

July 1, 1952

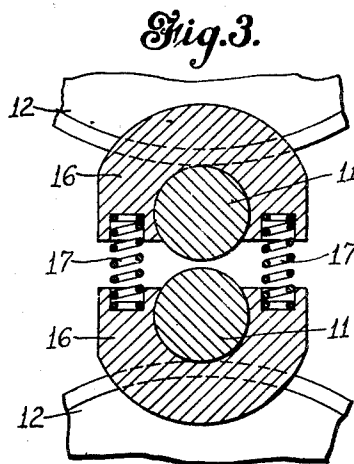
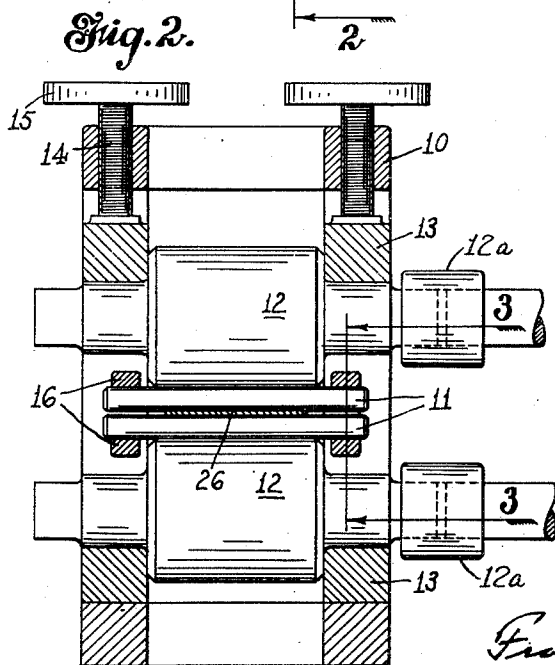
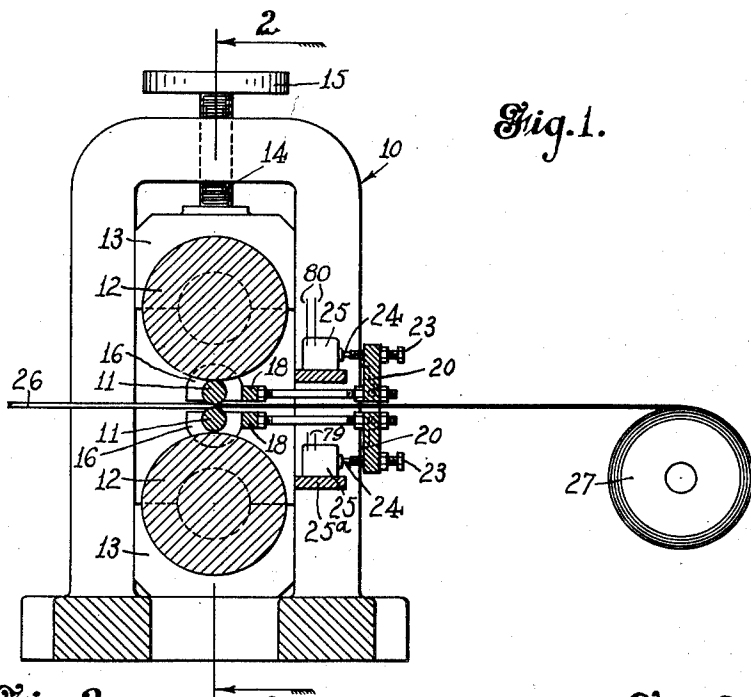
F. P. DAHLSTROM

2,601,792

APPARATUS FOR ROLLING STRIP MATERIAL

Filed July 27, 1946

5 Sheets-Sheet 1



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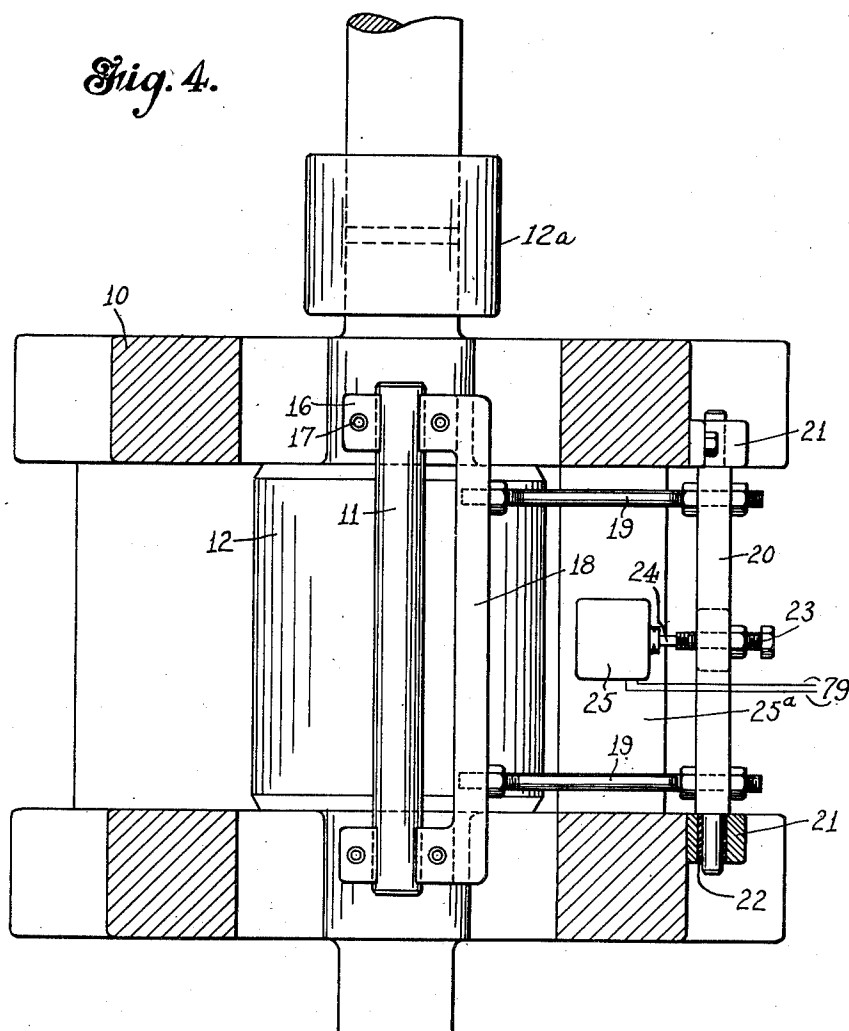
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APPARATUS FOR ROLLING STRIP MATERIAL

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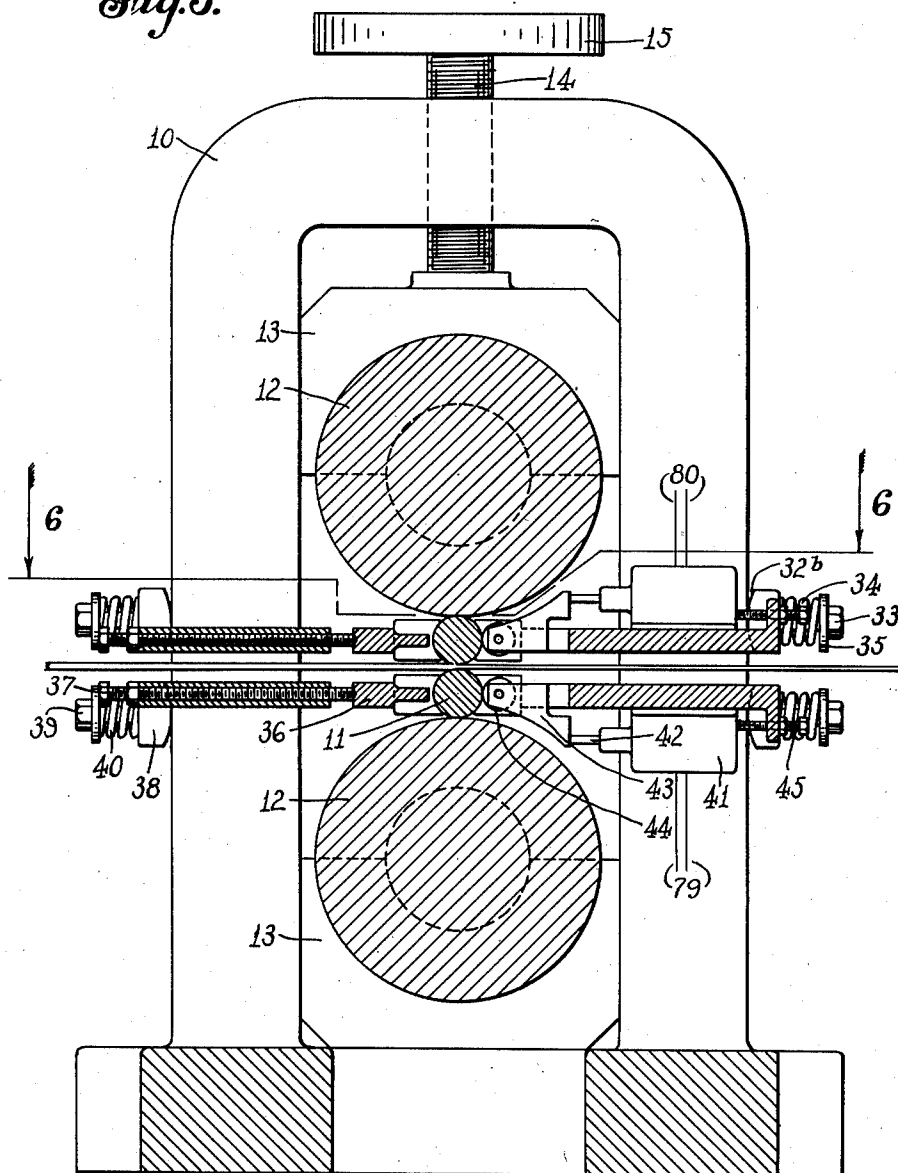
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Fig. 5.



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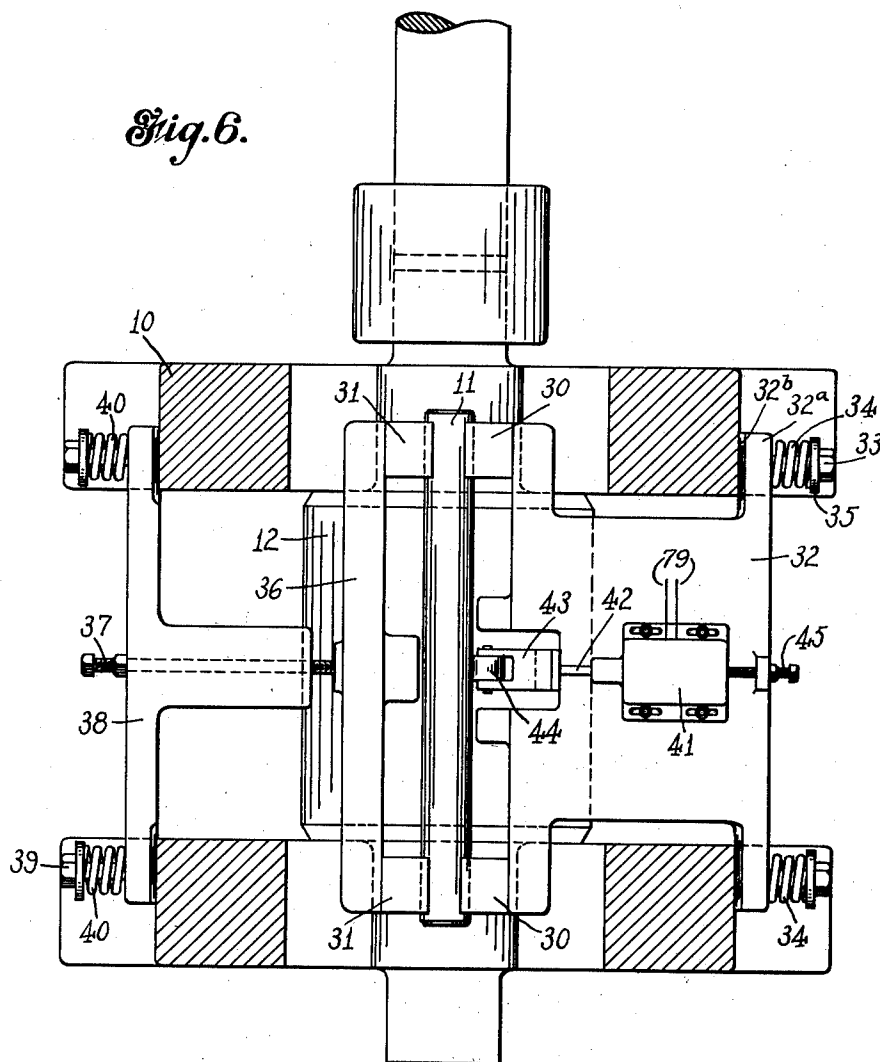
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Fig. 6.



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Fig. 7.

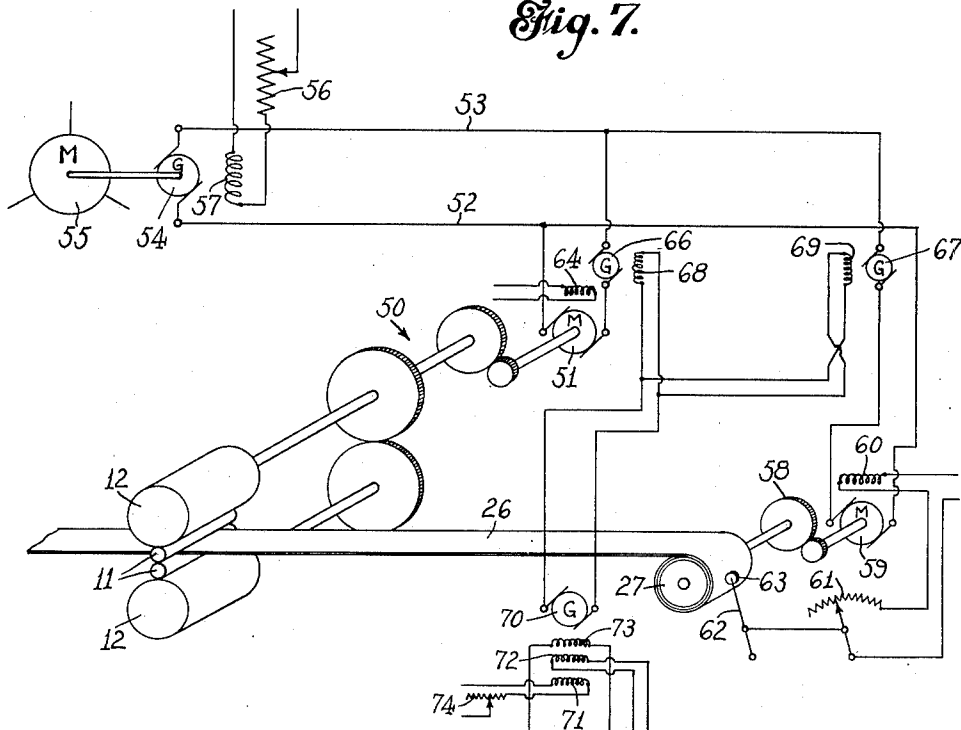
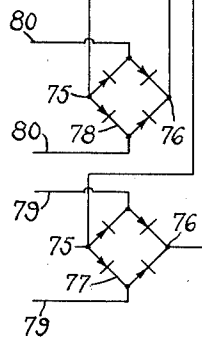
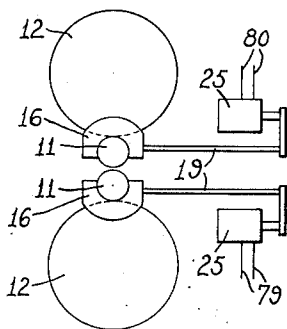


Fig. 8.



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APPARATUS FOR ROLLING STRIP MATERIAL

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Application July 27, 1946, Serial No. 686,746

4 Claims. (Cl. 80—35)

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This invention relates generally to metal rolling, and more particularly to apparatus for the cold rolling of metal into thin strip or sheet form.

It is an accepted fact that the problem of cold rolling sheet materials to thin gauges, with small errors in gauge, can best be solved by the use of small-diameter rolls. However, owing to the fact that small-diameter rolls are too weak to withstand the heavy rolling pressures required to make practical reductions in thickness, it has been necessary to employ so-called back-up rolls to support the work rolls.

The most obvious and widely used arrangement of this kind has been the so-called four-high mill, in which each work roll is supported by a single back-up roll, the axes of the four rolls being generally disposed parallel to each other and in substantially the same vertical plane. The back-up rolls are supported in large bearings which can carry a relatively great rolling pressure. Usually with such a construction, the work rolls have been connected or coupled to the driving motor of the mill, which requires the necks of the rolls to be sufficiently large to transmit the required torque without breaking. This driving arrangement operates as a definite limitation on the minimum size of the work rolls, and, in practice, the diameters of the work rolls must be from one-third to two-fifths of the diameter of the back-up rolls, and thus the use of smaller work rolls is prohibited in such an arrangement.

This limitation on the use of small diameter work rolls has been overcome in some cases by applying some or all of the power required for rolling in the form of a strong tension on the strip, so that the strip is pulled through the work rolls by power applied to the reel upon which the rolled strip is wound. In such an arrangement it is obvious that strong forces, tending to displace or deflect the work rolls laterally, in the direction of the strip's movement through the pass, are set up, and must be counteracted in order to insure uniformity of the gauge or thickness of the material being rolled.

It is also recognized that the limitation on the use of small size work rolls can be overcome by connecting the driving motor to the back-up rolls, in which case the work rolls, frictionally driven, are relieved of torque-transmitting duties. In such an arrangement, the direction of rotation of the power-driven back-up rolls is such as to create forces that tend to displace or deflect the work rolls laterally, in a direction opposite to the strip's movement through the pass, such forces, unless counteracted, being detrimental to

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maintenance of uniformity in the gauge or thickness of the material being rolled.

Since the lateral forces tending to displace or deflect the work rolls, in the two cases above considered, work in opposite directions, it is obviously of advantage, in the operation of a 4-high mill, to supply the mill's power requirements in part by tensioning of the strip and in part by drive of the back-up rolls, as disclosed for example in Klein and Rieger Patent No. 2,287,380, dated June 23, 1942. But with such an arrangement, it is not possible to achieve uniformity of gauge or thickness of the rolled product when, as frequently occurs, the lateral displacing or deflecting forces in one direction gain an appreciable ascendancy over the lateral displacing or deflecting forces in the opposite direction, this being a condition which practically nullifies the thickness adjustment of the reducing pass between the two small diameter working rolls.

Accordingly, the primary object of the present invention is to make provision, in 4-high strip rolling apparatus whose power requirements are supplied in part by tensioning of the strip and in part by drive of the back-up rolls, for the maintenance of a substantial balance between the aforesaid lateral forces that operate in opposite directions on the work rolls, whereby excessive displacement or deflection of the work rolls will be prevented and work rolls of relatively small size may be employed.

To these and other ends the invention consists in the novel features and combinations of parts to be hereinafter described and claimed.

In the accompanying drawings:

Fig. 1 is a sectional view of a 4-high rolling mill constructed in accordance with my invention;

Fig. 2 is a transverse sectional view on line 2—2 of Fig. 1;

Fig. 3 is an enlarged sectional view through the reducing pass;

Fig. 4 is a horizontal sectional view taken between the work rolls and looking downwardly;

Fig. 5 is an enlarged view similar to Fig. 1 and showing a slightly modified form of my invention;

Fig. 6 is a sectional view on line 6—6 of Fig. 5;

Fig. 7 is a diagrammatic view showing the arrangement for controlling the supply of power to the winding reel and the back-up rolls; and

Fig. 8 is a diagrammatic view showing the relation between the power-control circuit of Fig. 7 and the displacement or deflection of the work rolls.

To illustrate one embodiment of my invention,

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I have shown in Fig. 1 of the drawings a roll housing 10 of more or less conventional form, having mounted therein a pair of work rolls 11 supported by back-up rolls 12, as is the usual arrangement in a four-high mill. The back-up rolls are supported in bearings or journals 13, and the upper journal may be adjusted by means of a conventional adjusting screw 14 operated by the hand wheel 15, so that the size or thickness of the reducing pass between the working rolls may be varied, as desired. The drive for this 4-high stand of rolls is obtained by imparting rotation to the back-up rolls 12, as shown in Fig. 7, and as also indicated by the couplings 12^a, Figs. 2, 4 and 6, on the necks of said back-up rolls 12.

The work rolls 11 are supported in bearing chocks 16, which extend only part way around each roll, so that the work rolls can be set close together. As shown in Fig. 2, the chocks 16 are provided at each end of each of the work rolls. As shown in Fig. 3, separator springs 17 are employed between the chocks at each side of the housing to force the work rolls apart and against the upper and lower back-up rolls, and thus maintain the work rolls in open position to permit the insertion of the strip therebetween. It may also be noted that the axes of the work rolls are normally in the same plane as the axes of the back-up rolls so that the four rolls are in substantial vertical alignment.

As shown in Fig. 4, the bearing chock at one end of each of the work rolls is connected to that at the other end by a substantially rigid bar 18, and the chocks are held in position by means of thrust rods 19 connected with the bar 18 at their inner ends, and secured at their outer ends to a transverse bar 20. The connections of the rods 19 with the bars 18 and 20 are preferably adjustable, as shown, in order to initially adjust the work rolls so that their axes will be in the same vertical plane as the axes of the back-up rolls.

The ends of the bar 20 are preferably round, thereby allowing vertical swinging of the work rolls about these ends in response to vertical adjustment of the back-up rolls. The round ends extend through bearing blocks 21 secured to the respective sides of the housing 10. These bearing blocks are provided with resilient bushings 22 in which the ends of the bar 20 are mounted, these bushings permitting a certain very limited amount of lateral movement of the work rolls, such limited movement, however, being less than that which would seriously interfere with the uniformity of gauge of the strip.

At an intermediate part of the bar 20 is an adjustable contact screw 23 adapted to make contact with a push rod or plunger 24 of an electric gauge unit, shown conventionally at 25, the gauge unit being mounted upon a support 25^a secured to the housing uprights or sides. In Fig. 1 the strip undergoing reduction is indicated at 26 as moving toward the right between the work rolls 11, said strip being drawn from a supply reel, not shown, and being wound up on a suitable take-up reel 27, driven as hereinafter described. Any slight lateral movements of work rolls 11 permitted by the resilient bushings 22, whether to the right from the pull or tension of the strip, or to the left from the tangential thrust of the back-up rolls, will be transmitted to the bar 20, to cause corresponding movements of the screw 23, which movements will be followed by the plunger 24. It will be understood

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that this plunger will be spring pressed in an outward direction, or toward the right, as shown in Fig. 4, so as to follow movements of the screw 23 in that direction. The gauge unit 25 may be of any of the commercial forms of electric gauges employed for sensitive measurements, one form being shown in the Hathaway Patent No. 2,240,184, April 29, 1941, the plunger or spindle 14 of such patent corresponding to the part 24 of the present application.

The action of electric gauge 25 in the operation of my invention will be presently set forth, following the description of a modification of the above-described apparatus of Figs. 1 to 4 inclusive. In this modification, shown by Figs. 5 and 6, the roll housing 10 is provided with work rolls 11, driven back-up rolls 12, roll bearings 13, and adjusting screw and hand wheel 14 and 15, as before.

In this form of my invention, however, the ends of the work rolls are prevented from moving laterally by means of half bearings 30 on one side and 31 on the other side. The bearings 30 are connected to plates 32 having extensions 32^a which are secured to the roll housing posts by bolts 33. Strong springs 34 may be positioned between the plates 32 and washers 35 on the bolts 33, in order to permit relief of lateral pressures should the latter become sufficiently great to be dangerous. It will be understood, however, that the springs 34 will prevent movement of the plates 32 under any normal lateral pressure to which the work rolls will be subjected. The extensions 32^a are rounded slightly, as shown at 32^b, where they contact with the roll housing posts, which allow rocking movement sufficient to permit vertical movement of the work rolls in accord with screw down adjustment of the upper back-up roll.

At the other side of the work rolls the half bearings 31 are connected to a bar 36 against the rear edge of which bears an adjustable screw 37 secured in a T-shaped bar 38, the ends of which are connected to the housings by means of bolts 39 and strong springs 40 in a manner similar to the connection of the plate 32 with the housing. It will be understood that this will normally prevent any movement of the ends of the work roll to the left, as shown in Fig. 6, except under such excessive lateral pressures as would compress the springs 40.

It will be recalled that, in the form of my invention shown in Figs. 1 to 4, the movement of the work rolls to the right or left was measured by the gauge 25, and by means which will be hereinafter described, the power input to the back-up rolls or to the strip reel 27 is adjusted under control of this movement. In the form of my invention shown in Figs. 5 and 6, however, the ends of the work rolls are prevented from lateral movement, and the power input to the back-up rolls and the take-up reel for the strip is controlled by the deflection or bending of the intermediate portions of the work rolls.

For this purpose an electric gauge device 41 is mounted upon the plate 32, which gauge is similar to the gauge 25 previously referred to. Upon the end of the spring-pressed push rod or plunger 42 of the gauge is carried a bifurcated member 43 between the forks of which is rotatably mounted a roller 44 which bears against the central portion of the work roll. As shown in Fig. 5, one of these gauge devices, with the follower roller 44, is provided for each of the work rolls. This may not be necessary in all cases, but

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the result will be to give the average deflection of the two work rolls, as these values may not always be equal due to backlash in the gears, or other causes. The same is true of the gauges 25, for, although preferably two are provided, one for each of the work rolls, one may be sufficient in some installations. An adjusting screw 45, corresponding to the screw 23 of Figs. 1 and 4, is provided for initial setting of the gauge 41 and plunger 42.

In Figs. 7 and 8 of the drawings I have shown diagrammatically the method of driving the mill, and the means for controlling the drive by means of the lateral deflection or movement of the work rolls, which is the same for both forms of my invention. As shown in these figures, the back-up rolls 12 are driven by conventional gearing 50 from the armature 51 of a direct-current motor supplied with power from direct-current lines 52 and 53, these lines being in turn supplied from the armature 54 of a direct-current generator, driven in turn by a conventional constant-speed alternating-current motor 55. The voltage in the lines 52 and 53 may be varied at will or reduced to zero by an adjustable rheostat 56 which controls the strength of a shunt field 57 for the armature 54 of the direct-current generator.

The reel drum 27 is driven by gearing 58 from the armature 59 of a direct-current motor also connected to lines 52 and 53.

The armature 59 is energized by a separately excited shunt field 60, the strength of which may be varied by a rheostat 61, this rheostat being operated by a lever 62 having thereon a roll 63 which contacts with the outer coil of the strip on the reel drum 27. It will be understood that at the beginning of a rolling operation the outside diameter of the coil upon the drum 27 is a minimum, and the rheostat arm 62 will stand toward the left, as shown in Fig. 7, thus putting a maximum of resistance in series with the field winding 60, so that the armature 59 of the motor will run at a maximum speed but at reduced torque. As the coil increases in diameter, the rheostat arm is shifted to the right, thus strengthening the field 60, thus causing the winding motor to run at a reduced speed and increased torque so as to keep the tension on the strip substantially constant. This regulation of the speed of the winding drum driving motor according to the diameter of the coil of strip is conventional, and of itself forms no part of the present invention.

The armature 51 of the mill motor is energized from a separately excited shunt field 64, so that by varying the strength of the current in this field the speed of armature 51 may be adjusted initially.

Since the driving motor armature 51 of the mill rolls and the driving motor armature 59 of the reel drum are both connected to the lines 52 and 53, the speed of both motors can be simultaneously varied as desired by means of the rheostat 56. For purposes of supplementary control, however, and in order to automatically vary the pull exerted by one motor relatively to the other according to the lateral movement or deflection of the work rolls, a booster generator armature 66 is connected in series with the mill motor armature 51, and a similar booster generator armature 67 is connected in series with the reel motor armature 59. The generator armature 66 is provided with an exciting field 68, and the generator armature 67 provided with an exciting field 69, which

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fields are connected to the armature 70 of a pilot generator in such a manner that, when a voltage of given polarity appears at the terminals of the armature 70 of the pilot generator, a voltage is generated in the generator armature 66, which adds to the voltage of lines 52 and 53 and increases the voltage applied to the motor armature 51 for driving the back-up rolls while simultaneously a voltage is generated in the generator armature 67, which subtracts from the voltage of lines 52 and 53 and decreases the voltage applied to motor armature 59 driving the reel drum.

When a voltage of opposite polarity appears at the terminals of the armature 70 of the pilot generator, the reverse condition results; that is, the voltage applied to the mill roll motor armature 51 is decreased, while the voltage applied to the reel drum motor armature 59 is increased.

The voltage of the armature 70 of the pilot generator, both as to magnitude and polarity, depends on the strength of the field windings of this generator, these windings being designated at 71, 72 and 73. The excitation field 71 is separately excited and is provided for a zero deflection adjustment, as will be hereinafter described, and the strength of the current therein may be manually adjusted by the rheostat 74.

The excitation fields 72 and 73 are connected respectively to the output terminals 75 and 76 of the rectifier bridges 77 and 78, the input terminals of which are connected respectively by wires 79 and 80 to the electric gauges 25, in the case of the apparatus of Figs. 1 to 4 inclusive and to the electric gauges 41 in the case of the apparatus of Figs. 5 and 6.

The current in the field winding 71 will be opposite to that in the windings 72 and 73, so that the latter will tend to reduce or overcome the strength of the current in the winding 71 and thus determine the magnitude and polarity of the voltage generated by the generator armature 70.

In beginning a rolling operation, the controlling system is adjusted by adjustment of the gauge positioning screws 23 or 45, as the case may be so that a voltage of about fifty percent of the full value appears at the terminals 75 and 76 of the rectifier bridges 77 and 78. This will excite the field windings 72 and 73, so that about one hundred percent of the full positive voltage will appear at the terminals of the armature 70 of the pilot generator. The rheostat 74 may now be adjusted until the current of opposite direction in the excitation field 71 cancels that in the fields 72 and 73, so that no voltage appears at the terminals of the generator armature 70. This is the adjustment desired when no lateral deflecting force is applied to the bearing chocks 16.

In operation, the strip is withdrawn from an unwinding or supply reel, not shown, and passed between the work rolls 11 and attached to the reel drum 27. The screws 14 are then adjusted so as to force the journal blocks 13 against the back-up rolls, which in turn applies pressure to the work rolls sufficient to reduce the thickness of strip to the desired amount.

The rheostat 56 is now adjusted so as to cause a low starting voltage to be generated in the armature 54. Under normal conditions, both back-up rolls 12 and reel drum 27 should now rotate at a slow speed. If the strip 26 between the mill and the take-up reel is slack, there can be no tension exerted and all of the work of reducing the gauge of the strip would be supplied

by the back-up rolls. This would result in a movement or deflection of the work rolls to the left, which would immediately cause the booster generator armature 66 to reduce the voltage applied to the mill roll motor armature 51, which would prevent any further deflection to the left. At the same time, the booster generator armature 67 will increase the voltage applied to the reel motor armature 59 and cause it to take up the slack in the strip in a shorter amount of time.

As soon as the slack is taken up in the strip, the tension on the strip will cancel any force tending to deflect the work rolls to the left, and so soon as this is done no voltage will be generated in either of the booster generator armatures 66 and 67. It follows in the continued operation of the apparatus that if the work rolls are displaced or deflected slightly to the left, this means that the tangential force exerted thereon by the back-up rolls is greater than the pull exerted on said work rolls by the strip tension. Such leftward displacement or deflection is immediately reflected in a corresponding movement of the gauge rod 24 or 42, as the case may be, to produce an increased current in the fields 72 and 73, and as these magnetic exciting fields 72 and 73 are now in excess of field 71, such excess causes a voltage to be generated in the pilot generator armature 70. The output voltage of generator 70 is now applied to booster generator 68, so that the voltage of generator armature 66 opposes the line voltage from the main generator 67, which reduces the voltage applied to mill motor armature 51. This reduces the tangential force exerted by the backing rolls on the work rolls, thereby halting any further displacement or deflection of said work rolls. Simultaneously, the voltage of armature 70 is applied to field 69 so that voltage of generator armature 67 is added to the line voltage from main generator 57, which increases the voltage applied to the reel motor armature 59. This increased voltage increases the pull of the strip, thus tending to move the work rolls to the right, and thereby return them to their original undeflected positions.

It will be appreciated that, particularly with the use of plain bearings upon the necks of the back-up rolls, it is necessary to overcome a considerable amount of starting friction. For example, with plain bearings on the back-up rolls, the starting friction would be from 10 to 30 times the running friction, and, therefore, it is necessary to apply a disproportionally large amount of torque to start the back-up rolls. If it is assumed that a low voltage is applied to lines 52 and 53 for starting purposes, and the effect of the roll neck friction is great enough to prevent the rotation of the back-up rolls because of the limited torque available with the low starting voltage, then the reel drum would soon take up the slack in strip 26 and a moderate value of strip tension would be applied to the work rolls, which would tend to deflect or move the latter to the right.

Movement of the chocks 16 toward the right would permit the plunger 24 to move toward the right, and through the electric gauge 25 would cause an increase of the output at terminals 75 and 76, thus increasing the strength of the field windings 72 and 73, so that they would exceed the strength of the field windings 71 and produce a positive voltage at the terminals of the pilot generator armature 70 which will serve to

increase the mill motor torque and simultaneously reduce the voltage applied to the reel motor armature 59 so as to either decrease the tension on the strip or prevent it from increasing.

If the increased mill motor torque is not then enough to overcome the bearing friction of the back-up rolls, the field 57 may be further strengthened which will further tend to increase the torque of both motors. If the mill does not then start, the increased torque of the reel drum will be held to a minimum value by further small deflection of the work roll chocks to the right and the torque of the mill motor still further increased because of the added booster voltage generated in the armature 66 of the booster motor.

Since the design is such that adequate booster voltage and resulting torque is obtained with safe working deflections or movement of the work rolls or chocks (about .010 inch) a value is very soon reached when sufficient torque is developed to overcome any static bearing friction.

At times, due to edge cracks, etc., there is a chance of the strip 26 tearing apart between the work rolls and the take-up reel. Under such conditions, the rolls would be instantly deflected to the left and, due to inertia, it might be impossible to stop the mill before the work rolls would break.

A provision for such an event is shown in Figs. 6 and 7 wherein the springs 34 and 40 would permit movement of the ends of the work rolls. The force of these springs is somewhat less than the maximum safe force to which the rolls can be subjected without breakage, but is greater than any working force necessary to deflect the rolls to a sufficient extent for full correction by the automatic gauge system described. These springs would, therefore, permit bodily movements of the rolls themselves under such conditions.

The compression of these springs allows the work rolls to move laterally to a sufficient extent so that the work rolls may follow the curvature of the back-up rolls and thus allow them to separate and be relieved from pressure upon the work as they do not then reduce the thickness of the strip. This allows the mill to decelerate to a quick stop without damage.

A nominal amount of back tension is usually applied to the supply reel in rolling practice, and the resulting added roll deflection or movement to the left will affect the booster generators, so that more front tension will be exerted by the winding reel motor and less torque will be exerted by the mill motor.

While I have shown and described some preferred embodiments of my invention, it will be understood that it is not to be limited to all of the details shown, but is capable of modification and variation within the spirit of the invention and within the scope of the claims.

What I claim is:

1. In apparatus for rolling strip material, a 4-high stand of rolls comprising a pair of small diameter work rolls providing the reducing pass, and a large diameter back-up roll for each work roll, driving means connected to said back-up rolls, for imparting rotation by friction to the work rolls, the latter being thereby subjected to lateral forces tending to displace or deflect them in a direction opposite to said material's movement through said reducing pass, a take-up reel for the rolled material, a second driving means connected to said reel, and adapted in operation to produce tension or pull on said material,

thereby subjecting said work rolls to lateral forces tending to displace or deflect them in the same direction as the material's movement through said reducing pass, a member movable in response to a work roll's displacement or deflection in one or the other of said directions, means differentially operated by the two directional movement of said member, and means connecting said last named means to each of said driving means for decreasing the driving power of that driving means whose ascendant lateral forces have produced such displacement or deflection, and for increasing the driving power of the other driving means, thereby to cause return of said work rolls to their normal or undeflected position, and to substantially balance the opposed lateral forces to which said work rolls are subjected.

2. Apparatus as claimed in claim 1, having, as the respective driving means for the back-up rolls and for the take-up reel, two electric motors, each adapted to have its armature voltages raised or lowered, as required, by an associated booster generator, the latter's fields being supplied by a pilot generator, having field windings whose excitation is influenced by said movable member, so as to reflect the direction and mag-

nitude of the displacement or deflection of said work rolls.

3. Apparatus as claimed in claim 2, having work roll bearings mounted for limited lateral movements, in both directions, in response to said lateral forces, and arranged to transmit such movements to said movable member, the latter being part of an electric gauge device.

4. Apparatus as claimed in claim 2, having the work roll bearings substantially fixed, and provided with an electric gauge device having a movable member maintained in contact with the central portion of a work roll, to reflect by its movements the direction and magnitude of said work roll's deflection by the lateral forces operative thereon.

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