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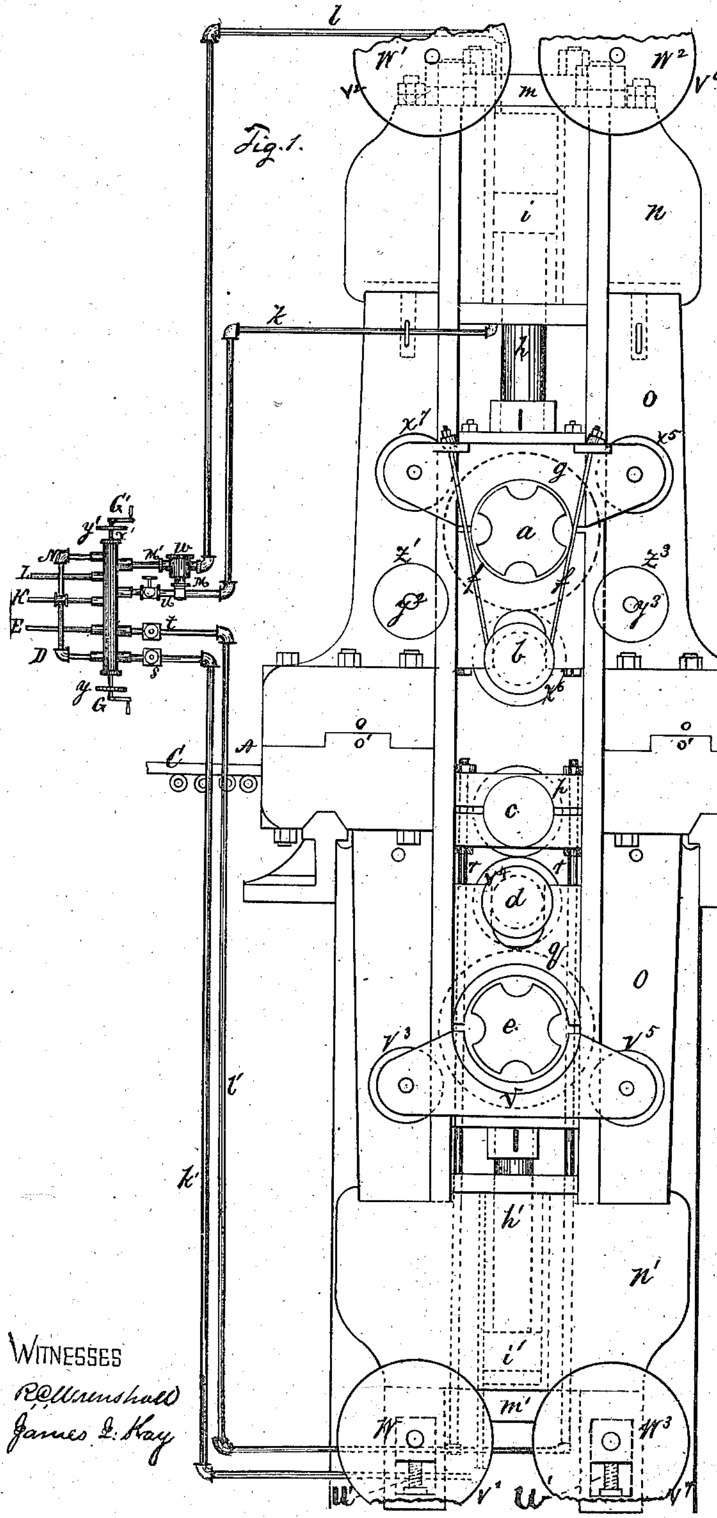
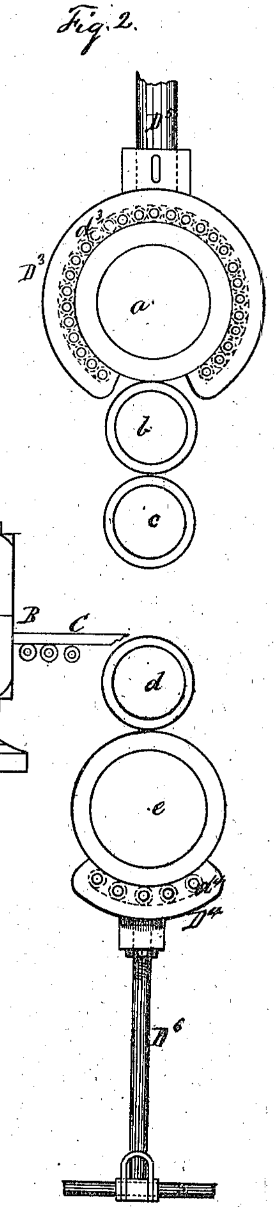
I. HAHN.

Rolling-Mill.

No. 165,819. Patented July 20, 1875.





Witnesses

R. C. Wrenshall

James J. Kay

Inventor

Ignatius Hahn

by Bakewell & Kerr

Attys

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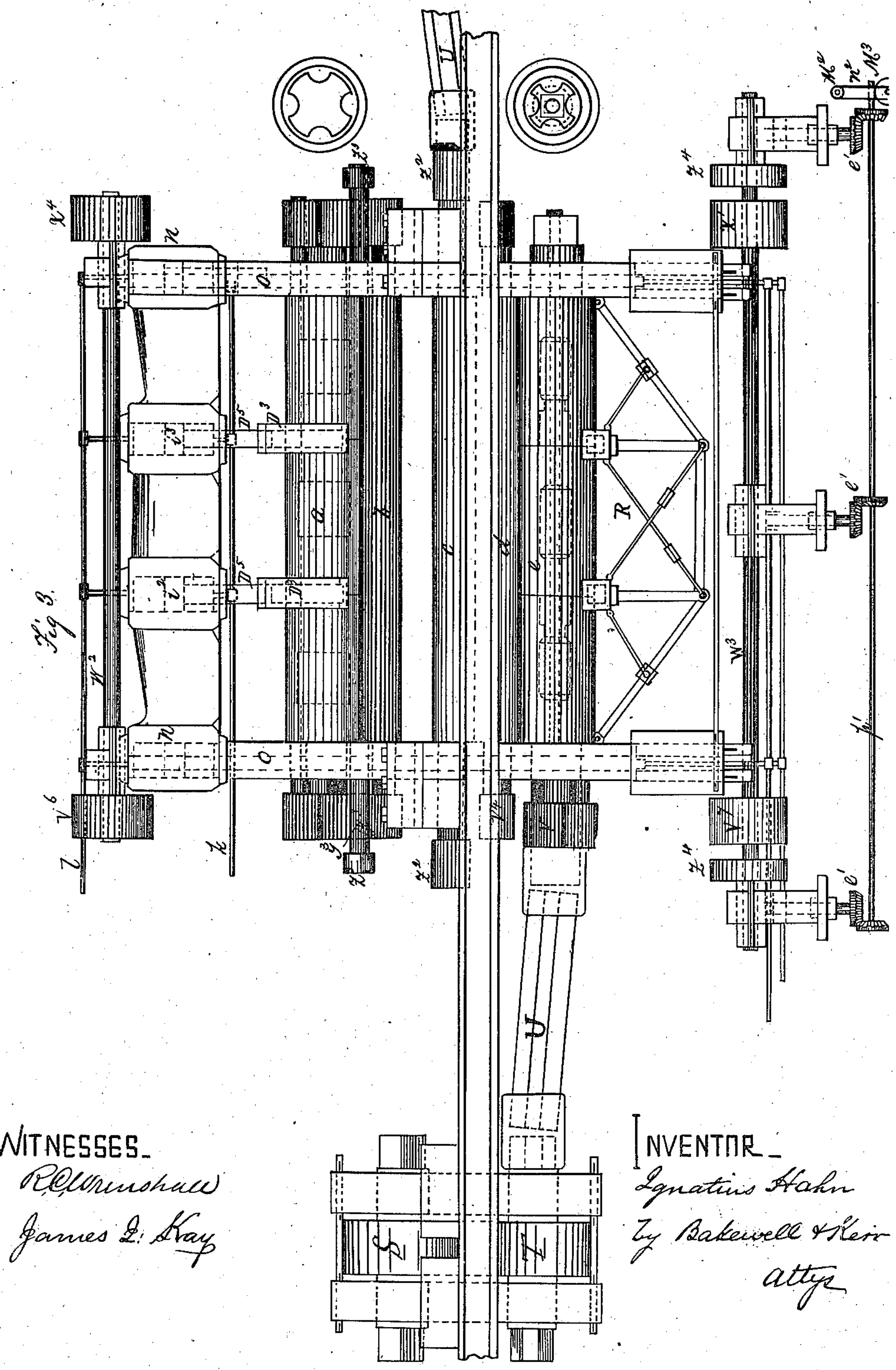

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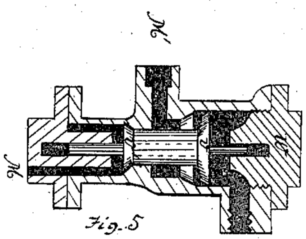

Fig. 5

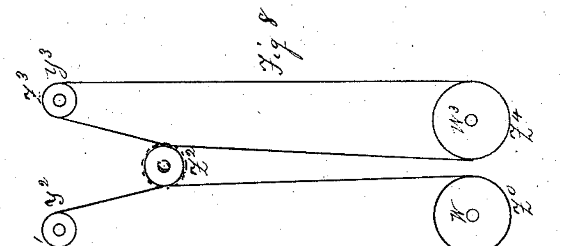

Fig. 8

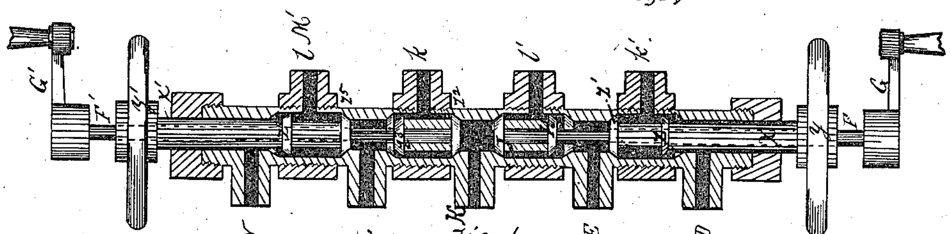

Fig. 4

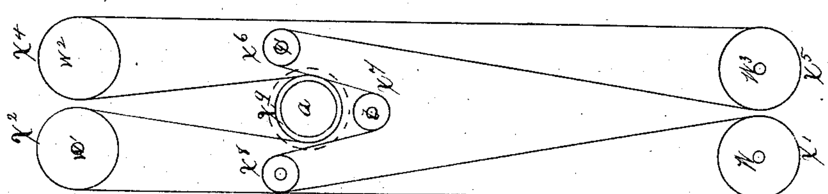

Fig. 7

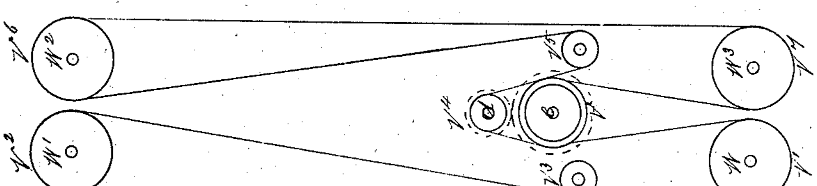

Fig. 6

WITNESSES.

R. C. Wrenshall

James L. Kay

INVENTOR.

Ignatius Hahn

by Bakewell & Kerr, Attys

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I. HAHN.

Rolling-Mill.

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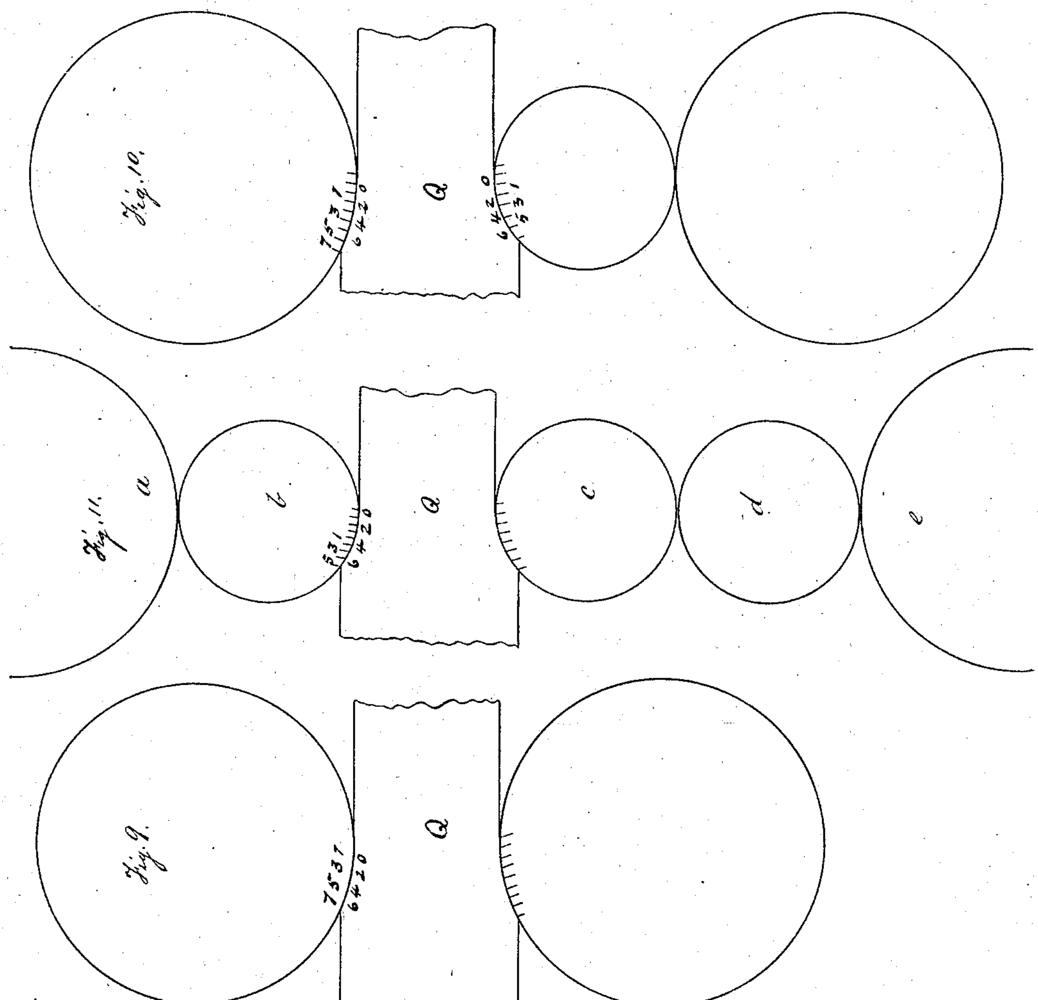

WITNESSES_

R. C. Wrenshall

James L. Kay

INVENTOR_

Ignatius Hahn

by Bakewell & Kerr

Atty.

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I. HAHN.

Rolling-Mill.

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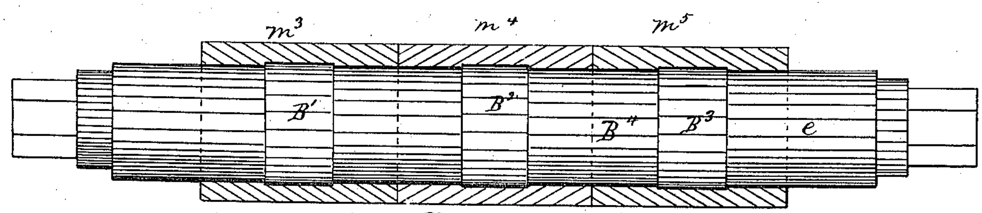

Fig. 12

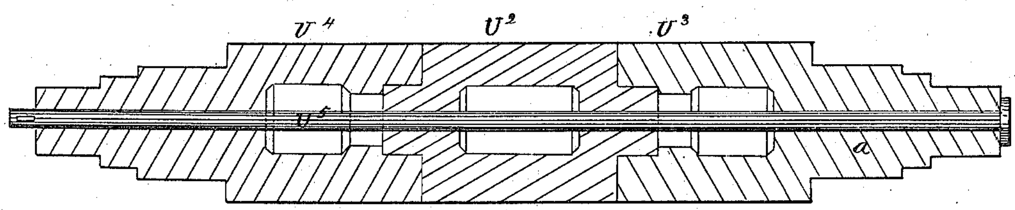

Fig. 13

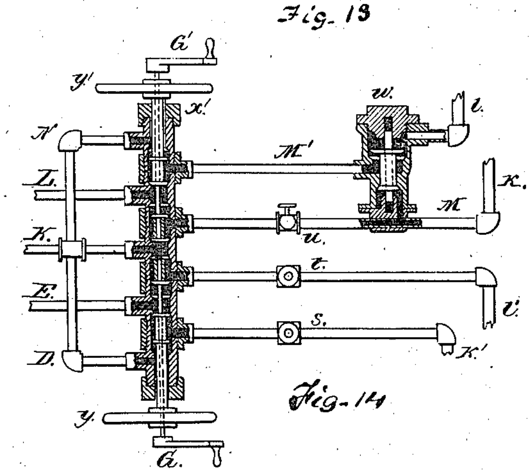

Fig. 14

WITNESSES.

R. C. Wrenshall
James E. Kay

INVENTOR.

Ignatius Hahn
by Bakewell & Kerr
Attys

UNITED STATES PATENT OFFICE.

IGNATIUS HAHN, OF PITTSBURG, PENNSYLVANIA.

IMPROVEMENT IN ROLLING-MILLS.

Specification forming part of Letters Patent No. 165,819, dated July 20, 1875; application filed February 21, 1875.

To all whom it may concern:

Be it known that I, IGNATIUS HAHN, of Pittsburg, in the county of Allegheny and State of Pennsylvania, have invented a new and useful Improvement in Rolling-Mills; and I do hereby declare the following to be a full, clear, and exact description thereof, reference being had to the accompanying drawing forming a part of this specification, in which—

Figure 1 is an end view of a machine embodying my invention, partly in dotted lines. Fig. 2 is a detached view of rolls and hydraulic struts. Fig. 3 is a front view of rolls, housing, &c. Figs. 4 and 14 are sectional views of a system of inlet and outlet valves for applying the hydraulic power in raising and lowering the rolls. Fig. 5 is a sectional view of a check-valve situated on the line of pipe leading to the upper piston-cylinder. Figs. 6, 7, and 8 are detached views, showing the preferred arrangement of belting for driving the intermediate rolls. Figs. 9, 10, and 11 are diagrams illustrating the operation of two, three, and five high rolls. Figs. 12 and 13 are views of a roll formed in sections.

Like letters refer to like parts wherever they occur.

My invention relates to the construction and operation of rolling-mills, more especially plate-mills; and it consists, first, in the combination of three small work-rolls with one large roll to the outside of, and in line with, each of the outer work-rolls, the central roll being of an equal or less diameter than its next adjoining ones; second, in combining with the outer brace-rolls three intermediate work-rolls of less diameter, one or more of the intermediate rolls being driven by belting from the main rolls, so as to obtain uniform circumferential speed of the rolls; third, in an arrangement of the belting and a series of fixed and movable pulleys, over which the belting passes, whereby the belting will be kept tight, and will press the intermediate rolls against the circumference of the next outer roll, and the use of counter-weights to take up the slack of the belting is avoided; fourth, applying the belting around the whole circumference of pulley of intermediate roll, whereby the movement of the pulley is made to take up the slack of the belting, and an increased contact between pulley and driving-belt is obtained; fifth, in the combination of a feed-table and three or more rolls, adjustable in relation to one another and to the table by means of hydraulic power for regulating the pass; sixth, in combining, with an adjustable roll, a hydraulic piston and cylinder, and a series of pipes for admitting fluid to both sides of the piston, so that the roll may be raised or lowered and held stationary by hydraulic power; seventh, in combining, with the outer roll of a series, one or more trusses secured to or traveling with the roll, so as to support and brace the roll at all times; eighth, in combining a check-valve with the line of pipes leading to that side of the pistons against which the pressure is coming at the time of rolling the bloom or pile, whereby the operating of a single valve for raising or lowering the piston operates the escape or waste in the opposite side of the piston-head; ninth, in combining, with the several pistons which operate the rolls, four pairs of inlet and outlet valves, all mounted in a common axial line, each pair secured to a common shaft and independent of the others, the outlet-valves of each two pairs communicating with a common outlet-pipe, and the inlet-valves of the two intermediate pairs communicating with a common inlet-pipe, whereby a single workman can operate the entire series of valves and raise and lower the rolls.

I will now proceed to describe my invention, so that others skilled in the art may apply the same.

The invention is illustrated upon a series of five high rolls; but the essential condition of the first combination is an independently-adjustable intermediate roll and outer rolls, one outer roll or one set of said outer rolls being likewise adjustable.

In the drawing, A′ B¹ represent fixed tables, such as are commonly employed with this class of devices. *a* represents the top roll, journaled in the boxes or riders *g*, said boxes preferably formed with upper and lower sections, which may be separated by liners, that can be changed to take up the wear of the rolls. The lower sections of boxes or riders *g* are slotted or recessed to receive the neck of intermediate roll *b*, which is held in position up against the outer roll by straps *f*, the ends of which pass through lugs upon the upper section of the boxes, whereby any wear of the journals or rolls may be readily corrected. The boxes *g* are secured to stems *h* of pistons *i*, which work in cylinders m^1, secured to or formed by the cross-pieces *n* of the housings. C is the independent movable intermediate roll, journaled in boxes or riders *p*, which boxes may be made in sections, as above specified, and are secured to pistons *r r*. Instead of the pistons and cylinders specified, the intermediate movable roll may be operated by counter-balances from below acting on the rider, if preferred. *d* and *e* are the lower intermediate and outer rolls, provided with the boxes or riders *q* and pistons and rods *h'* i^1, corresponding in detail with the upper pairs of rolls, excepting that the slings or straps *f* are omitted, as not necessary from the position of roll *d*, the upper section of boxes *q* being slotted for the necks of the intermediate roll, which rests upon the outer roll *e*.

The rolls are mounted in suitable housings, which slide upon the bed plate, as shown in Letters Patent No. 153,239; and where very long rolls are employed, (though not confined to that number,) yet I prefer to construct the housings of six separate pieces, as shown in the drawing—four jamb pieces, *o o o' o'*, and two cross-pieces, one at the top, *n*, and another at the bottom, n^1—the several parts being cast and planed, the jambs *o o o' o'* with lugs and recesses as seen at *o o'*, Fig. 1, whereby the bolts and rods which secure the parts are in a great degree relieved from undue strain. By this means large housings can be readily cast and built up, the cross-pieces *n* n^1 being tied by long wrought-iron or steel rods applied close to the line of strain where they are needed, and the jambs and cross-pieces may be further strengthened and secured by wrought-iron or steel rods, bolts, &c.

For raising, lowering, and adjusting the rolls, I provide the housings, either by bolting to the cross-pieces or by boring out the latter itself, with cylinders, provided with the usual pistons *i* i^1 *r*, (the piston *r* being a simple rod, the end thereof answering as a piston-head,) the rods of which are secured firmly to the boxes or riders of the several rolls.

Water, steam, or other fluid may be admitted to the cylinders *m* on both sides of the piston *i* by means of pipes *l k*, and to the under sides of the pistons i^1 *r* by means of the pipes *l' k'*, the flow of the fluid and its direction in the pipes being governed by a series of valves (clearly shown in Fig. 4) compactly arranged in a common axis, and by valves on the respective pipes.

It will be seen by reference to Figs. 4 and 14 that there are three pipes, D, K, and N, leading from the accumulator, and communicating through the valve-box with the pipes *l k l' k'*, and two waste-pipes, E and L, which likewise communicate with pipes *l k l' k'*, all of which are controlled by valves *z*, z^5, H, and J, part of said valves operated by the hollow stems *x* x^1, and part by solid stems F F'. The pipes *l* and *k* are connected by a double check-valve, *w*, and branch pipe M, arranged on the pipes at a point near the inlet-valves, by which means the admission of water to the under side of the upper piston causes an equal amount to be displaced above.

It will now be proper to describe the manner of operating the rolls by means of the devices already described, special reference therefor being made to Figs. 1, 2, and 4. Fig. 1 shows the position of the rolls for pass going from A to B through between intermediate rolls *b* and *c*, at which time valves *s*, *t*, and *u*, Fig. 1, are shut, as is also upper valve *v* of double check-valve *w*, Figs. 1 and 5. At the moment the pass is complete from A to B, an attendant turns hollow stem *x*, Fig. 4, inward by revolving hand-wheel *y*, which is fastened to *x*, thereby operating the two valves *z* and z^1, which are cast in one piece with the hollow stem *y*, closing z^1 and opening *z*, as seen in Fig. 4, thereby shutting off communication with waste-pipe E, and opening communication with pipe D, leading from the accumulator. Valve *s* is then opened, Fig. 1, which admits the fluid to the under side of piston i^1, and forces up rider *g* of the lower rolls. When the lower rolls *d e* have arrived at the position shown in Fig. 2, which can be determined by proper graduations or marks on the housings or other place off the rolls, the attendant shuts valve *s*, confining the fluid between *s* and piston i^1, and the rolls *d* and *e* will be in permanent position, resting on the fluid. This accomplished, the attendant turns solid valve-stem F (which passes through hollow stem *x*) outward by means of crank G, secured to the outer end of F, thereby operating valves H and J, closing H, and cutting off communication with waste-pipe E and opening J, establishing communication by means of pipe K between the accumulator and pipe *l'*, which leads to the under side of pistons *r*. Valve *t* is then opened, admitting the fluid through *l'*, Fig. 1, to the under side of pistons *r*, lifting rider *p* and intermediate roll *c*, until the lowest point of the circumference of *c* is as much above the upper surface of roll *d* as the desired reduction for the next pass amounts to, which point may also be determined by the marks or graduations above referred to. The valves *t* and J are then closed. The upper rolls have been previously lifted by turning outward solid valve-stem F', with its valves z^2 and z^3, closing waste-pipe L, and opening communication, by means of pipe K, between the accumulator and the under side of piston *i*, the valve *u* also being opened, and the valves z^4 and z^5 operated by hollow stem x^1, so as to open waste-pipe L and close pipe N, leading to the accumulator. The fluid passing through pipe *k* enters branch pipe M, and forces up double check-valve *v*, allowing the fluid above piston *i* to escape through pipes *l*

M^1 and waste-pipe L in the same ratio as fluid enters below the piston. As soon as box or rider *g* has reached its proper place valve *u* is closed, and the several rolls occupy the position shown in Fig. 2, which is the position they occupy on the second or return pass from B to A, the bloom now passing between the rolls *c d*. The pass from B to A having been accomplished, intermediate roll *c* is lowered down on roll *d*, and the exit-valves of pipes *l'* and *k'* are opened to allow the escape of fluid from beneath pistons *r' r* and i^1, as the rolls sink by their own weight, until the top of roll *c* is again on the level of table C, when the exit-valves of pipes *l'* and *k'* are closed. Simultaneously the exit-valve of pipe *k*, leading to the under side of piston *i*, is opened, allowing the rolls *a b* to descend the required distance, when the valve of pipe *k* is closed, and fluid admitted by pipe *l* to the cylinder above piston *i*, the exit of *l* closed, and the rolls are again in the position shown in Fig. 1, ready for the pass from A to B.

I will now proceed to describe the manner of driving the different rolls, referring more especially to Figs. 6, 7, and 8, as illustrating the arrangement of the belting whereby the tension is preserved, while at the same time the adjustability of the rolls is not interfered with, and this without the use of counter-weights for taking up slack. S, Fig. 3, is a pinion coupled to the fly-wheel shaft, gearing into pinion T, coupled to bottom roll *e* by breaking-spindle U, thus driving the lower outer roll *e* direct. It is evident that the intermediate rolls may, if preferred, be driven direct by this or similar gearing, as illustrated in Fig. 3, where T^3 and U^7 gear with roll *c*. On the end of roll *e*, Fig. 6, is pulley V, driving by a belt pulleys V^1 V^2 V^3 V^4, V^4 being on the neck of lower intermediate roll *d*, V^5, V^6, and V^7 back to V, thus driving shafts W, W^1, W^2, and W^3 below and above on the housings, as intermediate roll *d*. Of this combination, four of the pulleys, V^1, V^2, V^6, and V^7, are stationary, while the pulleys V and V^4 move with the rolls, as do also the pulleys V^3 and V^5, which are secured to the box or rider of rolls *d* and *e*, and it will thus be seen that any slack arising from the movement of the rolls in one direction must be taken up by the increase in the distance between the fixed and movable points on the opposite side. On shafts W W^3, Figs. 1, 3, and 7, are pulleys x^1 x^5, connected by belting with pulleys x^2 x^4 on shafts W^1 W^2, x^7 x^9 on rolls *a b*, and x^6 and x^8 loose on shafts *y* y^2. Thus the power from the lower driven roll *e* is communicated, by the belting which drives roll *d*, to the shafts W W^3, and thence transmitted, through pulleys x^1 x^5, to upper rolls *a b*. This second series of pulleys and belting are identical in arrangement and operation with that before described. The independently-adjustable intermediate roll *c* is driven as follows: On the lower shaft W, Fig. 8, is a pulley, z^0, connecting by belting with pulley z^1, loose on pin y^2; z^2, on neck of intermediate roll *c*; z^3, loose on pin y^3, z^4 on W^3; back over z^2 again, and thence to z^0, so that the belting is applied around the whole circumference of pulley z^2, whereby increased contact between belt and pulley is obtained. Here, as in the previous cases, the relation of fixed and movable pulleys is preserved, and it is obvious that whatever belting is loosened by the upward or downward movement of the rolls is immediately taken up on the side of the rolls opposite to the direction of travel.

For the purpose of tightening the belts, the lower shafts W and W^3 are hung in movable bearings, and operated by screws U^1, miter-wheels *e'*, shafts p^1, worm-wheels n^2, worms M^2, and hand-wheels M^3, so that the weight of the lower shafts and pulleys assists in tightening the belts, while by this method of driving the outer intermediate rolls are always kept tight against the circumference of the large rolls next adjoining.

As one of the main objects of the present invention is to use rolls of greater lengths than have heretofore been employed, and as, while it is practicable to obtain the small intermediate rolls of the required length, it is not at present everywhere practicable to obtain the larger or outer rolls of sufficient length, I shall now describe sectional rolls *a* and *e*, the construction of which is shown in dotted lines, Fig. 3, and enlarged in Figs. 12 and 13 of the drawing, and which I propose to use with the intermediate rolls. Said rolls are built up of two or more independent parts, and then properly secured together—as, for instance, as illustrated in lower roll *e*, Figs. 3 and 12, where B^4 is a central shaft formed in one piece, and provided with three shoulders, B^1 B^2 B^3, turned thereon, and having three separate rings, M^3 M^4 M^5, shrunk on shaft B^4, whose shoulders also act additionally to prevent the rings from moving laterally. In the upper roll *a*, Figs. 3 and 13, the three separate pieces U^2 U^3 U^4 are fitted together by boring or casting the inner ends of U^3 and U^4 to match projections U^2, formed on the middle section U^2, the sections being secured together by threads on u^2, or by central rods or shafts U^5, extending the whole length of the parts.

For either of the rolls *a e* described, a roll made of longitudinal staves, bolted to a central shaft and confined by shrinking bands thereon, may be substituted.

In order that the diameter of central shafts of sectional outer rolls may be reduced, said shaft may be driven from both sides, as shown (Fig. 3) in the case of central intermediate roll *c*, when, of course, each half length of the shaft transmits but half of the power, and can, therefore, be made of $\sqrt[3]{\frac{1}{2}}\times$ the full diameter of shaft required when the roll is driven from one side only; therefore, if in the latter case the shaft is seventeen inches, then in the former it would be $17 \times \sqrt[3]{\frac{1}{2}} = 17 \times \frac{100}{125} = 13.6$, or, say, a shaft of fourteen inches diameter, which will resist all the torsional strain going through this shaft or roll. The several parts of the sectional rolls may be made of cast-iron, wrought-iron, or steel, to suit circumstances. The same may be said of the intermediate or small rolls *b c d*, though these latter are preferably made in one piece, of cast-iron if short, or wrought-iron and steel if long, the latter metals being less liable to break, and offering greater resistance to torsional strain than cast-iron.

The trusses employed with the outer rolls, and which will be hereinafter described, should support the sectional outer rolls at the junction of the sections.

In order to show the advantages to be gained from my five-high mill, Figs. 9, 10, and 11 have been added to the drawings, in which Fig. 9 shows the ordinary two-high mill; Fig. 10, a three-high mill, having a small intermediate roll; and Fig. 11, my five-high mill, in which the small intermediate rolls are placed between larger rolls above and below. In all the figures pile 2 is shown of the same size and reduction given, and is also the same for every arrangement of rolls.

The surface of contact between pile and rolls (all the large and all the small rolls considered to be of like diameters, respectively) divided into a certain number—say, for instance, seven equal divisions—and admitting these divisions to represent inches, there are as follows: In Fig. 9, seven inches of contact of upper roll; in Fig. 9, seven inches of contact of lower roll; total, fourteen inches of contact on both sides. In Fig. 10, seven inches of contact between pile and outer roll; in Fig. 10, six inches of contact between pile and intermediate roll; total, thirteen inches of contact on both rolls. In Fig. 11, six inches of contact between pile and central roll; in Fig. 11, six inches of contact between pile and upper intermediate roll; total, twelve inches of contact between both rolls.

Now, suppose all rolls to be of equal lengths, say nine feet, and sheets of same width being rolled, as it takes five thousand pounds pressure per square inch to roll metal, we have, Fig. 9, $108 \times 7 \times \frac{5000}{2} + 108 \times 7 \times 2{,}500 = 2{,}500\ (2 \times 108 \times 7)\ 3{,}780{,}000$; Fig. 10, $108 \times 7 \times \frac{5000}{2} + 108 \times 6 \times 2{,}500 = 2{,}500 \times 108\ (7 \times 6)\ 3{,}510{,}000$; Fig. 11, $108 \times 6 \times 2{,}500 + 108 \times 6 \times 2{,}500 = 2{,}500 \times 108\ (2 \times 6)\ 3{,}240{,}000$; that is to say, we require 3,780,000 pounds pressure at the circumference of rolls in Fig. 9; 3,510,000 pounds pressure at circumference of rolls in Fig. 10; and 3,240,000 pounds pressure in Fig. 11, clearly showing that fifteen per cent. less power is required in my five-high mill than in the ordinary two high mills, and eight per cent. less power than in three-high rolls with small intermediate rolls, even supposing that all three of my intermediate rolls should be of like diameters with those in Fig. 10. But, owing to the mode of attaching the two outer intermediate rolls, *b* and *d*, to the large rolls *a* and *e*, I need not make them as large as in Fig. 10, and therefore gain additionally in power, or else, on applying the same amount of power, can use a roll so much longer. Where, for instance, a roll nine feet long be the limit in Figs. 9 and 10, my arrangement will permit me to use rolls of same diameters, ten feet long; but, as I never have less than two rolls below or above the pile or bloom while rolling it, the strength of these rolls must be considered from a different standpoint.

In Fig. 10 there is always on one side, either top or bottom, of the pile a single roll which has to take up the strain; consequently the ordinary three-high mill is no better than the two-high mill, as regards capacity of the rolls to resist breaking-strain.

Rolls are to be considered as beams of equal strength in all directions; and as, in ordinary beams, the greater the load for a certain span the higher must be the beam or beams, so in the case of rolls (or rotating beams) the greater their length the greater must be their height, (respective diameters;) but in the latter, as well as in the former, the same laws exist—first, the capacity of beams carrying a load uniformly distributed over the whole span increases to the square of its height; and, secondly, the capacity of beams to carry a load uniformly distributed over the whole span decreases in inverse ratio to such span. Or, in other words, a beam of double the height carries four times as much, and a beam of a given height will carry but half the load if the span is doubled.

Applying these rules to rolls, there is to be considered that the power these rolls have to resist increases in the same proportion as the width of sheets or plates to be rolled, so that a sheet ten feet wide absorbs twice as much power as one of but five feet width.

Now, suppose the outer rolls to be thirty-two inches in diameter, and the three intermediate rolls sixteen inches each, as before stated, without considering the resistance of the outer intermediate rolls, the rolls may be made ten feet long, where others use rolls nine feet in length; but as these outer intermediate rolls always bear tight against their next adjoining larger rolls, the strength of the latter is increased by the square of the thus enlarged height—*i. e.*, 32-inch beam + 16-inch beam $= 1\frac{1}{2} - 1.5^2 = 2\frac{1}{4}$.

Thus I have the ability of increasing the length of my rolls $\frac{1.25}{2} = 1\frac{5}{8}$, after making one-half deductions for the increased strain on rolls by increased width of sheet to be rolled. Therefore $10 \times 1.62 = 16$-feet-long roll, admissible; and by trussing said rolls, either by simple trusses R, as shown on lower roll, Fig. 3, or else by hydraulic pressure, I can readily increase the length of my rolls, so as to make plates for pipes, boilers, beams, tanks, &c., all in one piece, which can then either be bent and riveted on one longitudinal line only, or else bent and welded, finishing, for example, a boiler, &c., with no riveting whatsoever, except for putting on the heads.

It is now necessary to specify briefly the manner of applying the trusses to the large rolls.

Upon the lower roll *e*, Figs. 2 and 3, the simple form of truss is employed, secured to the roll, or some object traveling with the roll—as, for instance, the riders—while in the upper roll the truss is connected with pistons, which follow the roll. I provide for the upper roll a cap or clutches, D^3, having friction-rollers d^3 bearing against the face of the roll, said caps or clutches being secured to piston-rods D^5, which terminate in pistons i^2 i^3, working in cylinders secured to the upper cross-piece of the housings. The different pipe-lines *k* and *l* are continued to connect with the cylinders both above and below the pistons i^2 i^3, as in the case of the cylinders i i^1 of the housings proper, and the pistons i^2 i^3 are operated in the manner specified for i^1 i^2. For the lower roll, bed-pieces D^4, having friction-rollers d^4 bearing against the face of the lower roll, are provided, and these bed-pieces may be operated by extending pipes l' and k' to cylinders secured to the bed, or by other suitable devices; but however operated, sufficient provision should be made, by bracing the bed-piece or its rod D^6, to prevent lateral displacement.

Where the metal to be rolled is not so heavy but that it can be readily handled and lifted, I make either rolls *d e* with stationary riders, or make roll *c* permanent. In the former case roll *c* moves up and down, as do also rolls *a b*. In the latter instance *a b* and *d e* move in pairs to and from central roll *c*, so that if, for example, the bar should go through between rolls *b* and *c*, then rolls *d* and *e* must rest tight against the circumference of *c* to prevent it from breaking; and if the bar is passing between rolls *c* and *d*, then rolls *a b* must rest tight against the circumference of *c*, and this for the reason that roll *c* is made only sufficiently strong in diameter to resist the torsional strain to which it is exposed while work is being done.

In cases where but two intermediate rolls are employed one pass will be between both intermediate rolls, while the return pass occurs between one of the intermediate rolls and its next adjoining outer roll or rolls; and in such an arrangement of rolls, as well as in two-high rolls, where a single roll is subjected to great strain, the rolls may be trussed with good effect. Where only two intermediate rolls are employed the rolls *b* and *d* may be driven direct by suitable belting or gearing.

The mechanism herein specified may be varied to suit circumstances of existing machinery and to utilize the same. Properly-proportioned gearing may be applied to obtain equal circumferential speed of outer and intermediate rolls. Keys, screws, or steam pressure may be employed for bracing the rolls; all of which is within the present knowledge of the skilled mechanic, and may be done without departing from the spirit of my invention.

Among the many advantages of my arrangement of rolls may be cited one incident to two-high reversing-rolls, *i. e.*, avoiding the necessity of lifting the piece to be rolled, and another incident to three-high rolls, viz., working both ways without reversing the direction of the rolls, both of said advantages being derived from such means as are always required for regulating the distance between rolls for each succeeding pass of the pile or bloom, or for keeping the rolls at such predetermined distance while the bar is passing through the rolls.

By making very long rolls in sections and putting them together or building them up, as shown on roll *a*, Fig. 13, I am enabled to remove or take out the middle section, inserting a short idler in place thereof, and to move up the housings, so as to reduce the size of the mill at such times as the largest size plates are not being rolled, thus avoiding the necessity of investing capital in extra rolls of different length.

I am aware that three intermediate work-rolls have been used in combination with outer brace-rolls, one of the intermediate rolls being of greater diameter than the other two, and this I do not claim.

Having thus described my invention, what I claim, and desire to secure by Letters Patent, is—

1. In mills for rolling metals, the combination of three small work-rolls, *b*, *c*, and *d*, with one large roll, to the outside of and in line with each of the outer intermediate rolls *b d*, the central roll *c* being of equal or less diameter than its next adjoining ones *b d*, substantially as and for the purpose specified.

2. In combination with the outer brace-rolls, three intermediate work-rolls of less diameter, one or more of the intermediate rolls being driven by belting, substantially as and for the purpose specified.

3. In combination with two rolls which move together, and the belting for driving the same, four or more fixed pulleys, and two or more pulleys moving with the rolls, substantially as and for the purpose specified.

4. In combination with a pulley secured to the shaft of a driven roll, four or more fixed pulleys and the belt for driving the roll, the belt being applied to the entire circumference of the pulley of the driven roll, substantially as and for the purpose specified.

5. The combination of the adjustable rolls *b*, *c*, and *d*, having suitable riders, with pistons working in cylinders formed in or secured to the housings, for raising and lowering the rolls, substantially as specified.

6. The combination of a fixed feed-table and three or more rolls, adjustable in relation to one another and to the table, substantially as and for the purpose specified.

7. In combination with an adjustable roll,

a hydraulic piston and cylinder, and a series of pipes for admitting fluid to both sides of the piston, so that the roll may be raised and lowered and held stationary by hydraulic power, substantially as and for the purpose specified.

8. In combination with the outer rolls *a e*, the supports D^3 D^4, operated by pistons working in cylinders, substantially as specified.

9. In combination with the fixed table, three or more rolls, *b c d*, and the mechanism for raising and lowering the rolls, substantially as and for the purpose specified.

10. The combination, substantially as herein described, with the several pistons, of four pairs of inlet and outlet valves, all mounted in a common axial line, each pair secured to a common shaft, and independent of the others, the outlet-valves of each two pairs communicating with a common outlet-pipe, and the inlet-valves of the two intermediate pairs communicating with a common inlet-pipe.

11. The check-valve *w*, in combination with a double line of pipes, one of said pipes leading to the side of the piston against which the pressure in rolling is exerted, substantially as and for the purpose specified.

In testimony whereof I, the said IGNATIUS HAHN, have hereunto set my hand.

IGNATIUS HAHN.

Witnesses:

F. W. RITTER, Jr.,

T. B. KERR.