice over the ground, the speed being first increased by gearing from the engine to the flywheel, and then reduced again by gearing from the flywheel to the rolls; and that process necessarily occasioned a waste of power by friction, which was saved by the present plan of dispensing with the flywheel.

Mr. E. T. Bellhouse thought the new reversing rolling mill presented a very important practical embodiment of the great principle advocated by Mr. Nasmyth, of applying steam power direct to the work required to be done. In former years mechanical engineers had laboured under great disadvantages, owing to the want of machinery sufficiently accurate and fine for accomplishing properly the desired work. Hence it arose that, in forging, the principle of the common hammer had been made use of, and the hammer itself had been made of very great weight and driven by a powerful engine with very heavy flywheel, in order to perform the work by the aid of momentum. Subsequently these cumbrous engines and massive flywheels were superseded by Mr. Nasmyth by the direct application of the steam to the work, in the steam hammer of his invention; by which the power could be applied with the utmost nicety, exactly in proportion to the work to be done. The same important principle had since then been followed up in many other instances, and was now carried out in the new rolling mill that had been described, in which the stopping and reversing of the rolls and their adjustment for rolling to different thicknesses were effected with the greatest readiness and precision, by means of well designed mechanism; this could not however have been successfully accomplished formerly, in the absence of the facilities that were possessed at the present day in materials and manufacture. In thus dispensing with the cumbrous machinery required for obtaining the momentum that was necessary to go through the work by accumulation of force, and applying the power direct to the work in the exact proportion of the work itself, one practical result obtained was an important saving in the item of foundations, which had been a very heavy expense attendant upon the former ponderous machinery. He suggested that the same principle of driving independent sets of machinery by independent engines of

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comparatively small size, each working direct upon its own machines, might perhaps be advantageously carried out in the case of cotton mills and similar manufactures, instead of the present plan of driving the whole of the machinery in the works by a single engine of very large size; the principle had been already adopted in print works and warehouses, as well as in many engineering works.

Mr. J. FERNIE said he had recently seen the reversing rolling mill in operation at Crewe, and could fully bear out all that had been stated in regard to the very efficient way in which it worked; but in existing ironworks it generally happened that an engine had been put down for more purposes than one, and then this reversing arrangement would not be applicable. At the works with which he was connected the tyre mill and plate mill were both driven by the same engine, so that reversing by the plan adopted at Crewe was not practicable. He should like to enquire whether in making common iron the plates would stand this mode of rolling, and whether the reversing would not injure the fibre.

Mr. W. M. SPARROW thought there must be a severe concussion between the teeth of the two spur wheels gearing the engine to the mill, whenever the rolls were reversed while running at any considerable speed; and he enquired what had been the experience in respect to the wear of the wheels.

Mr. RAMSBOTTOM replied that he had not experienced any drawback from the wear of the gearing, as the parts which moved quickly were all so light, and there was no large mass in motion such as a heavy flywheel, and only the action of the elastic steam to check and reverse the motion. The power being brought to bear upon the work just as wanted, and direct from the engine, there was no accumulated force to be checked in reversing, and no more force was called into play than was actually required for accomplishing the rolling. The reversing was thus effected with no more trouble or wear than in the ordinary reversing of a locomotive engine.

With regard to rolling the plates in both directions in the reversing rolling mill, he had heard it objected by steel makers that steel would be deteriorated in quality by being rolled both ways; but having himself tested the steel that had been rolled both ways,

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he had found no difference in quality between that and the steel rolled only one way.

Mr. W. FAIRBAIRN considered it was immaterial in the manufacture of iron or steel whether the metal was rolled first in one direction and then in the other or rolled continuously in one direction only. The only effect of the rolling, as regarded the quality of the material, was that, supposing it to be a crystallised substance in the first instance, the crystals were elongated and formed into fibres by rolling. He had had an opportunity of seeing the new rolling mill at work a few days previously, and had certainly never seen any machinery better adapted for the purpose in view. With a flywheel of 40 or 50 tons weight, reversing would have been impracticable, because it could not have been stopped in time without destroying the machinery; but by getting rid of all that enormous mass in motion the rolls could now be reversed with the greatest facility. The reversing mill was an important move in the right direction, establishing a new method in the manufacture of both iron and steel, in consequence of which he had no doubt that they would be manufactured at a much lower cost than heretofore.

Mr. RAMSBOTTOM observed that one source of saving would be that the work was got over more rapidly in the reversing rolling mill. With regard to the principle introduced by Mr. Nasmyth of applying steam direct to the work to be performed, as in the present instance, it might be remarked that this principle was gradually becoming more extensively adopted, and it was already the practice in many forges to drive the different trains of machinery by separate engines, so that the operations of one mill might not be interfered with by those of another.

Mr. W. PERRY remarked that, in regard to the plan described in the paper of gearing together the two tightening-down screws of the top roll, a difficulty was often experienced in getting the plates rolled square on the edges and of regular thickness throughout the whole width when the two screws were connected together, on account of the iron happening to be more heated along one side than the other. Moreover if a slab had been wasted at a corner in the furnace, and the top roll was always kept parallel to the bottom roll, as in

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the new rolling mill, there would be considerable waste in shearing the plate square; but if the tightening-down screws were under independent control, they could be so managed as to bring up the wasted portion in rolling, so that the plate would not be wasted in shearing afterwards. On these accounts he thought it was preferable to have the tightening-down screws independent of each other, instead of gearing them together.

Mr. Ramsbottom said no difficulty such as was referred to had been experienced with the tightening-down screws geared together. In rolling plates it was customary to pass the bloom through sideways in the first instance, which made it uniform in thickness throughout its entire breadth, so that any waste in the furnace would be corrected by this process; and it was then turned round and finished for length. The rolls not being made quite parallel, but rather larger in diameter at the middle, any minor errors were met by going a little nearer to one end or the other of the rolls: and if more serious errors were ever occasioned by irregular heating in the furnace, he thought there should be a change in the management of the furnace, rather than working the tightening-down screws separately.

Mr. W. Yule said he had had many years' experience in working rolls in which the tightening-down screws were geared together, and he had never met with any difficulty arising from that plan.

Mr. H. Maudslay observed that in rolling angle iron or bar iron in an ordinary rolling mill, where the rolls ran constantly in the same direction, it was the practice to turn the iron over in passing it back over the top roll, so that the scale might be well knocked off before entering it again between the rolls. But in passing a heat backwards and forwards alternately through the reversing rolls, the scale would remain where it was on the iron; and he enquired whether the old plan would not have an advantage in this respect, by allowing of the iron being turned over and cleared from scale between each passage through the rolls.

Mr. Ramsbottom replied that they had not as yet rolled any angle iron in the reversing rolling mill; but in rolling plates no difference was found between one side of a plate and the other,

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as regarded scale. The large plates were not turned over during rolling, but the scale fell away freely from the lower side, and was always brushed off from the upper side with a broom between each passage through the rolls.

The PRESIDENT thought the improvements described in the paper that had been read were well worthy of being generally adopted in rolling mills; and he moved a vote of thanks to Mr. Ramsbottom for his paper, which was passed.

The Meeting was then adjourned to the following day. In the afternoon the Members were conveyed by special free train, by the kindness of the London and North Western Railway Company, to Crewe, to visit the Steel Works of the London and North Western Railway, where they were shown by Mr. Ramsbottom the manufacture of steel by the Bessemer process, and the manufacture of steel tyres; and also the operation of rolling plates in the reversing rolling mill described at the meeting.

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The Adjourned Meeting of the Members was held in the Lecture Theatre, Mechanics' Institution, David Street, Manchester, on Wednesday, 1st August, 1866; Joseph Whitworth, Esq., President, in the Chair.

The following paper, by Mr. Edward B. Marten, of Stourbridge, Engineer of the Midland Steam Boiler Association, was read:—

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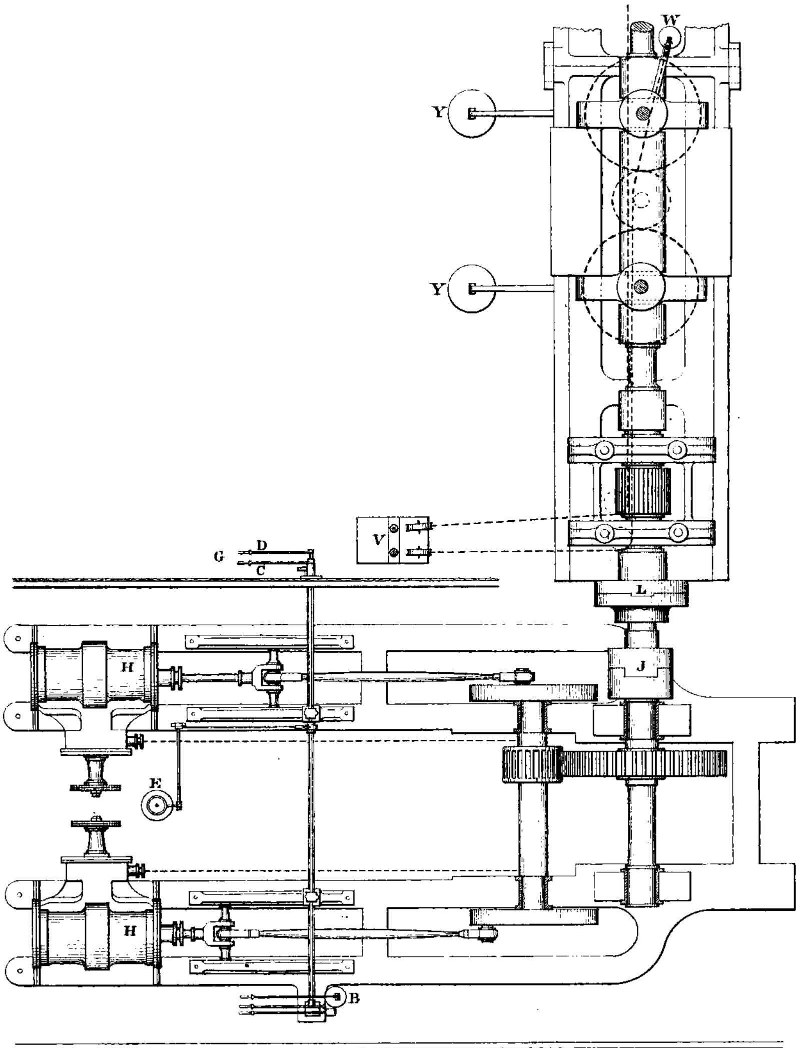
Fig. 1. *General Plan of Rolling Mill and Engines.*



Scale 1/100th

0 5 10 15 20 25 30 *Feet.*

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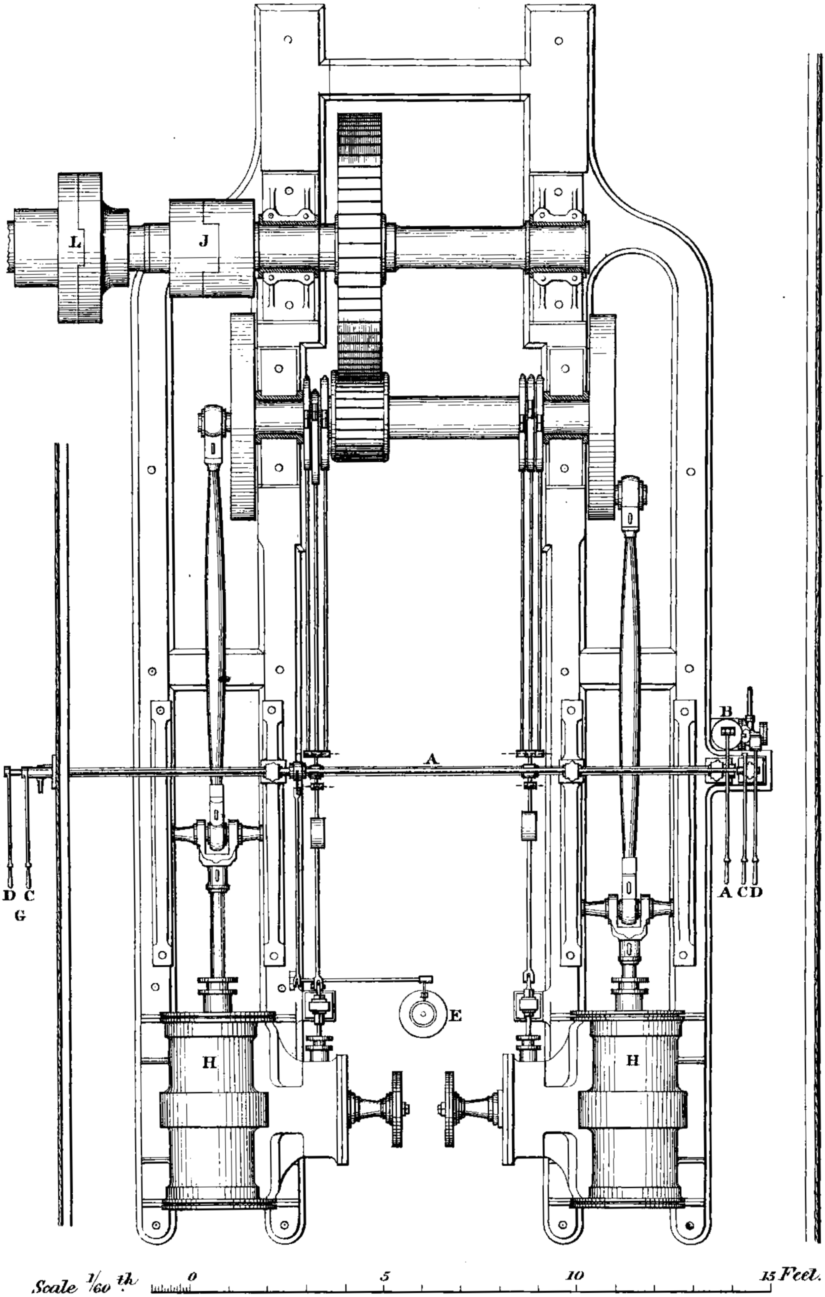
Fig. 2. *Enlarged Plan of Engines.*



(Proceedings Inst. M. E. 1866. Page 115.)

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REVERSING ROLLING MILL.

Fig. 3. *Side Elevation of Engines.*

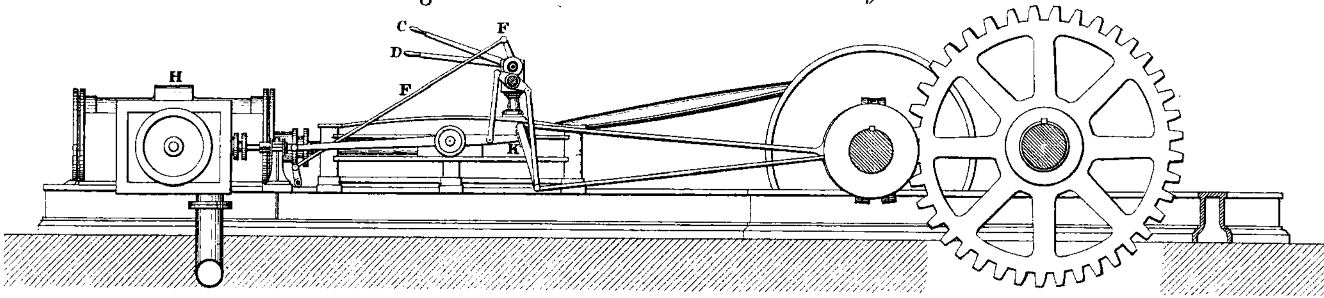
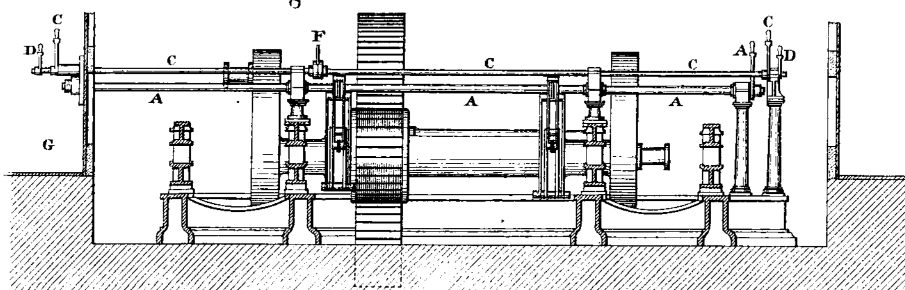


Fig. 4. *Transverse Section.*



(Proceedings Inst. M. E. 1866. Page 115.) Scale 1/60th 0 5 10 15 20 *Feet.*

REVERSING ROLLING MILL.

Fig. 5. *Link Motion.*
Scale 1/20th.

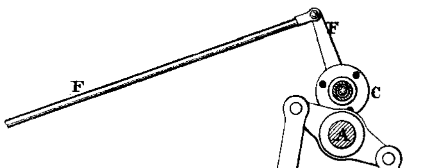
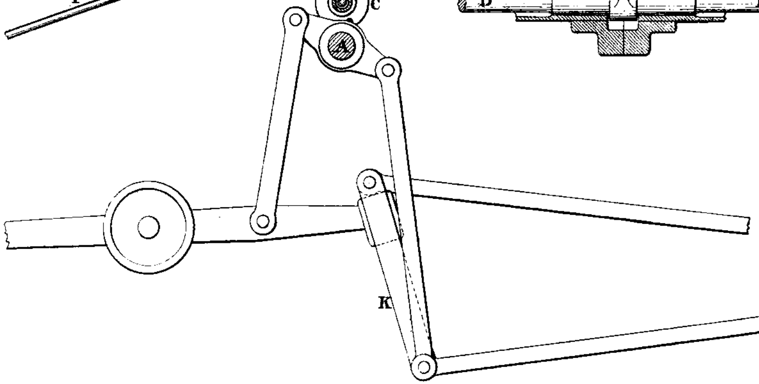



Fig. 6. *Scale 1/10th.*

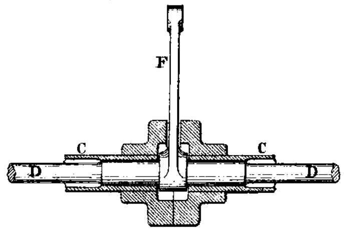
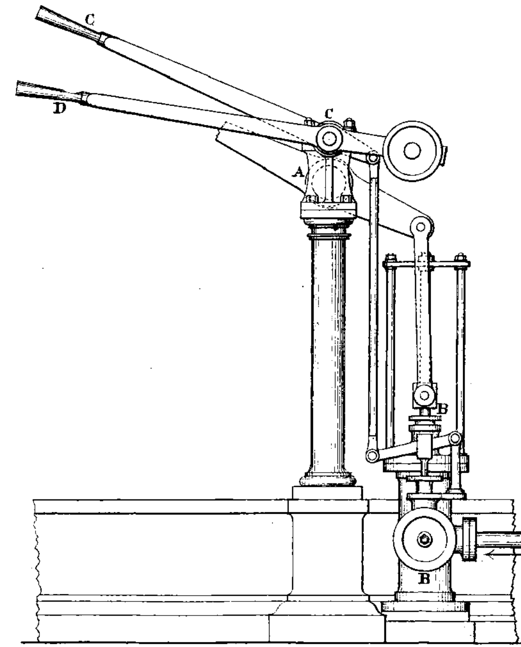


Fig. 7. *Hydraulic Reversing Gear.*
Scale 1/20th.

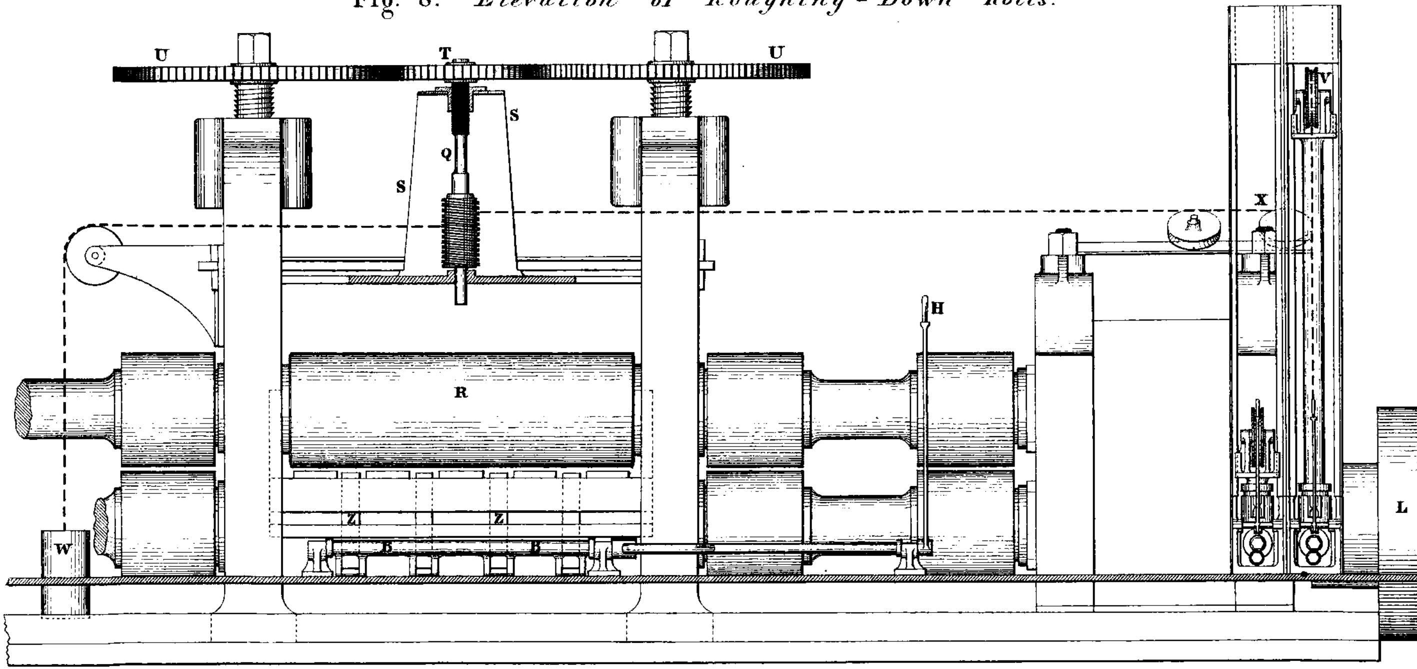


Scale 1/20th. 10 5 0 10 20 30 40 50 *Inches.*

(Proceedings Inst. M. E. 1866. Page 115.)

REVERSING ROLLING MILL.

Fig. 8. *Elevation of Roughing-Down Rolls.*

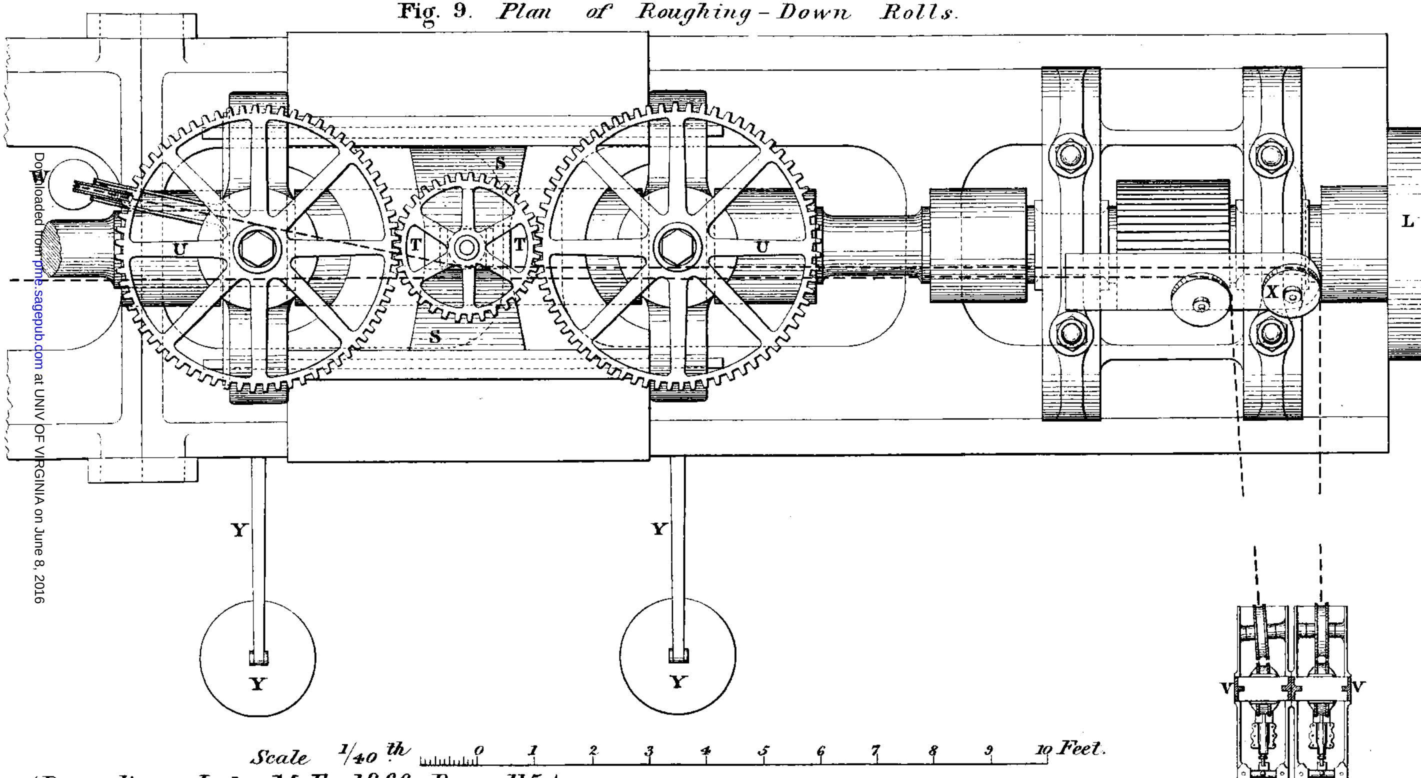


 Scale 1/40th

REVERSING ROLLING MILL.

Plate 39.

Fig. 9. *Plan of Roughing-Down Rolls.*



Scale 1/40th 0 1 2 3 4 5 6 7 8 9 10 *Feet.*

(Proceedings Inst. M. E. 1866. Page 115.)

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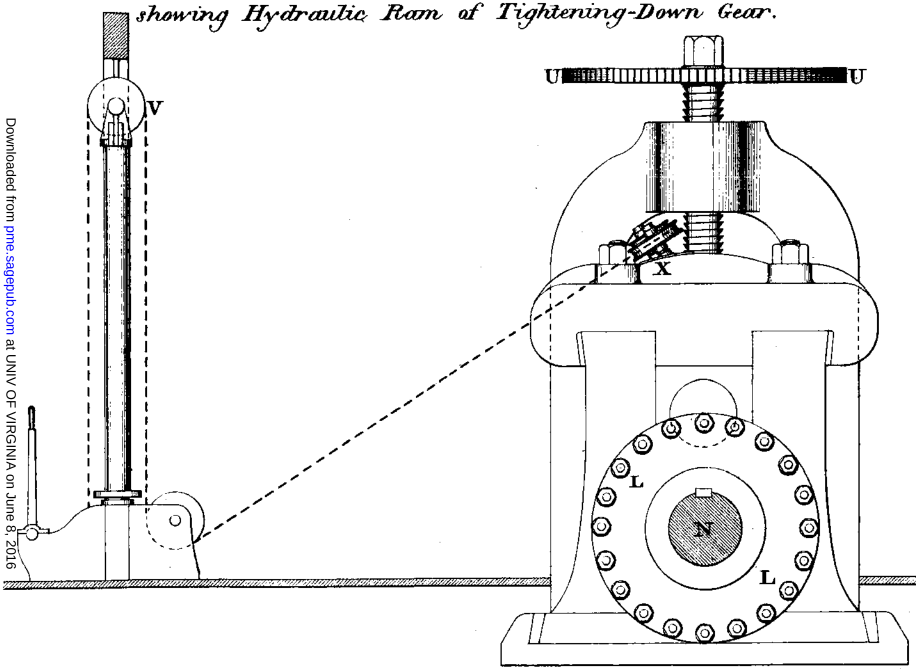
Fig. 10. *End Elevation of Rolling Mill, showing Hydraulic Ram of Tightening-Down Gear.*

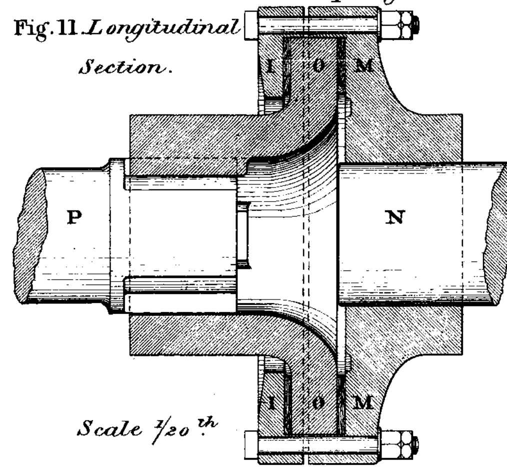


Scale 1/40th

0 1 2 3 4 5 6 7 8 9 10 Feet.

Friction Coupling.

Fig. 11. *Longitudinal Section.*



Scale 1/20th

Fig. 12. *Transverse Section.*

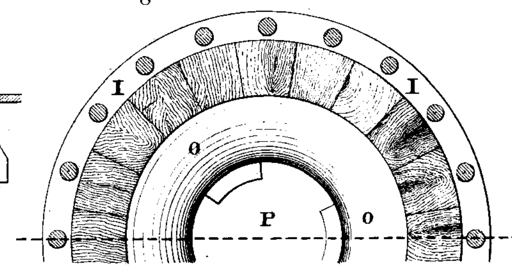


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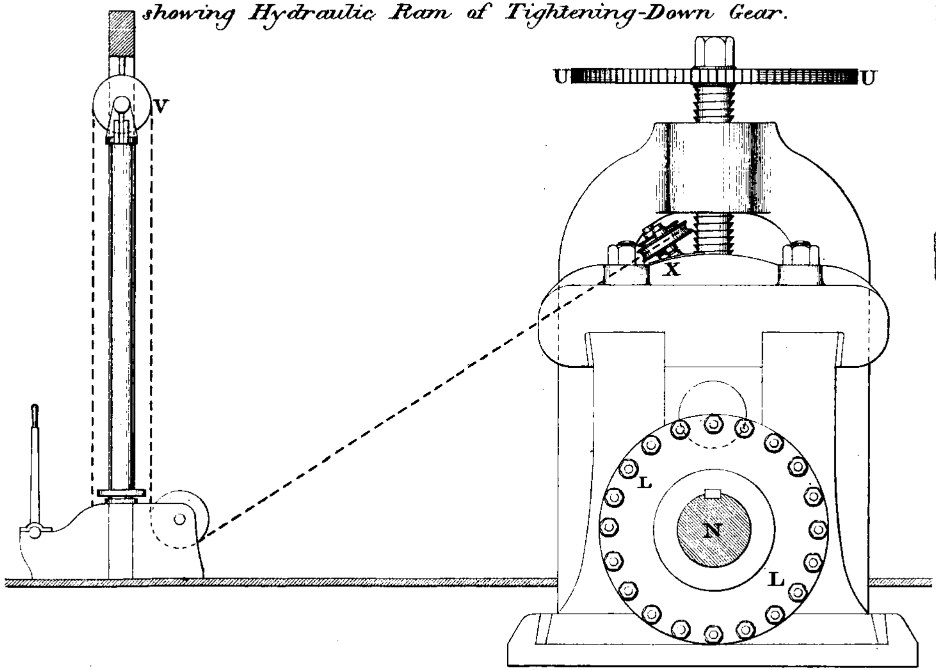
Fig. 10. *End Elevation of Rolling Mill, showing Hydraulic Ram of Tightening-Down Gear.*

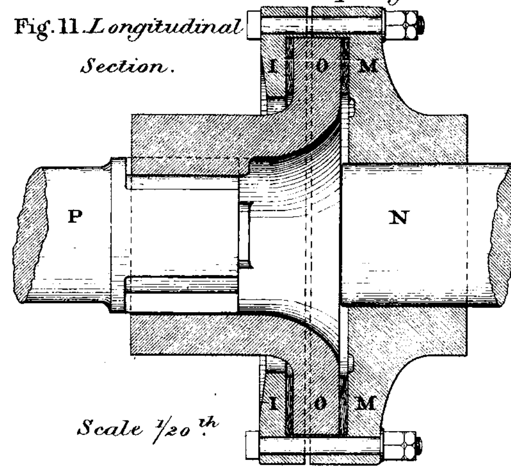


Scale 1/40th 0 1 2 3 4 5 6 7 8 9 10 Feet.

(Proceedings Inst. M.E. 1866. Page 115)

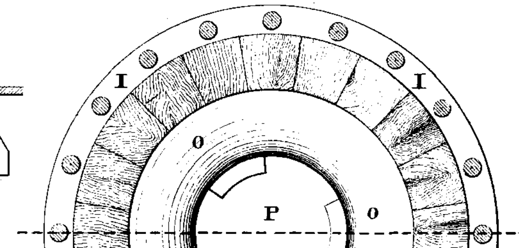
Friction Coupling.

Fig. 11. *Longitudinal Section.*



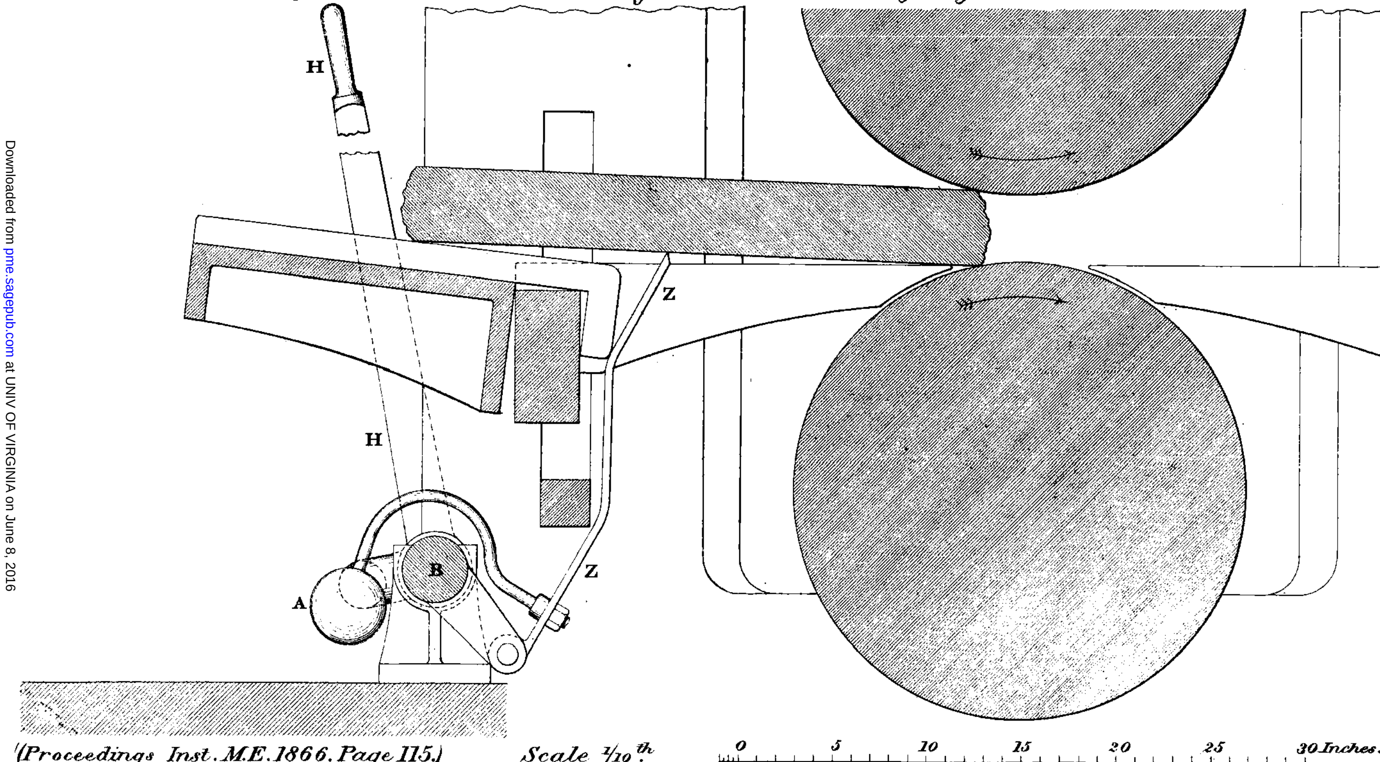
Scale 1/20th

Fig. 12. *Transverse Section.*



REVERSING ROLLING MILL. *Plate 42.*

Fig. 15. *Levers for entering Slabs into Roughing-Down Rolls.*



(Proceedings Inst. M.E. 1866. Page 115.) *Scale 1/10th.*

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