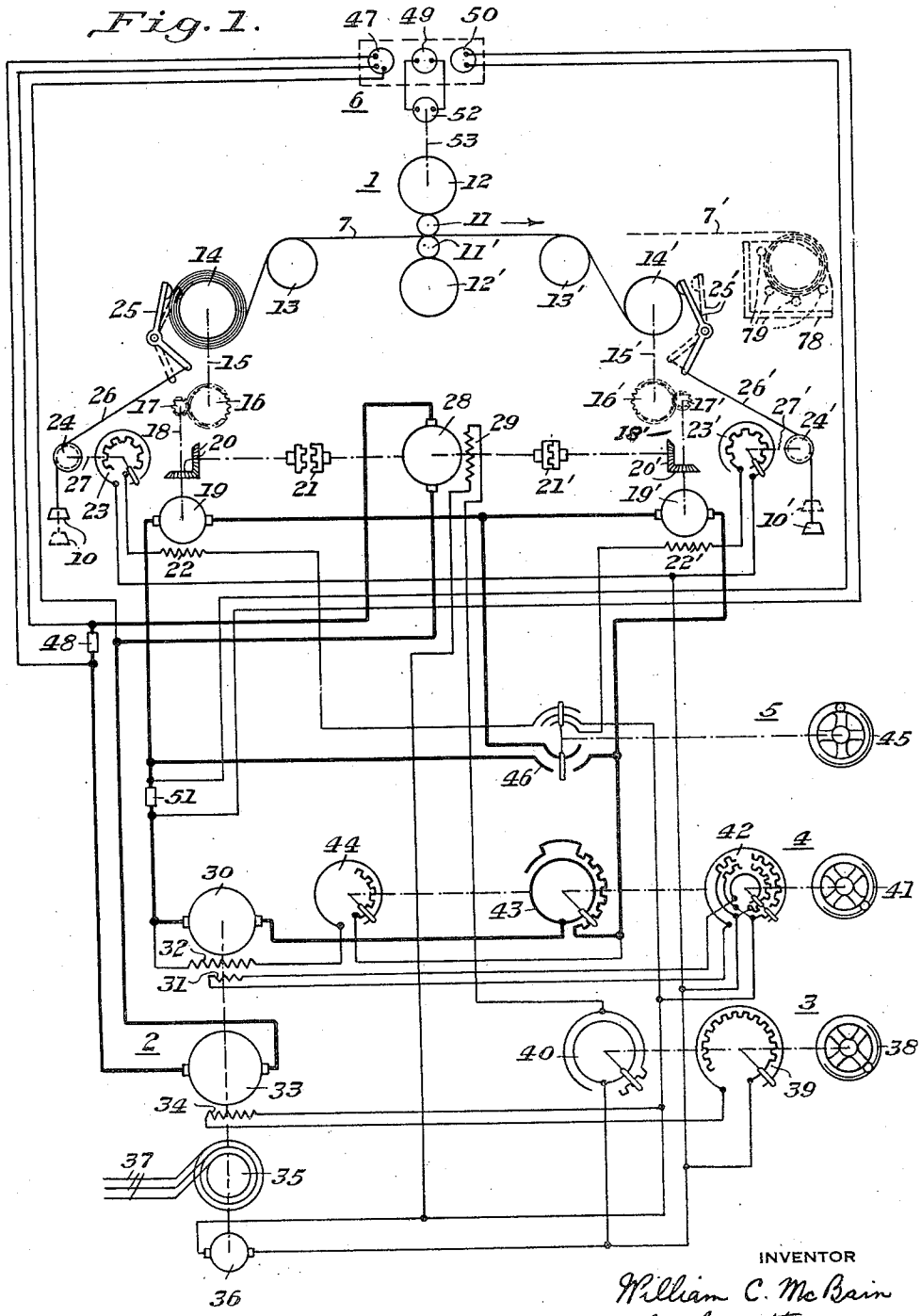
May 9, 1939. W. C. McBAIN 2,157,739

ROLLING MILL CONTROL

Filed Aug. 15, 1932 5 Sheets-Sheet 1

Fig. 1.



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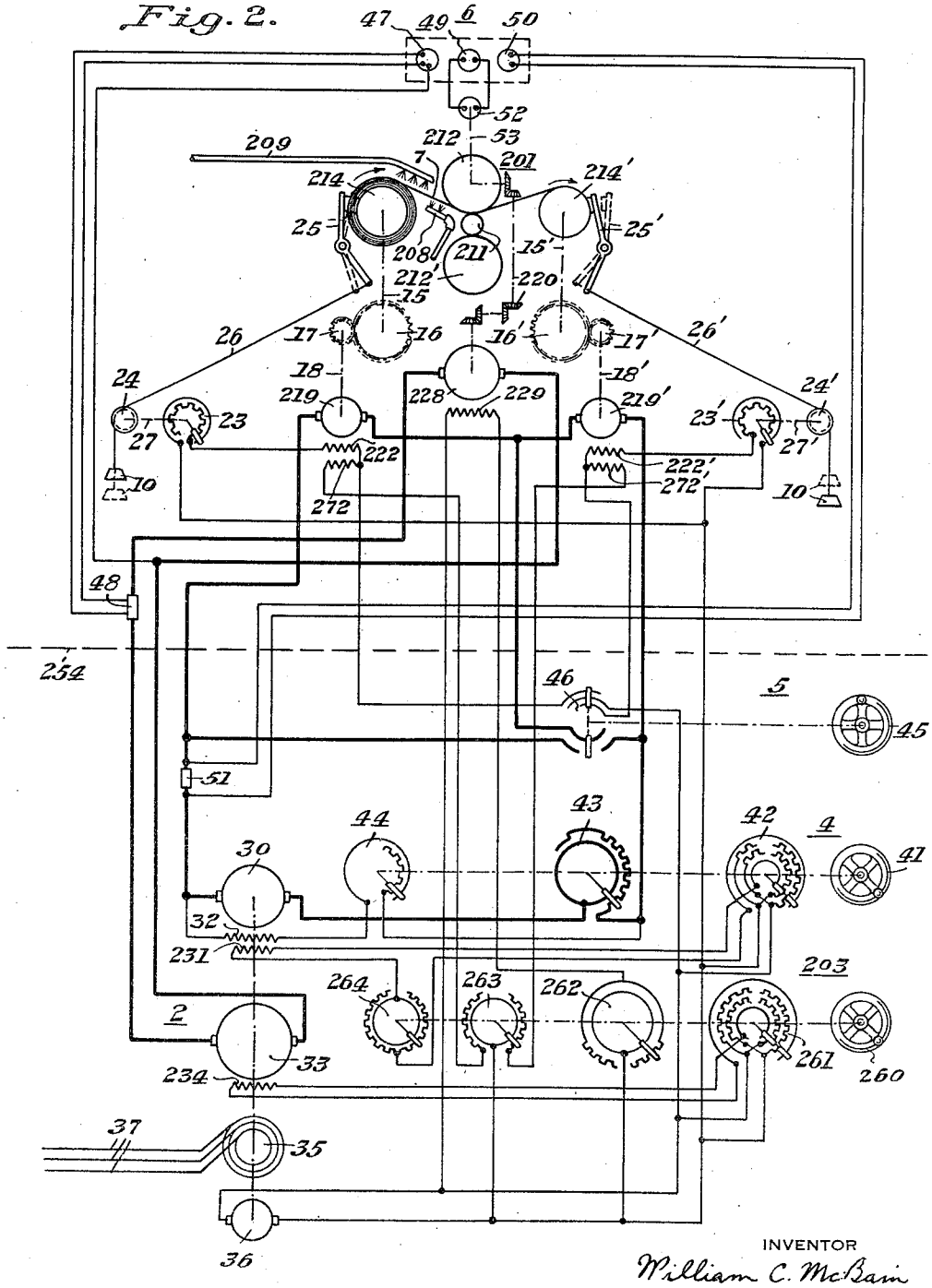
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ROLLING MILL CONTROL

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Fig. 2.



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May 9, 1939. W. C. McBAIN 2,157,739

ROLLING MILL CONTROL

Filed Aug. 15, 1932 5 Sheets-Sheet 3

Fig. 3.

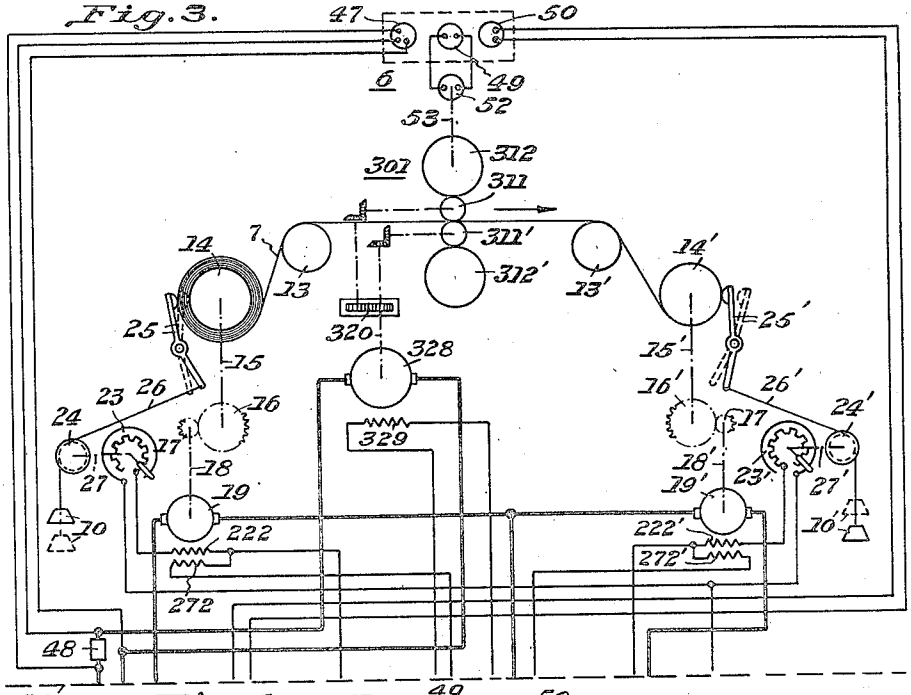
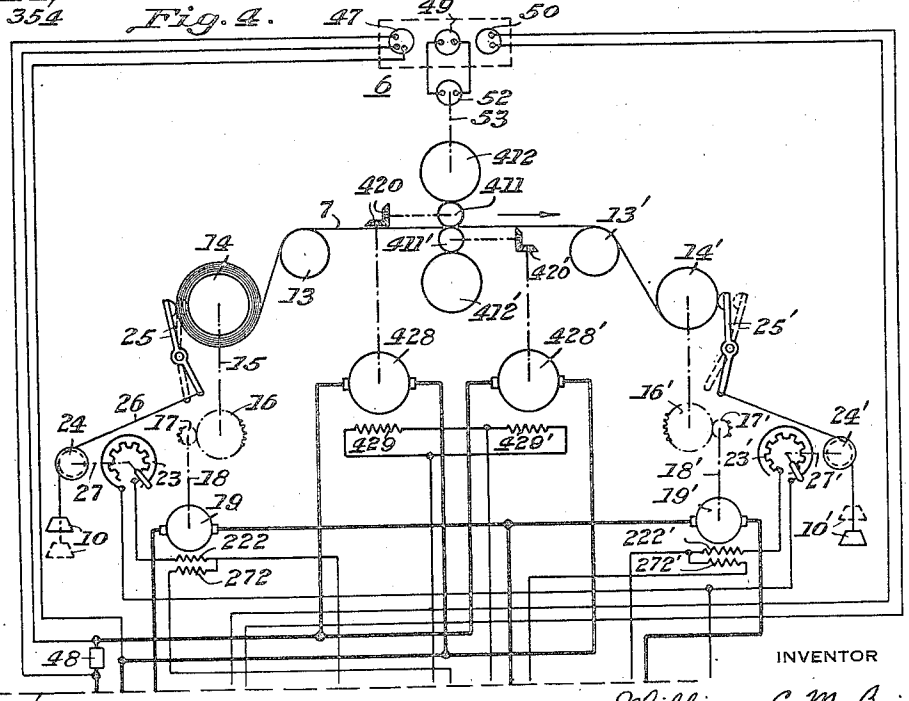


Fig. 4.



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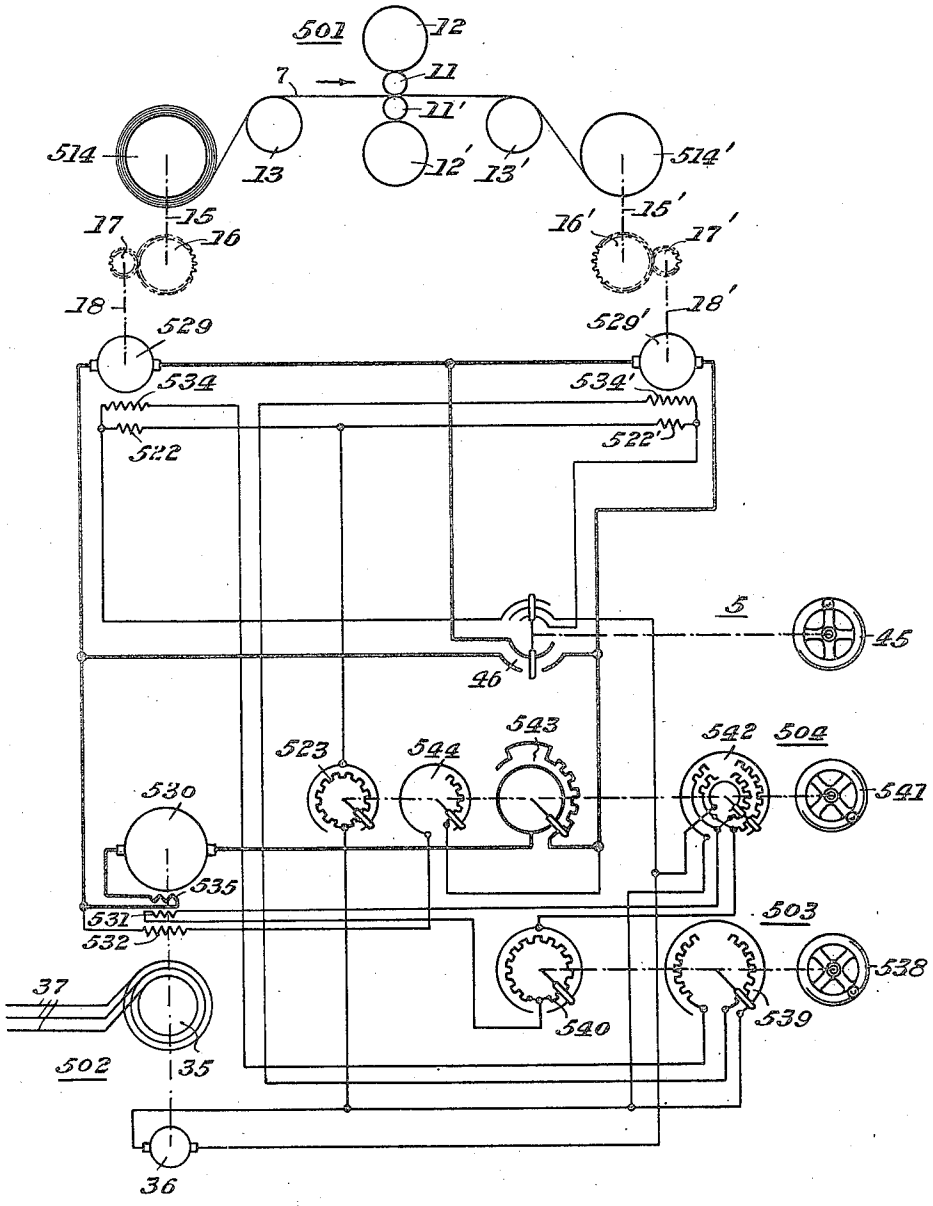
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May 9, 1939. W. C. McBAIN 2,157,739

ROLLING MILL CONTROL

Filed Aug. 15, 1932 5 Sheets-Sheet 4

Fig. 5.



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ROLLING MILL CONTROL

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Fig. 6.

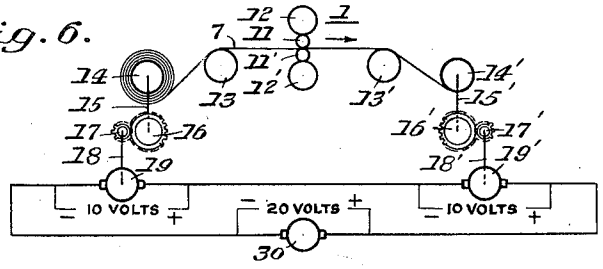


Fig. 7.

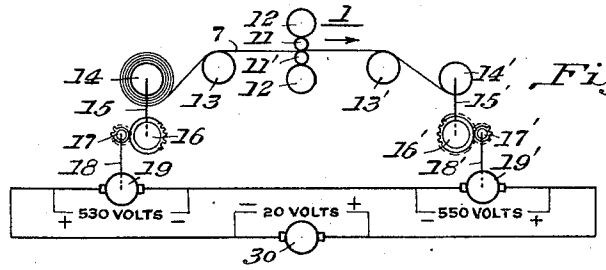


Fig. 8.

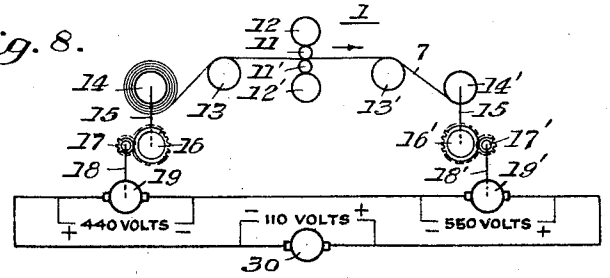


Fig. 9.

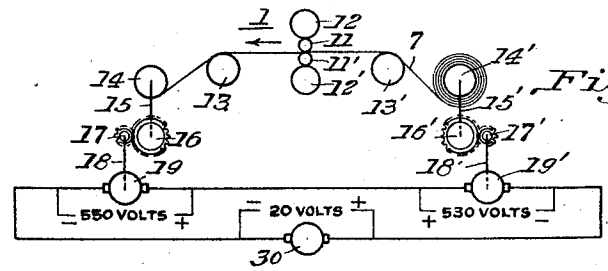
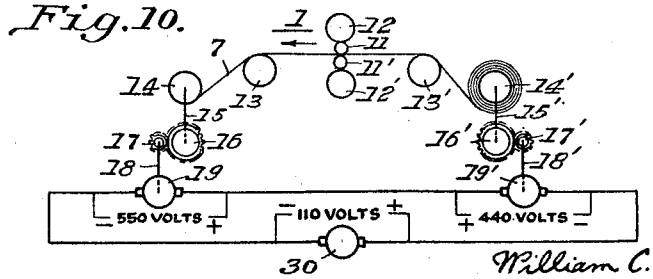


Fig. 10.



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Patented May 9, 1939

2,157,739

UNITED STATES PATENT OFFICE

2,157,739

ROLLING MILL CONTROL

William C. McBain, Youngstown, Ohio, assignor to The Cold Metal Process Company, Youngstown, Ohio, a corporation of Ohio

Application August 15, 1932, Serial No. 628,846

15 Claims. (Cl. 80—32)

My invention relates to the art of reeling and, in particular, to the reeling through a mill of metal in long lengths such as strips, under tension, although it has numerous other applications.

It has been the practice previously to tension a strip while being reeled back and forth through a mill, by means of a friction brake acting on a reel from which the coiled strip is unwound before passing through the rolling mill to a winding-up reel. Several objections to the use of the friction brake for this purpose have been encountered. In the first place, the tension actually introduced into the strip being rolled is not constant during the entire rolling of the strip for any one setting of the brake, because of the constantly varying diameter of the coil on the unwinding reel. The back tension created by a friction brake, furthermore, varies because the surfaces of the strips are apt to pick up oil, water or grease. Another objection is the jerk which occurs in starting due to the fact that the static friction on the brake is greater than the sliding friction. The friction brake, of course, dissipates energy as heat, which is not recoverable and therefore represents a total loss of energy.

In my U. S. Patent No. 1,881,056, granted October 4, 1932, for Tension devices, I have described and claimed the use of dynamo-electric machines for recovering the energy delivered by the strip moving against the back tension. It is the object of the present invention to improve upon the system disclosed in the above patent and also to provide a constant and predetermined back tension for each pass regardless of the variables tending to alter the same.

My invention consists of means for holding the back tension constant and at a predetermined amount by suitably regulating the amount of energy recovered, so that said amount is proportional to the speed of the strip entering the mill, this ratio holding practically constant and at a predetermined value for the duration of each pass. The factors making it difficult to maintain this ratio in this type of mill are the varying coil diameter on the unwinding reel; the amount of the reduction in the mill and the wide range in speeds that must be accommodated by the control system.

My invention not only provides the means of overcoming these factors, but, in addition, provides great flexibility in reversing the mill and also permits of rapid acceleration or retardation of the mill at the will of the operator. My system is also very flexible in that it permits of fine adjustment of the back tension to suit the thinner section of the strip for each pass through the mill. Other features of novelty will become apparent as the description proceeds and will be pointed out specifically in the appended claims.

In one form of my invention, I provide a constant current generator for supplying current to dynamo-electric machines tending to drive the winding and unwinding reels in opposite directions, whereby the strip is maintained under desired back-tension before the strip is set in motion due to the operation of the mill; and substantially the same back tension is maintained in the strip entering the rolls after the strip is set in motion by the starting of the mill.

While some of the features of my invention depend upon the use of a constant current generator, other features are not so dependent, and I do not, therefore, want to be limited to the use of a constant current generator in those features of the invention which are not dependent thereon.

The invention also contemplates means for compensating for the change in the diameters of the coils on the winding and unwinding reels, whereby a constant tension in the strip is provided.

In one form of the invention, I provide in addition to the dynamo-electric machines for creating the tension in the strip, a main driving motor for pulling the strip through the mill solely by the tension in the strip. The invention is also applicable to three-high mills; and a modified form of the invention provides a motor driving one or more rolls of such a mill. Four-high mills with driven work rolls can also take advantage of the invention, and a further modification thereof discloses how this may be accomplished. A single driving motor for the two work rolls, or as a further modification, a separate driving motor for each work roll may be employed.

In the preferred form of the invention, however, it is reduced to bare essentials, comprising the constant current generator and the dynamo-electric machine supplied thereby serving the functions of producing tension in the strip and drawing the strip through the rolls. From what has been said as to possible modifications of the invention, however, it will be apparent that it is characterized by extreme flexibility and applicability to a variety of installations.

In other modifications of the invention, I arrange to drive one or more of the rolls of the mill by one motor or the two work rolls by sep-

arate motors. In another form the mill is driven principally by the tension on the strip.

In all the forms of my invention, there are preferably included one principal cut-out switch and two principal controls. The cut-out switch is used principally for the first or loading pass to permit the operation of the reels individually. One of the controls regulates the back tension and holds it approximately constant regardless of the direction of rotation of the mill, the speed of rolling, amount of reduction and also preferably, regardless of the amount of strip on the coiling reels. The other control regulates the speed. It is this effective method of regulating the back tension that constitutes an important feature of the present invention.

For a complete understanding of the invention, reference is made to the accompanying drawings, in which:

Figure 1 is a schematic diagram showing a system embodying one form of the invention in which the only source of power actuating the work rolls is tension in the strip;

Figure 2 is a similar diagram showing a further embodiment of the invention as applied to a three-high mill with one roll power driven;

Figure 3 is a partial diagram of a modification with a control similar to Figure 2, but including a four-high mill with work rolls driven by one motor;

Figure 4 is another partial view similar to Figure 3, but with work rolls driven by individual motors;

Figure 5 shows a simplified form of my invention in which the only source of power actuating the work rolls is the strip tension; and

Figures 6 through 10 are partial schematic diagrams illustrating conditions in the circuits shown in Figures 1 through 4, under a variety of conditions.

Referring in detail to the drawings and for the moment to Figure 1, the principal parts are a reversing mill 1 and its drive, a motor generator set 2, speed control 3, back tension control 4, back tension cut-out 5 and instrument board 6. Conductors are shown as solid lines and shafting as dot and dash lines. For the sake of simplicity, I have omitted from my diagrams, electrical switches, screw-downs and other devices which are standard in rolling mill equipment. It is my aim to show and describe only those features in which my tension control system differs from the prior art without limitations as to standard strip mill practice.

The reversing mill 1, for the reduction of strip repeatedly passed therethrough under tension includes small diameter work rolls 11 and 11' and large diameter backing-up rolls 12 and 12', preferably mounted in antifriction bearings. Drums 13 and 13' guide a strip back and forth between reels 14 and 14', and if desired, may contain a circulating coolant for cooling the strip through the walls of said drums.

The details of the actual construction of the apparatus already described and some of that to be described hereinafter are already well known and need no explanation.

The reel 14 is driven in part or retarded by a dynamo-electric machine 19, through the shafts 15 and 18 and the gears 16 and 17, said dynamo-electric machine being capable of serving either as a generator or a motor. A similar machine 19' drives in part (or retards) the reel 14' through the gears 17' and 16' and shafts 18' and 15'. In Figure 1, the strip 7 is shown as passing from the reel 14 serving as an unwinding reel to the reel 14' serving as a winding-up reel. The machine 19 is now driven by the unwinding reel and acts as a generator, while the machine 19' acts as a motor to help drive the reel 14'. On account of the special service, part of the time serving as motor and part of the time serving as generator, I designate the machines 19 and 19' as dynamo-electric machines.

The armatures of the machines 19 and 19' are energized by a generator 30. Each machine has a separately excited field winding regulated by a rheostat. The field windings for 19 and 19' are indicated at 22 and 22' respectively, and the rheostats at 23 and 23'. Excitation for all the motor generators and dynamo-electric machines is preferably furnished by the exciter 36.

In one form of my invention, the field rheostat 23 is provided with an operating mechanism comprising a bell crank 25, one arm of which bears against the strip coiled on the unwinding reel 14. A cable 26 counterweighted with weight 10 connected to the other arm of the bell crank 25 traverses pulley 24. The pulley 24 operates the rotatable arm of the rheostat 23 through a shaft indicated at 27. The use of mechanical means to vary the torque in accordance with the coil size is diagrammatic only, and I do not wish to be limited to such means for accomplishing my objective.

Identical operating means for the rheostat 23' of the machine 19' is indicated by the same reference numerals, primed, as are employed to designate the parts of the operating mechanism for the rheostat 23.

The motor generator set 2 consists of the generators 30 and 33 and exciter 36, driven by the synchronous motor 35 which is driven by an outside source of power fed in through the main 37. The generator 30 is preferably of the constant current type or is so regulated as to have constant current characteristics to the extent that the current in amperes delivered by it is approximately constant for each setting of a back tension control handle 41, regardless of the speeds of the dynamo-electric machines 22 and 22' as long as said speeds are within the range required by the mill 1 during rolling. In the diagram the constant current characteristics are obtained by the assistance of two fields 31 and 32. Field 31 is separately excited by the exciter 36 and, controlled by a field-regulating rheostat 42, provides part of the excitation for generator 30. The remainder is provided by the field 32 which is connected across the outside armature terminals of the dynamo-electric machines 19 and 19' and has in its circuit a field rheostat 44. This field does not function until there is a difference of potential across the outside terminals of said dynamo-electric machines. Rheostat 44 serves to correct the regulation of field 32 to obtain the desired ratio of strength as compared to that of field 31 in all positions of the control handle 41. Rheostat 43 is in series with the armature of generator 30 and serves to make the control more sensitive when said control is set for a small back tension.

The speed control 3 consists of a hand wheel 38, operating the field rheostat 39, regulating the field 34 of the generator 33 for slow speed variations, and the additional field rheostat 40 for regulating the field current of the main drive motor 28 to assist in the mill speed regulation at higher speeds. Reversal of the mill is obtained by throwing the clutches 21 and 21' so that the

motor 28 drives that one of the reels 14 or 14' which was previously the unwinding reel. With suitable design of gears 20 and 20', as shown in Figure 1, it is unnecessary to provide for reversal of the motor 28, as this motor runs in the same direction for the alternate as well as the even passes of the strip through the mill.

The back tension control 4 consists of a hand wheel 41 operating the field rheostat 42 for the field coils 31 of the generator 30, the armature circuit rheostat 43, and the field rheostat 44, for the field coils 32 of the generator 30. The rheostat 42 is provided with a few points of reversed field for demagnetizing the field 32, when desired. The reversal points on this control also allow for a slight backward rotation of either reel by first cutting out the other dynamo-electric machine by means of the cut out 5. This reversing feature is of value when preparing to insert the end of a coil to be rolled into the reel, in that it enables the operator to rotate the reel in either direction to the exact position required for the purpose of attaching a length of strip thereto. The armature circuit rheostat 43 serves to stabilize the tension regulation through various speeds, especially at the lighter tensions. Its resistance is gradually reduced in the higher-tension positions of the control hand wheel 41, as such accurate adjustment is necessary only in rolling thin strip under comparatively low total tension. The field rheostat 44 assists in maintaining the proper degree of energization of winding 32 at all positions of the control handle 41 to produce the desired constant current characteristic in the generator 30.

Back tension cut out 5 is shown diagrammatically by the control handle 45 operating the controller switch 46. This may be used to cut out either one of the dynamo-electric machines 19 or 19' after which the other one may be used as a motor. This is of special importance in the preliminary or loading pass in which one reel only is operative.

The instrument board 6 carries the horsepower meter or wattmeter 47, the tachometer 49 and the ammeter 50. The horsepower meter or wattmeter 47 is suitably connected in the armature circuit of main drive motor 28, said connections involving the use of a suitable shunt 48. The tachometer 49 is connected to one of the rolls 12 by means of the tachometer generator 52, coupled up to said roll by the connection 53. Ammeter 50 is properly connected to the ammeter shunt 51 in the circuit of the dynamo-electric machines 19 and 19'. These instruments perform the usual service rendered by such instruments to the operator, the ammeter 50 being of special value as its reading is approximately proportional to the amount of back tension in the strip going through the mill.

A coil box 78 containing rollers 79 and a coil of strip 7' ready to be rolled are shown in dotted lines.

When it is desired to place the mill control system shown in Figure 1 in operation, the motor 35 is started in any convenient manner to drive the generators 30, 33 and 36. Before starting the motor 35, however, the speed and tension control mechanisms 3 and 4 should be set in neutral position. The moving contacts of the speed control 3 should extend vertically downward and those of the tension control 4 should extend vertically upward. Field circuits of both the generators 30 and 33 being open, they supply no current to the motors 19, 19' and 28.

Let it be assumed that the coil of steel 7' is in position in the coil box 78 and resting on the rollers 79, as shown in dotted lines. The end of the strip is threaded through the mill in a direction opposite to that of the arrow. Motor cut out 5 is rotated counterclockwise to cut out motor 19'. A slight rotation of reel 14 in either direction may then be effected by means of the tension control 4 to bring said reel into suitable position to attach the strip 7'. After the strip 7' is attached to the reel 14, the rolls 12, 11, 11' and 12' are adjusted in the usual manner to effect the proper reduction in the loading pass. The cut out 5 is still in position to cut out the motor 19' and the speed control 4 may be used to control the motor 19. The clutch 21 is engaged and 21' is disengaged, thus coupling the motor 28 to the reel 14 in addition to its permanently connected dynamo-electric machine 19. By simultaneously operating the controls 3 and 4, both motors 19 and 28 may be used at the same time to operate the reel 14.

After the preliminary or loading pass has been completed and the mill brought to rest, the opposite end of coil 7' is attached to the reel 14'. The motor cut out 5 is returned to the normal position for the operation of both dynamo-electric machines 19 and 19'. The clutch 21' is engaged and clutch 21 disengaged, and the mill is ready for the second pass in the direction of the arrow. If the tension control mechanism 4 is now rotated clockwise while the speed control mechanism remains in neutral position, the field 31 of the generator 30 will be connected to the exciter 36 through the rheostat 42. The generator 30, being driven by the motor 35, thereupon supplies current to the machines 19 and 19'. The field windings of the latter machines are connected in parallel across the exciter, each field winding being connected in series with its control rheostat 23 or 23'.

The rheostat 23 is in its position of minimum resistance in order to provide the maximum retarding torque on the shaft 15. The maximum-retarding torque is required because the tension in the strip acts through a greater lever arm when the reel is full than when it is empty. The rheostat 23' correspondingly is in position of maximum resistance in order that the motor 19' shall exert a minimum torque. Since the winding reel is empty, the lever arm of the strip tension is shorter and less torque is required of the motor 19'. The bell cranks 25 and 25' and their connected mechanisms operate progressively to adjust the settings of the field rheostats 23 and 23' to properly correlate the speeds and torques of the machines 19 and 19', as the strip moves from one reel to another.

Before starting the mill, the machines 19 and 19' are adjusted to produce the desired tensions in the strip 7. The degree of tension can be varied by changing the setting of the rheostat 42 which controls the excitation of the generator 30 and, therefore, the current supplied to the machines 19 and 19'. The field 32 of the generator 30 is subject to the voltage across the armature of the generator and is, therefore, not appreciably energized as the generator 30 starts up with the motor 35. As long as the armatures of the two dynamo-electric machines 19 and 19' rotate at approximately the same speed, and in the same direction, there is practically no energization of the field 32. This is due to the fact that they are connected to oppose each other and the electromotive force of one machine is

practically balanced by the electromotive force of the other. The difference of potential across their outside terminals required to overcome their electrical resistance is supplied by the generator 30. When the mill is set to effect a reduction of the strip, however, the winding up reel 14' revolves faster than the unwinding reel 14 and the counter E. M. F. of dynamo-electric machine 19' exceeds that of 19 and this difference of potential energizes the field 32 to assist in giving the generator 30 a constant-current characteristic.

When the tension in the strip has been adjusted properly, the mill may be started by rotating the speed control mechanism 3 clockwise. The generator 33 then supplies current to the motor 28 and, the clutches 21 and 21' having been shifted to the positions shown in Figure 1, the reel 14' is driven to pull the strip through the mill. As soon as the strip starts to move, the machines 19 and 19' start to rotate. They continue to exert equal and opposite torques, the motor 28 supplying the energy to drive the strip forward. The machine 19, since it is driven against the torque exerted thereby, acts as a generator connected in series with the generator 30. The machine 19', since it turns in the direction of its torque, acts as a motor and absorbs the output of the generator 19. The generator 30, therefore, supplies only the additional current necessary to maintain the desired strip tension. The motor 28 furnishes the additional torque required on the winding up reel to advance the strip through the mill at the desired speed.

The output of the generator 30 is controlled by its two fields 31 and 32, both of which are under control of the tension regulator 4. When the voltage across the outside terminals of the dynamo-electric machines 19 and 19' is low, as when the mill is not reducing the strip, the field 31 is most effective and causes the generator to generate the proper amount of current to establish the desired restraining torque in the dynamo-electric machine 19 and thereby the desired back tension in the strip 7. When the mill is in operation reducing the strip, however, an appreciable difference of potential becomes established across the terminals of the field 32, and it increases the voltage of the generator 30 sufficient to maintain it, and thereby the torques of the dynamo-electric machines 19 and 19', substantially constant. This furnishes the desired back tension in the strip 7.

Figures 6 to 10, inclusive, show some of the parts taken from Figure 1 under various hypothetical conditions of operation. In Figure 6, it is assumed that the mill is stationary and that the tension control is set to produce a heavy tension in the strip 7. Under these conditions, the constant current generator 30 will only be producing sufficient voltage across the terminals to overcome the copper loss in the connections and in the two armatures of the dynamo-electric machines 19 and 19'. Neglecting the copper loss in the external conductors, we will assume that the generated voltage is 20 volts and that the drop across each armature is 10 volts as shown in the diagram. In this diagram and the four following examples given, 20 volts across the generator will cause sufficient amount of current to flow to furnish the desired back tension in the strip when the mill is at rest preparatory to starting the pass.

Figure 7 shows the same working parts, but with the strip mill and strip in motion, the strip moving to the right as indicated by the arrow without reduction of the strip. Neglecting at this time the difference in coil diameters on the reels 14 and 14', the dynamo-electric machines 19 and 19' will be rotating at approximately the same speed and the counter-electromotive force of the dynamo-electric machine 19' will be balanced by the generated voltage of the dynamo-electric machine 19, so that we still have the same number of volts generated by the generator 30 as we had in Figure 6; namely, 20 volts. The terminals of the dynamo-electric machine 19' are assumed to be at their maximum voltage difference. This difference of potential is assumed to be 550 volts, of which 540 volts is the counter-electromotive force and the difference of 10 volts represents the copper loss through said armature 19'. Likewise, the theoretical voltage of the dynamo-electric machine 19 at this speed and neglecting copper loss, is 540 volts. The copper loss through the armature of this dynamo-electric machine 19 is assumed to be 10 volts, thus making the terminal voltage across its armature 530 volts.

Figure 8 is a similar diagram with the strip moving near the maximum speed to the right and the mill 1 set to reduce the strip, said reduction probably being between 10% and 30% to give the voltages assumed. The dynamo-electric machine 19' which helps to drive the winding up reel 14' shows a voltage as before of 550 volts across the armature. On account of the fact that the mill is set to reduce in this diagram, the reel 14 is now traveling at a slower speed than under the conditions assumed in Figure 7, and the dynamo-electric machine 19, driven by the reel 14, is assumed to have a terminal voltage across its armature of 440 volts. The generator 30 being a constant current generator supplies the additional voltage to make up the difference between 550 volts and 440 volts and in this case has 110 volts across its armature terminals.

Figure 9 shows the mill 1 in operation in the reverse direction, the strip now passing to the left in the direction of the arrow and under the same tension as in Figure 7. Reel 14 now becomes the winding up reel and 14' the unwinding reel. In this diagram, we assume there is no reduction in the mill, and the constant current generator 30 now generates 20 volts the same as it did in Figure 7. The polarity of its terminals is the same as in Figure 7. Dynamo-electric machines 19 and 19', however, have been reversed in direction of rotation without reversal of their fields, and therefore, the polarity of the electromotive force generated by dynamo-electric machines 19 and 19' have been reversed. The voltage across the armature terminals of dynamo-electric machine 19 is assumed to be 550 volts while that across the dynamo-electric machine 19' is assumed to be 530 volts. The difference of 20 volts is supplied by the generator 30 to overcome the copper losses in the armatures 19 and 19'.

Figure 10 shows the mill 1 in operation with strip moving to the left, similar to Figure 9, as indicated by the arrow, but with the mill set to reduce the strip 7. Reel 14 is the winding up reel and 14' the unwinding reel.

The dynamo-electric machine 19 is assumed to be driven at its maximum voltage, the terminals of its armature showing a difference of potential of 550 volts. The dynamo-electric machine 19' traveling at a slower speed than the dynamo-electric machine 19 (on account of the elongation of the strip 7 being reduced in the

mill), now shows a voltage across its terminals of only 440 volts. The difference in voltage of the dynamo-electric machines 19 and 19' or 110 volts is supplied by the constant current generator 30, which voltage is assumed sufficient to overcome the copper loss and also to compensate for the difference in speed of the dynamo-electric machines 19 and 19'.

The figures assumed in these examples are for aid in visualizing the direction of flow of current in the circuit in one form of my invention and of showing the relative performance under different conditions of operation. These figures are subject to considerable deviation in actual operation.

As the strip 7 is pulled through the mill, the coil on the reel 14' increases in diameter, while that on the reel 14 decreases. The bell crank mechanisms associated with the reels operate the rheostats 23 and 23' to vary the excitations of the field windings of the machine 19 and 19', as previously explained.

The speed of travel of the strip 7 is indicated on the tachometer voltmeter 49 and may be varied by shifting the handwheel 38 to change the setting of the rheostat 39 which controls the excitation of the generator 33 and, in turn, the speed of the motor 28, up to the point where rheostat 40 becomes effective and produces still higher speeds by weakening the field of the motor itself. The degree of tension to which the strip is subjected is approximately proportional to the reading of the ammeter 50 and this tension may be varied by adjusting the rheostats 42, 43 and 44 by means of the handwheel 41.

When the strip 7 has been entirely wound on the reel 14', the system may be reversed to run the strip back through the mill. On the completion of the pass, the mill is stopped by setting the speed control handle 38 to the zero speed position. The clutches 21 and 21' are thrown, clutch 21' being disengaged and the clutch 21 engaged before the motor 28 is again started. The motor 35, of course, runs continuously in the same direction at synchronous speed and the generator 30 supplies a substantially constant current to the circuit through the armatures of the motors 19 and 19'. The necessary further passes of the strip through the mill can be carried out in the manner indicated with the assurance that the strip will always be subjected to a constant tension corresponding to the position of the handwheel 41, which is set for lighter tensions to suit the thickness of the strip after each pass. While the generator 30 has been described as being preferably a constant current generator, it is understood that it supplies a substantially constant current only for any particular setting of the rheostat 41.

Figure 2 shows an application of my invention to a three-high mill 201. There are some special advantages in this type of mill which are not common to all the other types I have shown. Some of the special advantages of this type of mill are as follows: very low percentage of loss of strip in the unrolled portions at each end of the coil; saving in time of setting up mill due to elimination of top and bottom guides; possibility of rolling defective steel due to absence of top and bottom guides to snag the defects in the steel; the small floor space occupied by the mill; the possibility of heavier reductions than on a mill operated by pull of the strip alone; fewer breakages than in a mill operated by the pull of the strip alone. This type of mill also permits the use of lighter motors (or dynamo-electric machines) and gears on the coiling reels than in mills driven by the tension in the strip alone. This reduces the inertia of the coiling reel drives and, when combined with my sensitive back tension control, eliminates slap in the strip when reversing the mill or subjecting the mill to rapid acceleration or retardation.

In Figure 2 and in subsequent diagrams where the parts are similar to those used in Figure 1 and where the former description will suffice I have used the same reference numerals. Elements that differ from those of Figure 1, I have given a new series of numbers in the two hundred series for easy reference.

The mill 201 includes the large driven work roll 212, the backing up roll 212' and the small work roll 211. Roll 211 is preferably driven by the pull of the strip 7.

The reel 214 is retarded or driven by a dynamo-electric machine 219 through the shafts 15 and 18 and the gears 16 and 17, said dynamo-electric machine being capable of serving either as a generator or motor. A similar machine 219' drives or retards the reel 214' through the gears 17 and 16' and shafts 18' and 15'. In Figure 2, the strip 7 is shown as passing from the reel 214 serving as an unwinding reel to the reel 214' serving as a winding-up reel. The machine 219 is then driven by the unwinding reel and acts as a generator, while the machine 219' acts as a motor to drive the reel 214'.

The reels 214 and 214' are preferably interchangeable with spares of the same type. This allows rapid emptying of mill after a coil of steel is rolled by removing the loaded reel and substituting another reel, either empty, or loaded with another coil to be rolled.

The armatures of the machines 219 and 219' are energized by the generator 30. Each machine has a separately excited field winding 222 and 222', respectively, each of which is regulated by a field rheostat 23 and 23', respectively. The rheostats 23 and 23' operate like the two rheostats similarly designated in Figure 1. In addition to these fields, the dynamo-electric machines 219 and 219' are provided with the auxiliary fields 272 and 272', respectively, both of which fields are controlled by a two-circuit field rheostat 263, which rheostat forms a part of the speed control 203. Rheostat 263 allows the field of the dynamo-electric machine driving the winding reel to become more fully energized than the one that is being driven by the unwinding reel. This produces more tension in the strip leaving the rolls than in the strip entering the rolls. By this means, greater reductions are possible than with the same tension in the strip on the two sides of the mill.

Due to the lack of cooling drums in this type of mill, it is advisable to introduce sprays of cooling liquid 208 through the pipes 209 and 209' to carry off the heat generated during the rolling operation. A suitable light mineral oil may be used for this purpose. The cooling liquid 208 also serves to wash the surface of the strip.

The speed control 203 in Figure 2, in addition to controlling the speed of the mill, also controls its direction of rolling. This is due to the fact that the main drive motor 228 is a reversing motor not relying on the use of clutches. The speed (and direction) control 203 consists of a hand wheel 260 operating a reversing field rheostat 261 regulating the field 234 of the generator 33 for slow speed variations and reversing the generator

field 234 when necessary to reverse the direction of rolling in the mill 201. Handwheel 260 also operates the field rheostat 262 for regulating the field 229 of the main drive motor 228 to assist in the mill speed regulation at higher speeds, said motor 228 driving work roll 212, shown diagrammatically through gear train 220. Handwheel 260 also operates the rheostat 263 to increase the tension in the strip leaving the rolls 211 and 212 by increasing the torque of the dynamo-electric machine driving the winding-up reel, and thus helps the motor 228 to advance the strip 7 through the mill allowing greater reductions than would be possible without this provision. The rheostat 264 serves to regulate the strength of the field 231, and thereby helps regulate the output of the generator 30 to compensate for the varying power requirements at different speeds. The broken line 254 divides the motor generator set and controls from the rest of the diagram and will be referred to later.

In operation, the strip 7 is always in contact with the roll 212 and thus enters and leaves the rolls continually in the same position relative to the rolls, thus doing away with the necessity of top and bottom guides as used in ordinary strip mills. This permits the rolling of steel with imperfections that would hang up or snag on the ordinary top and bottom guides and tear the strip.

Figure 3 shows an application of my invention to a four-high mill 301, which includes the power-driven work rolls 311 and 311' and the two idling backing-up rolls 312 and 312'. The two work rolls 311 and 311' are driven by the main drive motor 328 through the pinion stand and shafting 320. The field 329 of the motor 328 is regulated in the same manner as field 229 in Figure 2. The remaining features of this system are the same as in Figures 1 or 2, and are correspondingly designated. The control devices and the motor generator set below the line 254 are the same as shown below the line 254 in Figure 2 and are therefore not duplicated in Figure 3.

Figure 4 shows an application of my invention to a four-high mill 401 which includes the two power-driven work rolls 411 and 411' and the two idling backing-up rolls 412 and 412'. The work roll 411 is driven by the motor 428 through the shafting and gears shown diagrammatically at 420 and the work roll 411' by the motor 428', through the shafting and gears shown diagrammatically at 420'. The armatures of motors 428 and 428' are connected in parallel and the motors are operated simultaneously in the same manner as the single armature of motor 228 in Figure 2. Fields 429 and 429' are connected in parallel and together are controlled the same as the single field 229 of Figure 2. In Figure 4, the two motors 428 and 428' take the place of motor 228 in Figure 2.

Figure 5 shows a simplified form of invention in which the only source of power actuating the work rolls is the strip tension. This diagram is somewhat similar to Figure 1, but is greatly simplified in that no clutches are used and only one motor (or dynamo-electric machine) is used to drive the winding-up reel.

The motor generator set is also simplified in that one less generator is required than shown in the former diagrams. Referring to the diagram, the principal parts are a mill and its drive 501, motor generator set 502, speed control 503, back tension control 504, and motor cut-out 5. The motor cut-out 5 and many parts of the mill 501 are the same as corresponding parts similarly numbered in Figure 1. In the mill 501, I preferably use reels 514' somewhat larger than I used on the mills shown in the other diagrams. This lessens the need for compensation for variable coil diameter. In some cases, the back tension control 504 may be operated either manually or otherwise to compensate for the variable coil diameter and thereby to maintain a sufficiently uniform back tension in the strip 7. The dynamo-electric machine 529 drives (or is driven by) the reel 514. Dynamo-electric machine 529' similarly drives (or is driven by) reel 514'. Dynamo-electric machine 529 is provided with two sets of field coils 522 and 534 of which 522 is preferably regulated by the back tension control hand-wheel 541 and its regulation is used to assist in the regulation of the back tension of the strip entering the rolls of the mill 501. The field 534 is controlled by the speed control handwheel 538 and it is preferably so connected in the field rheostat 539 that it is only in use when the reel 514, connected to dynamo-electric machine 529, is being used as a winding-up reel. The regulation of field 534 by rheostat 539 assists in regulating the speed of the winding-up reel and thereby the speed of the strip through the mill. The dynamo-electric machine 529' is similarly used to drive or restrain the reel 514', the description of its action being similar to that of 514, similar parts bearing the same numbers primed.

A motor generator set 502 consists of a synchronous motor 35, driving the exciter 36 and generator 530. The exciter 36 furnishes excitation current for the generator 530 and the two dynamo-electric machines 529 and 529'.

The generator 530 is of the constant current type. The field 531 is used primarily to establish the light load output of the generator 530 and the field 532 is used to increase the field strength with the output and thereby to help give the generator 530 a constant current characteristic. The differential field 535 in series with the armature of the generator 530 is preferably connected to oppose the fields 532 and 531, and helps to give said generator 30 a constant current characteristic.

The speed control 503 consists of the control handwheel 538, operating the two-circuit field rheostat 539, and the field rheostat 540. The field rheostat 539 regulates the field 534 or 534' of whichever dynamo-electric machine 529 or 529' is driving the winding-up reel. The field rheostat 540 is a subordinate rheostat which allows field 531 to strengthen gradually for the higher mill speeds and assists in maintaining the output of generator 530 under heavy loads.

Back tension control 504 consists primarily of the handwheel 541 connected to operate the rheostats 542, 543, 544 and 523. Rheostat 542 is in series with field 531 of the constant current generator 530 and is one of the main factors in regulating the light load current output of the generator 530. It contains a few reverse points for neutralizing the fields of generator 530 when desired, or for assisting in bringing either reel to exact position for attaching strip. Rheostat 543 is in series with the armature of the generator 530 and serves to make the back tension control 504 more sensitive at light loads. Rheostat 544 is in series with field 532 and also serves to make the back tension control more sensitive at light loads. Rheostat 523 controls the amount of current going to the fields 522 and 522' of the dynamo-electric machines 529 and 529' and is one of the main factors in determining the restraining torque exerted by the dynamo-electric machines driven by the unwinding reel.

Motor cut out 5 is similar to that described in the description of Figure 1.

The form of my invention shown in Figure 5 has the great advantage of extreme simplicity. While this form of back tension control does not hold the back tension in the strip as exactly constant as some of the other forms of my invention, it holds it constant enough for many practical purposes and I desire to have it included as a part of my invention.

It will be apparent from the foregoing explanation that the invention is characterized by numerous advantages over the systems of the prior art. As above stated, the most important result of the invention is that the strip is subject to a substantially constant back tension throughout the rolling, thus overcoming the ordinary unfavorable conditions in strip mill operation tending to cause said tension to vary. Practically the same back tension is maintained whether the mill is operating or stationary. The degree of back tension can be adjusted to the desired value very easily and when adjusted, is maintained constant for any desired reduction in the material. For any given setting of the tension control, the amount of energy recovered is, theoretically, by my method, approximately proportional to the speed of the strip, thus giving a constant back tension. The amount of tension is easily measured and indicated. There is no jerk in starting. The retarding torque on the unwinding reel is converted to useful energy and the entire system is of simple construction and satisfactory in operation. It does not interfere with high rolling speeds.

Although I have illustrated and described herein but a few of the possible embodiments of the invention, it will be recognized that many changes in the system disclosed may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. In an apparatus for rolling strip material, the combination with reducing rolls and winding and unwinding reels for passing material through the rolls, of a motor for driving the winding reel, and means for maintaining a substantially constant predetermined tension in the strip between winding and unwinding reels, regardless of the speed or direction of travel of the strip, comprising a motor exerting a driving torque on said winding reel, a generator exerting a restraining torque on said unwinding reel and a means for supplying constant current connected in series with said last mentioned motor and generator.

2. In an apparatus for handling strip material including winding and unwinding reels, means for maintaining a constant tension in said material leaving the unwinding reel, comprising a motor for exerting a winding torque on said unwinding reel, a motor for exerting a winding torque on said winding reel, and means for supplying a substantially constant current to said motors in series.

3. Apparatus for rolling strip comprising a mill, winding and unwinding reels on opposite sides of the mill, dynamo-electric machines for driving and restraining said reels, and a constant current generator connected across said machines in series, said generator having a resistor in series therewith and a shunt field winding connected across the armature of the generator and said resistor in series.

4. Means for maintaining a substantially constant tension in strip material passing from an unwinding reel to a winding reel, comprising dynamo-electric machines for exerting winding torques on both said reels, said machines being connected in series, and means for supplying a substantially constant current to said machines.

5. In an apparatus for rolling strip material, the combination with reducing rolls and winding and unwinding reels for passing material therebetween, of dynamo-electric machines for exerting winding torques on both said reels, means for energizing the armatures of said machines to the same extent, a motor, and means for connecting the motor to either of said reels for moving strip through the mill in a predetermined direction while subject to the tension exerted thereon by said dynamo-electric machines.

6. In a strip mill, feeding and winding reels, motors connected to said reels, a motor for driving the mill, a generator supplying current to said mill motor, and common means for reversing the polarity of said generator and varying the excitation of said mill motor.

7. In a reversing strip mill, feeding and winding reels, motors connected to said reels, a constant current source connected to said motors in series, and means for increasing the resistance in circuit with said motors, opening said circuit and reclosing it with all said resistance in circuit.

8. In a reversing strip mill, feeding and winding reels, motors connected to said reels, a constant current source, means for connecting the motors in series to said source, means for controlling the torque exerted by said motors, a motor for driving the mill, a generator supplying current to the mill motor, means for controlling the generator excitation, and common actuating means for the generator-excitation controlling means and the torque-controlling means.

9. The combination with a reversing strip mill, of feeding and winding reels, motors connected to said reels, a constant-current source, said motors being normally connected in a series circuit including said source, and means for removing either of said motors selectively from said circuit.

10. Apparatus for rolling strip material, comprising reducing rolls, winding and unwinding reels for passing the material therethrough, dynamo-electric machines for exerting winding torques on both said reels, a common supply source adapted to be connected to the armatures of said machines in series, a switch effective to connect one of said armatures to said source and to shunt the other of said armatures, and means on said switch to open the field circuit of the shunted motor.

11. A control system for apparatus having an element operating on a strip of material and a reel for said strip comprising a motor for driving said element, a motor for driving said reel, a pair of variable voltage supply generators individualized to said motors, and means common to both said generators for simultaneously varying the excitation of both said generators to vary the speed of both said motors.

12. The combination with a reversing strip mill, a reel for feeding strip thereto and means for applying a restraining tension to said strip as it enters the mill, of means for utilizing the energy absorbed from the strip by said restraining means, means for regulating the amount of energy utilized to maintain the restraining tension substantially constant, means for stopping the mill and starting it in the opposite direction

without causing any appreciable change in the amount of said tension in the strip.

13. The combination with a reversing strip mill, of dynamo-electric machines for tensioning strip being passed back and forth through the mill, and a generator and a stabilizing resistor connected in series with said machines.

14. Apparatus for rolling strip, comprising a mill, winding and unwinding reels on opposite sides of the mill, dynamo-electric machines for driving and restraining said reels, a motor for providing additional driving force to the winding-up motor and thereby providing additional tension in that portion of the strip between the rolls and the winding-up reel to cause the mill to roll said strip, said motor being equipped with means whereby it may be coupled to which ever reel is the winding-up reel and may be disengaged from the reel that is the unwinding reel.

15. The combination with a strip mill having a reel on each side thereof, adapted to wind material issuing from the mill in a coil and unwind the coil of material entering the mill, of a dynamo-electric machine connected to each of said reels, of suitable control mechanism, and of a common source of excitation for said dynamo-electric machines, the armatures of said machines being connected in series to a supply source capable of delivering a substantially constant predetermined current.

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