Dec. 3, 1940. A. F. KENYON 2,223,728

CONTROL SYSTEM FOR REVERSIBLE ROLLING MILLS

Filed July 16, 1938 2 Sheets-Sheet 1

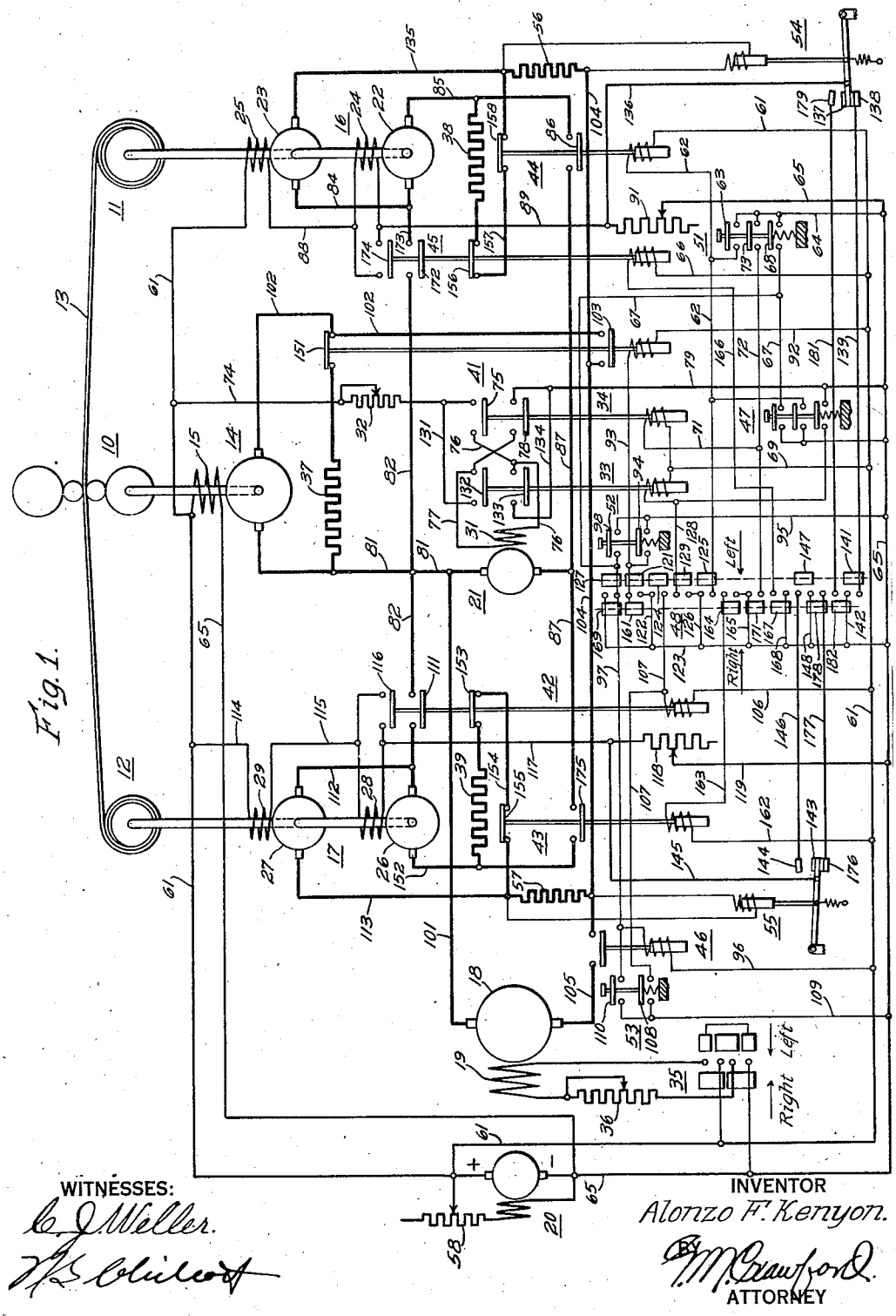

Fig. 1.

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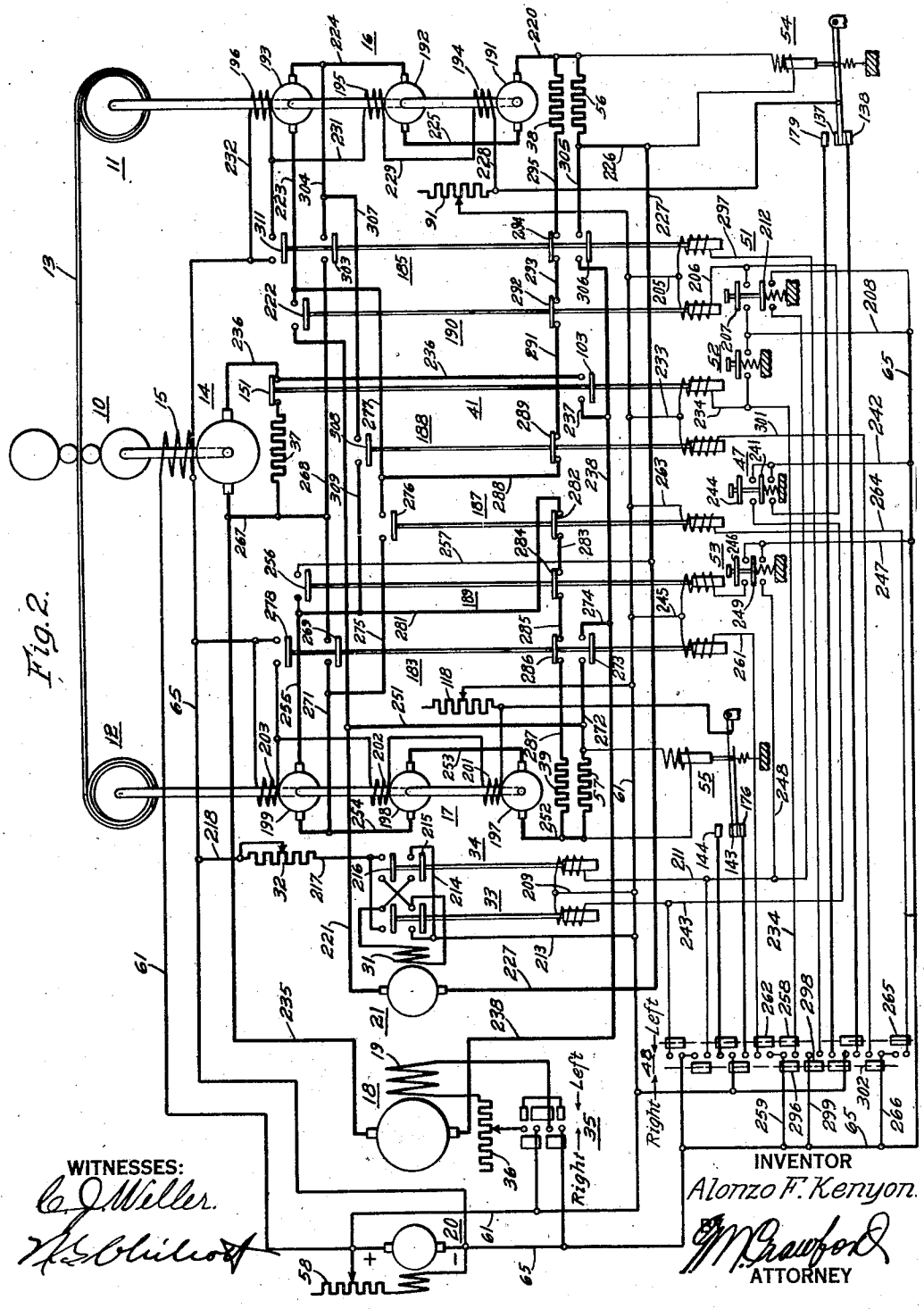

Fig. 2.

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2,223,728

CONTROL SYSTEM FOR REVERSIBLE ROLLING MILLS

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Application July 16, 1938, Serial No. 219,530

14 Claims. (Cl. 80—32)

My invention relates, generally, to electric drives and control systems for rolling mills and, more particularly, to an electric drive and control system for a single stand reversible strip mill having a reel on each side of the main roll stand.

The present invention is an improvement of the invention disclosed in Patent No. 2,084,035, issued June 15, 1937, to A. F. Kenyon and W. G. Cook. In the system described in the aforesaid patent, a booster generator, of approximately half the voltage rating of the main generator and reel motors, is connected in series with the reel motor that is operating as a braking generator on the unwinding reel to permit the unwinding reel to run at the slower speed than the winding reel necessitated by the reduction in the strip thickness during the passage through the mill rolls. The booster generator must be of the same ampere capacity and approximately half the voltage rating as the reel motors and, therefore, of relatively large size.

An object of my invention is to provide for reducing the voltage rating and the size of the booster generator in a reversible rolling mill drive.

Another object of my invention is to provide an electric drive for a rolling mill which is inherently suitable for making predetermined reductions in the thickness of the material during each pass through the mill.

A more general object of my invention is to provide an electric drive for a rolling mill which shall be simple and efficient in operation and which may be economically manufactured and installed.

Other objects of my invention will be explained fully hereinafter or will be apparent to those skilled in the art.

In practicing my invention, the reel motors of a reversible rolling mill are made double or triple armature, depending upon whether it is desired to make reductions up to approximately 50% or 33⅓% in the thickness of the strip during each pass. When the reel motors are provided with two armatures, they may be so connected that both armatures are in series on the low speed unwinding reel, and only one armature is utilized on the higher speed winding reel, thus establishing conditions to make reductions up to 50%. Likewise, when triple armature reel motors are utilized, they are so connected that the three armatures are in series when operating on the unwinding reel and two armatures are connected in series, and the third not used, on the winding reel, thus establishing conditions to make reductions up to 33⅓%. In this manner, the booster generator may be of a low voltage rating, as it is only utilized for RI drop compensation, and for inching and stalled tension during the starting operations.

For a fuller understanding of the nature and objects of the invention, reference may be had to the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of one embodiment of my invention wherein double armature reel motors are utilized; and,

Fig. 2 is also a diagrammatic view of a modification of my invention in which the reel motors are provided with three armatures.

Referring now the drawings, and particularly to Fig. 1, the rolling mill shown therein comprises a roll stand 10 and right and left reels 11 and 12, respectively, for handling a strip of material 13 while it is being worked by the rolls 10. The roll stand 10 may be driven by a suitable direct current motor 14 having a field winding 15. Likewise, the reels 11 and 12 may be driven or braked by dynamo-electric machines 16 and 17, respectively, which will be described more fully hereinafter. The power for operating the mill motor 14 and the dynamo-electric machines 16 and 17 is supplied by a direct current generator 18 having a field winding 19. The current for exciting the field windings of the generator 18, the motor 14 and the dynamo-electric machines 16 and 17, as well as for operating the control equipment, may be supplied by an exciter 20 or any other suitable power source. The generator 18, the exciter 20, and the booster generator 21, described later, may be driven by a synchronous motor (not shown) or by any other suitable means.

As explained hereinbefore, it is desirable to provide a booster generator 21 to operate in series with whichever of the reel motors is functioning as a braking generator on the unwinding reel to permit the unwinding reel to operate at a slower speed than the winding reel. In order to reduce the voltage rating and the size of the booster generator 21, as well as the size of the machines which drive the reels, the dynamo-electric machines 16 and 17 are each provided with a plurality of armature windings.

As shown in Fig. 1, the machine 16 has two armature windings 22 and 23 and two field windings 24 and 25. Likewise, the machine 17 has two armature windings 26 and 27 and two field windings

28 and 29. The armature windings for each machine are mounted on the same shaft. However, if desired, the machines may be provided with individual shafts which may be coupled together.

When the reel 11 is operating as the unwinding reel the armatures 22 and 23 are connected in series-circuit relation and in series with the booster generator 21 across the main generator 18. The armature 27, which drives the winding reel 12 is connected directly across the generator 18, and the armature 26 is not used. If desired, the armatures 26 and 27 may be connected in parallel-circuit relation across the generator 18 to increase the torque on the winding reel. Likewise, when the reel 11 is the winding reel and the reel 12 the unwinding reel, the armatures 26 and 27 are connected in series-circuit relation and in series with the booster 21 across the generator 18 while the armature 23, or armatures 22 and 23 in parallel, is connected directly across the generator 18.

In this manner, the machines which operate the reels are so connected that the mill is inherently suitable for making a reduction of 50% in the thickness of the strip at each pass through the reducing rolls 10 since the unwinding reel can operate at half the speed of the winding reel and the dynamo-electric machines on the unwinding reel still develop sufficient voltage to regenerate current into the power system, since the armatures of these machines are connected in series.

Therefore, the booster generator is required only for RI drop compensation and for inching and stalled tension. Hence it can be of a low voltage rating and kilowatt capacity. As will be explained more fully hereinafter, the booster generator 21 may be utilized for certain of the inching and stalled tension operations required when the strip is being threaded through the mill.

The booster generator 21 is provided with a field winding 31 which is energized from the exciter 20 through a variable resistor 32. Reversing switches 33 and 34 are provided for controlling the polarity of the booster generator. A reversing switch 35 of the drum type is provided for reversing the polarity of the main generator 18 to control the direction of operation of the mill. The excitation of the generator field 19 and, therefore, the voltage of the generator may be controlled by a variable resistor 36.

Dynamic braking resistors 37, 38 and 39 are provided for stopping the mill motor 14 and the reel motors 16 and 17, respectively, in a well known manner. A plurality of electrically operated switches or contactors 41 to 46 inclusive, are provided for establishing the proper motor and generator connections during the operation of the mill. The operation of the foregoing contactors may be controlled by a drum switch 48. The usual inching and stalled tension operations for threading the strip 13 through the mill stand may be controlled by push-button switches 47, 51, 52 and 53.

In order to hold the strip tension at a predetermined amount, the excitation of the field windings of the reel motors is governed by current regulators 54 and 55, which may be of any suitable type, as, for example, the well known vibrating regulator. The actuating coils of the regulators 54 and 55 are energized from shunts 56 and 57, respectively, in accordance with the load currents of the reel motors or generators, thereby holding these currents and, therefore, the strip tension within predetermined limits.

In order that the functioning of the foregoing apparatus may be more clearly understood, the operation of the system will now be described in more detail.

It may be assumed that the main generator 18, the exciter 20, and the booster generator 21 are operating at the required speed. It is also assumed that a variable resistor 58 has been adjusted to provide the proper voltage on the exciter 20 for the excitation of the machines utilized during the operation of the mill. It is further assumed that a coil of strip material to be rolled has been placed on the reel 11 driven by the dynamo-electric machine 16. Therefore, the first pass through the mill will be from right to left, as viewed in Fig. 1. Accordingly, the drum switch 35 is actuated to the left to provide the proper polarity of the main generator 18 for rolling the strip from right to left. Furthermore, the variable resistor 36 should be adjusted to provide a reduced voltage on the main generator 18 during the inching operations which are required for threading the strip 13 through the mill.

The reel 11 may be inched to permit the end of the strip 13 to be advanced to the rolls 10 by closing the push-button switch 51, thereby closing the contactors 44 and 46 and the field reversing switch 34 to cause the main generator 18 and the booster generator 21 to supply power for driving the reel 11 in the desired direction. The energizing circuit for the actuating coil of the contactor 44 may be traced from the positive terminal of the exciter 20 through conductor 61, the actuating coil of the switch 44, conductor 62, contact members 63 of the push-button switch 51, conductor 64 and conductor 65 to the negative terminal of the exciter 20. The energizing circuit for the actuating coil of the switch 46 extends from the previously energized conductor 61 through conductor 96, the coil of the switch 46, conductors 97 and 67, contact members 68 of the push-button switch 51, and conductor 64 to the negative conductor 65. The energizing circuit for the actuating coil of the reversing switch 34 extends from the positive conductor 61 through conductor 69, the coil of the switch 34, conductors 71 and 72, contact members 73 on the switch 51 and conductor 64 to the negative conductor 65.

The closing of the field reversing switch 34 connects the field winding 31 of the booster generator 21 across the exciter 20 through a circuit which may be traced from the positive terminal of the exciter through conductors 61 and 74, the adjustable rheostat 32, contact members 75 of the reversing switch 34, conductor 76, the field winding 31, a conductor 77, contact members 78 and conductor 79 to the negative conductor 65.

Therefore, the field winding 31 of the booster generator is energized to provide the proper polarity of the booster generator 21 to assist the generator 18 in driving the armatures 22 and 23 of the dynamo-electric machine 16 in the direction for unwinding the strip 13 from the reel 11. The circuit for the armature windings 22 and 23 is established by the closing of the contactors 44 and 46 and may be traced from one terminal of the main generator 18 through conductor 101, the booster generator 21 through conductor 87, the contact members 86 of the switch 44, conductor 85, the armature winding 22, conductor 84, the armature winding 23, conductor 135, the shunt 56, conductor 104, the switch 46 and con-

ductor 105 to the other terminal of the generator 18.

At this time, the field windings 24 and 25 of the dynamo-electric machine 16 are energized by the exciter 20 through a circuit which extends from the positive conductor 61 through the field winding 25, conductor 88, the field winding 24, conductor 89, a variable resistor 91 and the conductor 65 to the negative terminal of the exciter 20. At this time the rheostat 32 should be adjusted to cause the booster 21 to generate a relatively low voltage since the booster voltage is added to the main generator voltage, which is below normal.

When it is desired to thread the strip 13 through the rolls 10, the mill motor 14 may be inched by closing the push-button switch 52 to operate the contactors 41 and 46. The energizing circuit for the actuating coil of the contactor 41 may be traced from the positive conductor 61 through conductor 92, the coil of the switch 41, conductor 93, contact members 94 of the push-button switch 52 and conductor 95 to the negative conductor 65. The energizing circuit for the actuating coil of the switch 46 extends from the positive conductor 61 through conductor 96, the actuating coil of the switch 46, conductor 97, contact members 98 and conductor 95 to the negative conductor 65.

The closing of the switches 41 and 46 connects the armature winding of the mill motor 14 across the main generator 18 to drive the rolls 10. However, in view of the reduced voltage of the generator 18, the rolls are driven at a relatively slow speed. The energizing circuit for the armature winding 14 may be traced from the one terminal of the main generator 18 through conductors 101 and 81 to the armature of the mill motor 14, conductor 102, the contact members 103 of the switch 41, conductor 104, the switch 46 and conductor 105 to the other terminal of the generator 18. The field winding 15 of the mill motor 14 is connected across the exciter 20 through a circuit which extends from the positive terminal of the exciter 20 through conductor 61, the field winding 15 and conductor 65 to the negative terminal of the exciter 20.

By inching the mill motor 14 in the manner just described, the end of the strip 13 may be advanced to the winding reel 12. If it is necessary to rotate the reel 12 in order that the strip may be properly clamped in the reel in the usual manner, the left reel motor may be inched by closing the push-button switch 53 to operate the switches 42 and 46, thereby connecting the armature winding 27 across the main generator 18. The energizing circuit for the switch 42 may be traced from the positive conductor 61 through conductor 106, the actuating coil of the switch 42, conductor 107, contact members 108 of the push-button switch 53 and conductor 109 to the negative conductor 65. The energizing circuit for the switch 46 extends from the previously energized conductor 96 through the actuating coil of the switch 46, conductor 97, contact members 110, and the conductor 109 to the negative conductor 65.

The closing of the switches 42 and 46 energizes the armature winding 27 of the dynamo-electric machine 17 through a circuit which extends from the one terminal of the main generator 18 through conductors 101, 81 and 82, contact members 111 of the switch 42, conductor 112, the armature winding 27, conductor 113, the shunt 57, conductor 104, the switch 46 and conductor 105 to the other terminal of the generator 18. At this time, the field winding 29 of the dynamo-electric machine 17 is energized through a circuit which extends from the positive conductor 61 through conductor 114, the field winding 29, conductor 115, contact members 116 of the switch 42, conductor 117, a variable resistor 118 and conductor 119 to the negative conductor 65.

As soon as the end of the strip has been entered into the mill, the stalled tension push-button 47 may be actuated to close the contactors 44 and 46 and the reversing switch 33, thereby reversing the polarity of the booster 21 and causing the right reel motor 16 to rotate in a direction to take up the slack in the strip and then stall. The rheostat 32 is adjusted to raise the voltage of the booster to a higher value than the main generator in order to reverse the current in the reel motor 16.

After the strip 43 is clamped in the reel 12, the rolling operation may be performed. As explained hereinbefore, the dynamo-electric machine 17 functions as a motor to wind the strip 13 on the reel 12 and the machine 16 functions as a braking generator to apply tension on the strip 13 during the rolling operation. Furthermore, the armature windings 22 and 23 of the dynamo-electric machine 16 are connected in series-circuit relation in order that the reel 11 may operate at one-half the speed of the reel 12 and the machines 16 still generate sufficient voltage to cause current to be returned to the power system. In this manner, the booster generator 21 which is connected in the circuit with the armatures 22 and 23 is required only for RI drop compensation as the strip is transferred from one reel to the other during a rolling operation in which a reduction of approximately 50% in the thickness of the strip is obtained for each pass through the rolls 10.

The operation of the mill at this time is controlled by the drum switch 48 which is actuated toward the left, as indicated on the drawings, when the strip is being rolled from the right to the left. At this time, the contactors 41, 42, 44 and 46 and the booster field reversing switch 33 are closed to establish the necessary connections for the operation of the mill. The energizing circuit for the actuating coil of the contactor 41 may be traced from the positive conductor 61 through conductor 92, the actuating coil of the contactor 41, conductor 93, contact segment 121 of the switch 48, conductor 122 and conductor 123 to the negative conductor 65. The energizing circuit for the contactor 42 extends from the positive conductor 61 through conductor 106, the actuating coil of the switch 42, conductor 107, contact segment 124, and conductors 122 and 123 to the negative conductor 65. The energizing circuit for the contactor 44 extends from the positive conductor 61 through the actuating coil of the switch 44, conductor 62, contact segment 125, conductors 126 and 123 to the negative conductor 65. The energizing circuit for the switch 46 may be traced from the positive conductor 61 through conductor 96, the actuating coil of the switch 46, conductor 97, contact segment 127 and conductor 123 to the negative conductor 65. The actuating coil of the reversing switch 33 is energized through a circuit which extends from a positive conductor 61 through conductor 69, the coil of the switch 33, conductor 128, contact segment 129 and conductors 126 and 123 to the negative conductor 65.

The closing of the switch 33 energizes the field winding 31 to cause the booster generator 21 to generate a potential which is added to that produced by the dynamo-electric machine 16 which is connected across the main generator 18 and

functions as a braking generator during the rolling operation, as explained hereinbefore. The energizing circuit for the field winding 31 may be traced from the positive conductor 61 through conductor 74, the resistor 32, conductor 131, contact members 132 of the switch 33, conductor 77, the field winding 31, conductor 76, contact members 133, conductor 134, and conductor 79 to the negative conductor 65.

The closing of the switches 41 and 45 connects the mill motor 14 across the main generator 18 through a circuit which may be traced from one terminal of the generator 18 through conductors 101 and 81, the armature winding 14, conductor 102, the contact members 103 of the switch 41, conductor 104, the switch 46, and conductor 105 to the other terminal of the generator 18. At this time, the resistor 36 should be adjusted to raise the generator voltage 18 to its normal value, thereby maintaining normal speed of the mill motor 14 during the rolling operation.

The closing of the contactor 42 connects the armature winding 27 of the dynamo-electric machine 17 across the main generator 18 to operate the reel 12 to wind the strip 13 on the reel. Since the energizing circuit for the armature 27, established by the closing of the switch 42, has been previously traced, it will not be retraced at this time.

The closing of the switch 44 connects the armature windings 22 and 23 in series-circuit relation and in series with the booster generator 21 across the main generator 18, thereby causing the dynamo-electric machine 16 to function as a braking generator. The circuit through the armatures 22 and 23 may be traced from the one terminal of the armature 22 through conductor 85, the contact members 86 on the switch 44, conductor 87, the booster generator 21, conductor 101, the main generator 18, conductor 105, the switch 46, conductor 104, the shunt 56, conductor 135, the armature 23 and conductor 84 to the other terminal of the armature 22.

As explained hereinbefore, the regulators 54 and 55 control the field excitation of the dynamo-electric machines 16 and 17 during the rolling operation to maintain the motor current within predetermined limits, thereby regulating the tension on the strip 13. As shown, the actuating coil of the regulator 54 is connected across the shunt 56 and it, therefore, responds to the current flowing through the armatures 22 and 23. The contact members of the regulator are disposed to shunt the resistor 91 from the field excitation circuit of these machines when in the position shown in the drawing, thereby providing maximum excitation on the machines and causing them to generate maximum current. The shunt circuit around the resistor 91 extends from the terminal of the resistor 91 through conductor 136, contact members 137 and 138 of the regulator 54, conductor 139, contact segment 141 of the drum switch 48 and conductors 142 and 123 to the negative conductor 65. When the current in the shunt 56 exceeds a predetermined value, the actuating coil of the regulator opens the contact members 137 and 138, thereby inserting the resistor 91 in the field winding circuit and reducing the excitation on the machines to reduce the generated current.

Likewise, the regulator 55 functions to control the current flowing through the armature 27, thereby controlling the tension applied to the strip 13 by the motor 17. When the regulator 55 is in the position shown in the drawings, the resistor 118 is connected in the excitation circuit for the field winding 29 of the motor 17, thereby providing minimum excitation and maximum speed of the motor. If the current drawn by the motor flowing through the shunt 57 exceeds a predetermined value, the actuating coil of the regulator 55 closes contact members 143 and 144 of the regulator to shunt the resistor 118 from the field winding circuit, thereby increasing the excitation on the motor and decreasing its speed which, in turn, decreases the tension applied to the strip 13. The shunt circuit for the resistor 118 extends from the conductor 117 through conductor 145, the contact members 143 and 144 of the regulator 55, conductor 146, contact segment 147, and conductors 148 and 123 to the negative conductor 65. In this manner, a tension on the strip 13 is maintained within predetermined limits during the rolling operation.

When it is desired to stop the mill at the end of the pass, the main control switch 48 may be actuated to the off position thereby deenergizing the switches 41, 42, 44 and 46 to disconnect the machines 16 and 17 and the mill motor 14 from the main generator 18 and also to apply dynamic braking to the mill motor 14 and the machines 16 and 17. At this time, the switch 35 may also be actuated to the off position to remove the excitation from the main generator 18.

The dynamic braking circuit for the mill motor 14 may be traced from one terminal of the armature 14 through conductor 81, the dynamic braking resistor 37, contact members 151 of the switch 41 and conductor 102 to the other terminal of the armature 14. The dynamic braking circuit for the dynamo-electric machine 17 may be traced from one terminal of the armature 27 through conductor 112, the armature 26, conductor 152, the dynamic braking resistor 39, contact members 153 of the switch 42, conductor 154, contact members 155 of the switch 43, and conductor 113 to the other terminal of the armature 27. The dynamic braking circuit for the dynamo-electric machine 16 may be traced from one terminal of the armature 22 through conductor 85, the dynamic braking resistor 38, contact members 156 of the switch 45, conductor 157, contact members 158 of the switch 44, conductor 135, the armature winding 23 and conductor 84 to the other terminal of the armature 22.

Assuming that the mill has been stopped before the end of the strip 13 has left the reel 11, the mill may be reversed to roll from left to right by simply actuating the switch 35 toward the right to reverse the polarity of the main generator 18, thereby reversing the direction of operation of the mill motor 14 and the reel motors 16 and 17, and also actuating the switch 48 toward the right to energize the actuating coils of the switches 41, 43, 45, 46 and the reversing switch 34 to establish the proper connections for rolling from left to right. The energizing circuit for the switch 41 may be traced from the positive conductor 61 through conductor 92, the actuating coil of the switch 41, conductor 93, a contact segment 161 on the switch 48 and conductors 122 and 123 to the negative conductor 65. The energizing circuit for the switch 43 may be traced from the positive conductor 61 through conductor 162, the actuating coil of the switch 43, conductor 163, contact segment 164 and conductors 165 and 123 to the negative conductor 65. The energizing circuit for the switch 45 extends from the positive conductor 61 through conductor 66, the actuating coil of the switch 45, conductor 166, contact seg-

ment 167, and conductors 168 and 123 to the negative conductor 65. The energizing circuit for the switch 46 may be traced from the positive conductor 61 through conductor 96, the actuating coil of the switch 46, conductor 97, contact segment 169, and conductor 123 to the negative conductor 65. The energizing circuit for the reversing switch 34 extends from the positive conductor 61 through conductor 69, the actuating coil of the switch 34, conductors 71 and 72, contact segment 171 and conductors 165 and 123 to the negative conductor 65.

The closing of the switches 41 and 46 connects the mill motor 14 across the generator 18 in the manner described hereinbefore to operate the rolls 10. The closing of the switch 45 connects the armature winding 23 across the generator 18 to drive the reel 11, which now becomes the winding reel. The circuit for the armature winding 23 may be traced from one terminal of the generator 18 through conductors 101, 81, and 82, contact members 172 of the switch 45, conductors 173 and 84, the armature winding 23, conductor 135, the shunt 56, conductor 104, the switch 46 and conductor 105 to the other terminal of the generator 18. At this time, the field winding 25 is energized through a circuit which extends from the positive conductor 61 through the field winding 25, conductor 88, contact members 174 of the switch 45, conductor 89 and the resistor 91 to the negative conductor 65.

Since the reel 12 now becomes the unwinding reel, the armatures 26 and 27 of the dynamo-electric machine 17 are connected in series-circuit relation in order that the machine 17 will function as a braking generator in the manner hereinbefore described to apply a tension on the strip 13. The circuit through the armature windings 26 and 27 may be traced from one terminal of the armature 26 through conductor 152, contact members 175 of the switch 43, conductor 87, the booster generator 21, conductor 101, the generator 18, conductor 105, the switch 46, the shunt 57, conductor 113, the armature winding 27 and conductor 112 to the other terminal of the armature winding 26.

The regulators 54 and 55 function to control the motor current during the rolling operation in the manner hereinbefore described. The contact members 143 and 176 of the regulator 55, which is now controlling the dynamo-electric machine 17 which is now functioning as a generator, establish a shunt circuit for the resistor 118, thereby increasing the generated current until it reaches a value which causes the actuating coil of the regulator 55 to open contact members 143 and 176. The shunting circuit for the resistor 118 may be traced from a conductor 117 through conductor 145, contact members 143 and 176, conductor 177, contact segment 178 and conductors 148 and 123 to the negative conductor 65.

When the current through the armature winding 23 of the reel motor 16 is sufficient to cause the regulator 54 to close its contact members 137 and 179, a shunting circuit is established for the resistor 91 to increase the excitation of the motor 23, thereby reducing its speed and decreasing the tension applied to the strip 13 in the manner previously described. The shunting circuit for the resistor 91 may be traced from the conductor 89 through conductor 136, contact members 137 and 179, conductor 181, contact segment 182, and conductors 142 and 123 to the negative conductor 65.

The mill may be stopped at the end of the pass by actuating the switch 48 to the off position to apply dynamic braking to the motors in the manner hereinbefore described. If it is desired to reverse the mill in order to perform another rolling operation upon the strip of material 13, the switches 35 and 48 are actuated toward the left. If the strip has been reduced to the desired thickness, the reel containing the strip may be removed and another reel placed on the shaft driven by the motors 16 and the new strip threaded through the mill in the manner hereinbefore described, after which the rolling operation is performed as previously explained.

The modification of the invention shown in Fig. 2 is similar to the structure shown in Fig. 1, with the exception that the dynamo-electric machines 16 and 17 are each provided with three armature windings instead of two, as in the system shown in Fig. 1. During the rolling operation, two of the armature windings on the winding reel are connected in series and all three of the armature windings on the unwinding reel are connected in series, thereby establishing conditions to make reductions up to 33⅓% in the thickness of the strip 13 during each pass through the mill instead of 50% as in the system shown in Fig. 1, in which double armatures are used. In the system shown in Fig. 2, the elements of apparatus which are similar in structure and perform the same functions as in the system shown in Fig. 1 are designated by the same reference characters. Therefore, it is believed to be unnecessary to repeat the description of this apparatus at this time.

In addition to the swtich 41 which connects the mill motor 14 across the generator 18 as hereinbefore described, switches 183, 185, 187, 188, 189 and 190 are provided for establishing the proper connections for the machines during the operation of the mill. The dynamo-electric machine 16 is provided with armature windings 191, 192, and 193 and field windings 194, 195 and 196. Likewise, the dynamo-electric machine 17 is provided with armature windings 197, 198 and 199 and field windings 201, 202 and 203.

In addition to the push-button switches 51, 52 and 53, which may be utilized to control the inching operations, the push-button switch 47 may be utilized to provide a stalled tension condition of the unwinding reel 11 when the mill is being put into operation. The current for operating the reel motor 16 is supplied by the booster generator 21 during the stalled tension condition. The current for inching the reel motors 16 and 17 is also supplied by the booster generator 21.

Assuming that the reel containing the strip of material 13 which is to be rolled by the rolls 10 has been placed on the shaft driven by the motors 16 and that the generator 18, the exciter 20 and the booster generator 21 are being driven at the proper speed, it is first necessary to actuate the switch 35 toward the left to provide the proper polarity of the generator 18 for rolling from right to left. Furthermore, the voltage of the generator 18 should be set at a relatively low value by means of the resistor 36 during the inching operations, after which the voltage should be raised to the normal value to perform the rolling operations.

The reel 11 may be inched to advance the strip 13 to the rolls 10 by closing the push-button switch 51 which energizes the contactor 190 and the reversing switch 34 for the booster field 31. The energizing circuit for the switch 190 may be traced from the positive conductor 61 through conductor 205, the actuating coil of the switch

190, conductor 206, contact members 207 of the switch 51 and conductor 208 to the negative conductor 65. The energizing circuit for the switch 34 may be traced from the positive conductor 61 to conductor 209, the actuating coil of the switch 34, conductor 211 and contact members 212 of the switch 51 to the negative conductor 65.

The closing of the switch 34 connects the field winding 31 of the booster generator across the exciter 20, thereby providing excitation for the booster generator. The energizing circuit for the field winding 31 may be traced from the positive conductor 61 through conductors 213 and 214, contact members 215 of the switch 34, the field winding 31, contact members 216, conductor 217, the resistor 32 and conductor 218 to the negative conductor 65. The closing of the switch 190 connects the motor 16 across the booster generator 21 through a circuit which may be traced from one terminal of the booster generator through conductor 221, contact members 222 of the switch 190, conductor 223, the armature winding 193, conductor 224 to the armature winding 192, conductor 225, the armature winding 191, conductor 220, the shunt 56, conductors 226 and 227 to the other terminal of the booster generator 21.

At this time, the field windings for the machine 16 are connected across the exciter 20 through a circuit which may be traced from the positive conductor 61 through the resistor 91, conductor 228, field winding 194, conductor 229, field winding 195, conductor 231, the field winding 196 and conductor 232 to the negative conductor 65. Therefore, the machine 16 will operate the reel 11 to advance the strip 13 toward the rolls 10.

When it is desired to thread the strip 13 through the rolls 10, the mill motor 14 may be inched by closing the push-button switch 52, thereby energizing the actuating coil of the switch 41 and causing this switch to connect the mill motor across the main generator 18. The energizing circuit for the switch 41 may be traced from the positive conductor 61 through conductor 233, the actuating coil of the switch 41, conductor 234, the push-button switch 52, and conductor 208 to the negative conductor 65.

The closing of the switch 41 connects the mill motor 14 across the generator 18 through a circuit which may be traced from one terminal of the generator 18 through conductor 235, the armature of the mill motor 14, conductor 236, contact member 103 of the switch 41, and conductors 237 and 238 to the other terminal of the generator 18.

At this time, tension may be applied to the strip 13 by closing the push-button switch 47 to energize the switches 190 and 33, thereby connecting the reel motor 16 across the booster generator 21 and reversing the polarity of the booster to reverse the direction of operation of the reel 11. The energizing circuit for the switch 190 extends from the positive conductor 61 through conductor 205, the actuating coil of the switch 190, conductor 206, the contact members 241 of the push-button switch 47 and conductor 242 to the negative conductor 65. The energizing circuit for the reversing switch 33 may be traced from the positive conductor 61 through conductor 209, the actuating coil of the switch 33, conductor 243, contact members 244 and conductor 242 to the negative conductor 65. Closing the switch 190 connects the motor 16 across the booster generator 21 through a circuit previously traced. Therefore, the motor will operate to take up the slack in the strip 13 after which it will stall.

In case it is necessary to rotate the reel 12 into the proper position before attaching the end of the strip 13 to the reel, it may be inched by closing the push-button switch 53 to energize the switch 189 and the switch 34 to energize the field winding of the booster 21. The energizing circuit for the switch 189 may be traced from the positive conductor 61 through conductor 245, the actuating coil of the switch 189, contact members 246 of the push-button switch 53 and conductor 247 to the negative conductor 65. The energizing circuit for the switch 34 extends from the positive conductor 61 through conductor 209, the actuating coil of the switch 34, conductors 211 and 248, the contact members 249 of the switch 53 and conductor 247 to the negative conductor 65.

The closing of the switch 34 energizes the field winding 31 through a circuit previously traced. The closing of the switch 189 connects the motor 17 across the booster generator 21 through a circuit which may be traced from one terminal of the booster generator through conductors 221 and 251, the shunt 57, conductor 252, the armature winding 197, conductor 253, and armature winding 198, conductor 254, the armature winding 199, conductor 255, contact members 256 of the switch 189, and conductors 257 and 227 to the other terminal of the booster generator 21.

After the strip 13 is attached to the reel 12, the rolling operation my be performed by actuating the main control drum 48 to the left to energize the actuating coils for the switches 41, 183 and 187, thereby connecting the armatures 197 and 198 of the dynamo-electric machine 17 across the main generator 18 to drive the winding reel 12 and also connecting the three armatures of the dynmo-electric machine 16 in series-circuit relation and in series with the booster generator 21 across the main generator 18 to function as braking generator for the reel 11. The energizing circuit for the switch 41 extends from the positive conductor 61 through conductor 233, the actuating coil of the switch 41, conductor 234, a contact segment 258, on the switch 48, and conductor 259 to the negative conductor 65. The energizing circuit for the switch 183 extends from the positive conductor 61 through conductor 245, the actuating coil of the switch 183, conductor 261, the contact segment 262 and conductor 259 to the negative conductor 65. The energizing circuit for the switch 187 may be traced from the positive conductor 61 through conductor 263, the actuating coil of the switch 187, conductor 264, a contact segment 265, and conductor 266 to the negative conductor 65.

The closing of the switch 41 connects the mill motor 14 across the main generator 18 through a circuit previously traced. The closing of the switch 183 connects the armatures 197 and 198 of the dynamo-electric machine 17 in series-circuit relation and across the generator 18 through a circuit which may be traced from one terminal of the generator through conductors 235, 267 and 268, contact members 269 of the switch 183, conductors 271 and 254, the armature winding 198, conductor 253, the armature winding 197, conductor 252, the shunt 57, conductor 272, contact members 273 of the switch 183, conductors 274 and 238 to the other terminal of the generator 18.

The closing of the switch 187 connects the armature windings 191, 192 and 193 of the dynamo-electric machine 16 in series-circuit relation and in series with the booster generator 21 across

the main generator 18 thereby causing this machine to regenerate current into the power system and function as a brake on the coil 11 to apply tension to the strip 13 during the rolling operation. The circuit through the armature windings of the machine 16 may be traced from one terminal of the generator 18 through the conductors 235, 267 and 268, the contact members 269 of the switch 183, conductors 271 and 275, contact members 276 of the switch 187, conductors 277 and 223, the armature winding 193, conductor 24, armature winding 192, conductor 225, the armature winding 191, conductor 220, the shunt 56, conductors 226 and 227, the booster generator 21, conductors 221, 251 and 272, contact members 273 of the switch 183 and conductors 274 and 238 to the generator 18.

In this manner, the machine 17 drives the reel 12 to wind the strip on this reel and the machine 16 functions as a braking generator for the reel 11. In view of the fact that only two of the armatures of the machine 17 are connected in series while three of th armatur windings of the machine 16 are connected in series during the rolling operation from right to left, the system is inherently suitable for reductions up to 33⅓% in the thickness of the material for each pass through the rolls 10, since the machine 16 will operate at ⅔ of the speed of the motor 17 with the same voltage. As in the system shown in Fig. 1, the booster generator is, therefore, required only for the RI drop compensation and for variations in the size of the reels as a result of the transfer of material from one reel to the other. The booster is also utilized for the inching and stalled tension operations, as described hereinbefore.

It will be noted that the armature 199 is not utilized when the mill is rolling from right to left. No voltage is developed in the armature winding 199, since the field winding 203 is shunted from the excitation circuit by contact members 278 on the switch 183.

At the end of the pass, the mill may be stopped by actuating the switch 48 to the off position thereby deenergizing the switches 41, 183, and 187 to apply dynamic braking to the mill motor 14 and the reel motors 16 and 17. The dynamic braking circuit for the mill motor 14 extends from one terminal of the motor through conductor 236, contact members 151 of the switch 41, the resistor 37 and conductor 267 to the other terminal of the motor 14. The dynamic braking circuit for the reel motor 17 may be traced from one terminal of the armature winding 199 through conductors 255 and 281, contact members 282 on the switch 187, conductor 283, contact members 284 on the switch 189, conductor 285, contact members 286 on the switch 183, conductor 287, the resistor 39, conductor 252, the armature winding 197, conductor 253, armature winding 198 and conductor 254 to the other terminal of the armature winding 199. The braking circuit for the motor 16 may be traced from one terminal of the armature winding 193 through conductors 223, 277 and 288, contact members 289 on the switch 188, conductor 291, contact members 292 on the switch 190, conductor 293, contact members 294 on the switch 185, conductor 295, the resistor 38, conductor 220, armature winding 191, conductor 225, the armature winding 192 and conductor 224 to the other terminal of the armature winding 193.

The operation of the mill may be reversed to roll the material from left to right by actuating the switch 48 to the right and also the switch 35 to the right to reverse the polarity of the main generator 18. When the mill is rolling from left to right, the reel 11 becomes the winding reel and the reel 12 the unwinding reel and the operation of the switch 48 to the right energizes switches 41, 185 and 186 to connect the mill motor 14 to the main generator and establish the proper connections for the machines 16 and 17. The energizing circuit for the switch 41 may be traced from the positive conductor 61 through conductor 233, the actuating coil of the switch 41, conductor 234, a contact segment 296 on the switch 48 and conductor 259 to the negative conductor 65. The energizing circuit for the switch 185 may be traced from the positive conductor 61 through conductor 295, the actuating coil of the switch 185, conductor 297, contact segment 298 on the switch 48 and conductor 299 to the negative conductor 65. The energizing circuit for the switch 188 extends from the positive conductor 61 through conductor 233, the actuating coil of the switch 188, conductor 301, a contact segment 302, and conductor 266 to the negative conductor 65.

The closing of the switch 41 connects the mill motor 14 across the generator 18 through a circuit previously traced. The closing of the switch 185 connects two of the armature windings of the machine 16 across the main generator to drive the reel 11. The circuit for the motor 16 may be traced from one terminal of the generator 18 through conductors 235, 267, and 268, contact members 303 on the switch 185, conductors 304 and 224, the armature winding 192, conductor 225, the armature winding 191, conductor 220, the shunt 56, conductor 305, contact members 306 on the switch 185 and conductor 238 to the other terminal of the generator 18.

The closing of the switch 188 connects all three of the armature windings of the machine 17 in series-circuit relation and in series with the booster generator 21 across the main generator 18. The circuit through the machine 17 may be traced from one terminal of the generator 18 through conductors 235, 267 and 268, the contact members 303 of the switch 185, conductors 304 and 307, contact members 308 on the switch 188, conductors 309, 281 and 255, the armature winding 199, conductor 254, the armature winding 198, conductor 253, the armature winding 197, conductor 252, the shunt 57, conductors 272, 251 and 221, the booster generator 21, conductors 227, 226 and 305, the contact members 306 of the switch 185 and conductor 238 to the other terminal of the generator 18.

In this manner, the dynamo-electric machine 16 functions as a motor to drive the reel 11 and the machine 17 functions as a braking generator for the reel 12, thereby applying tension to the strip 13. The armature winding 193 does not function during this operation since its corresponding field winding 196 is shunted from the excitation circuit by a contact member 311 on the switch 185.

The switches 33 and 34 function to reverse the polarity of the booster generator in the manner hereinbefore described. Therefore, it is believed to be unnecessary to describe further their operation at this time. Likewise, the regulators 54 and 55 control the tension applied to the strip 13 by regulating the current in the excitation circuits for the machines 16 and 17 during the operation of the mill, as described hereinbefore.

The mill may be stopped at the end of the pass by actuating the switch 48 to the off position to

apply dynamic braking to the motors as previously described. If it is desired to reverse the operation of the mill to roll the sheet again from right to left, the switches 35 and 48 are actuated to the left and the operation of the mill repeated. In this manner, the strip may be rolled until the desired thickness is attained, it being understood that the rolls 10 may be screwed down between passes by any suitable means.

From the foregoing description, it is apparent that I have provided a rolling mill drive which is inherently suitable for making predetermined reductions in the thickness of the strip for each pass through the mill. Furthermore, I have provided a system of operation which makes it possible to utilize a booster generator of a relatively low voltage rating and also to utilize machines of a smaller dimension for operating the winding reels.

Since many modifications may be made in the apparatus and arrangement of parts, without departing from the spirit of my invention, I do not wish to be limited other than by the scope of the appended claims.

I claim as my invention:

1. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for connecting certain ones of the armatures of either of said machines to the power source to operate as motors only and certain ones of the armatures of the other machine to the power source to operate as braking generators to tension the material while it is being worked by the mill.

2. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a plurality of dynamo-electric machines for driving each of the reels, and means for connecting certain ones of the machines for either of said reels to the power source to operate as motors only and certain ones of the machines for the other reel to the power source to operate as braking generators to tension the material while it is being worked by the mill.

3. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for connecting a portion of the armatures of either machine to the power source to operate as motors only and all of the armatures of the other machine to the power source operate as braking generators to tension the material while it is being worked by the mill.

4. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a plurality of dynamo-electric machines for driving each of the reels, and means for connecting a portion of the machines for either of said reels to the power source to operate as motors only and all of the machines for the other reel to the power source to operate as braking generators to tension the material while it is being worked by the mill.

5. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for connecting a portion of the armatures of either machine to the power source to operate as a motor and for connecting the armatures of the other machine to the power source in series-circuit relation to operate as braking generators to tension the material while it is being worked by the mill.

6. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a plurality of dynamo-electric machines for driving each of the reels, and means for connecting a portion of the machines for either of said reels to the power source to operate as motors, and for connecting all of the machines for the other reel to the power source in series-circuit relation to operate as braking generators to tension the material while it is being worked by the mill.

7. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a booster generator, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for connecting a portion of the armatures of either machine directly to the power source to operate as motors and for connecting the armatures of the other machine to the power source in series-circuit relation and in series with the booster generator to operate as braking generators to tension the material while it is being worked by the mill.

8. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a booster generator, a plurality of dynamo-electric machines for driving each of the reels, and means for connecting a portion of the machines for either of said reels directly to the power source to operate as motors and for connecting all of the machines for the other reel to the power source in series-circuit relation and in series with the booster generator to operate as braking generators to tension the material while it is being worked by the mill.

9. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for operating either of said machines as a motor at the voltage of the power source and the other machine as a braking generator, the armatures of the machine which is operating as a generator being connected to the power source in series-circuit relation.

10. In a rolling mill, in combination, winding and unwinding reels for handling strip material being worked by the mill, a power source, a booster generator, dynamo-electric machines for driving the reels, each of said machines having a plurality of armatures, and means for operating either of said machines as a motor at the voltage of the power source and the other machine as a braking generator, the armatures of the machine which is operating as a generator being connected to the power source in series-circuit relation and in series with said booster generator.

11. The combination with a rolling mill and winding and unwinding reels on opposite sides thereof, of a dynamo-electric machine connected to each of said reels adapted to serve as a driving motor or as a regenerative brake therefor, each of said machines having a plurality of armatures, a source of power, a booster generator, and means for connecting the booster generator across

the power source in series-circuit relation with all of the armature windings of the dynamo-electric machine functioning as the regenerative brake to cause the voltages developed by each to be added, thereby permitting the braking machine to operate at a slower speed than the motoring machine.

12. The combination with a rolling mill and winding and unwinding reels on opposite sides thereof, of a dynamo-electric machine connected to each of said reels adapted to serve as a driving motor or as a regenerative brake therefor, each of said machines having a plurality of armatures, a source of power, a booster generator, means for operating the dynamo-electric machine functioning as a motor at the voltage of the power source, and means for connecting the booster generator across the power source in series-circuit relation with all of the armature windings of the dynamo-electric machine functioning as the regenerative brake to cause the voltages developed by each to be added, whereby said braking machine may operate at a slower speed than the motoring machine and regenerate power into the power source.

13. The combination with a rolling mill and winding and unwinding reels for handling strip material being worked by the mill, of a dynamo-electric machine connected to each of said reels, one of said machines functioning as a motor and the other as a braking generator, each of said machines having a plurality of armatures, a source of power, a booster generator, and means for connecting said machines to the power source, said generating machine having a greater number of armatures connected to the power source in series-circuit relation than said motoring machine, said booster generator being also connected in series-circuit relation with the armatures of said generating machine.

14. The combination with a rolling mill and winding and unwinding reels for handling strip material being worked by the mill, of a dynamo-electric machine connected to each of said reels, one of said machines functioning as a motor and the other as a braking generator, each of said machines having a plurality of armatures, a source of power, a booster generator, means for operating the motoring machine at the voltage of the power source, and means for connecting the armatures of the generating machine to the power source in series-circuit relation and in series with the booster generator.

ALONZO F. KENYON.