

April 24, 1962

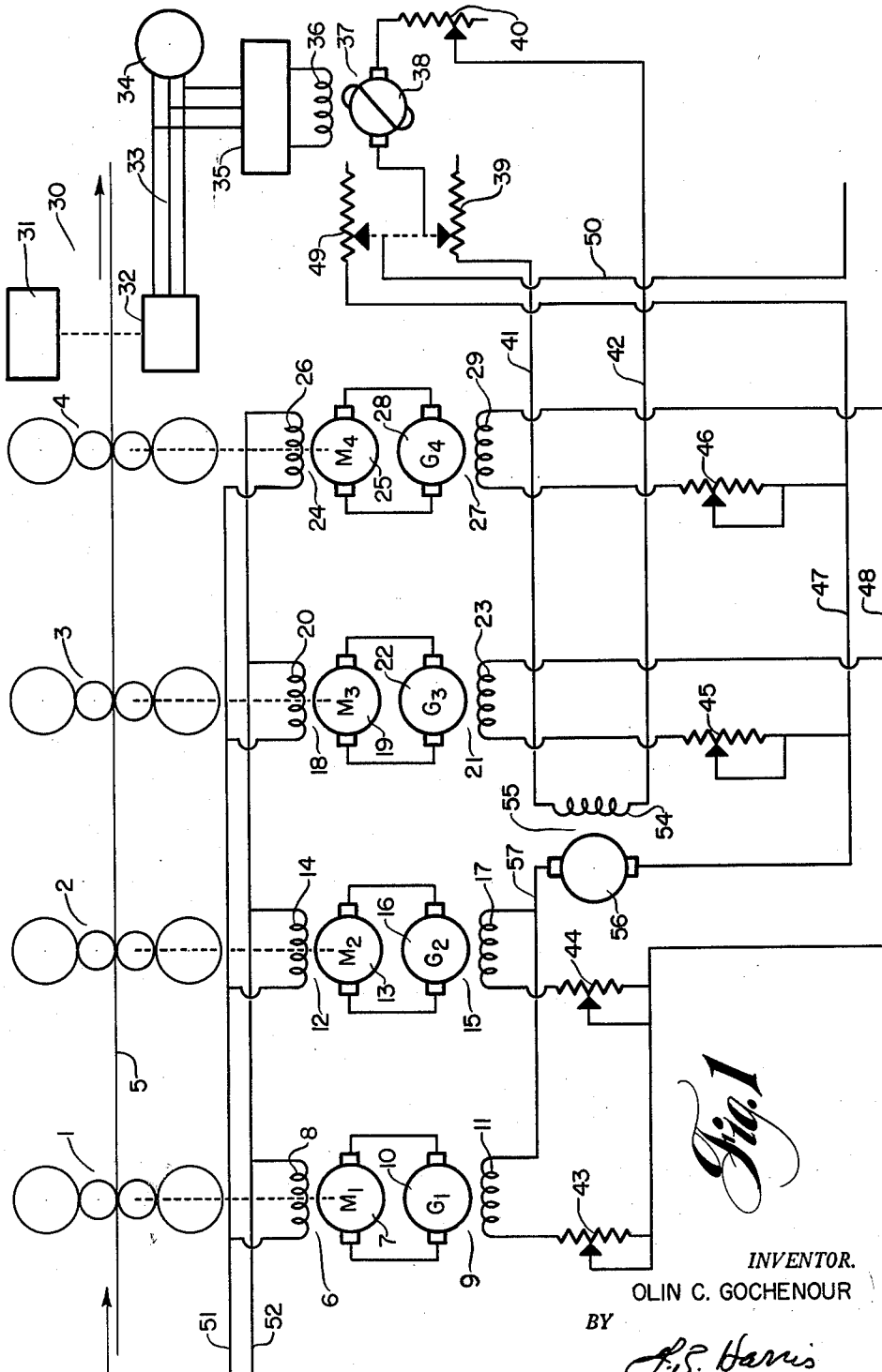
O. C. GOCHENOUR

3,030,836

CONTINUOUS STRIP GAUGE CONTROL MEANS

Filed July 8, 1957

2 Sheets-Sheet 1



April 24, 1962

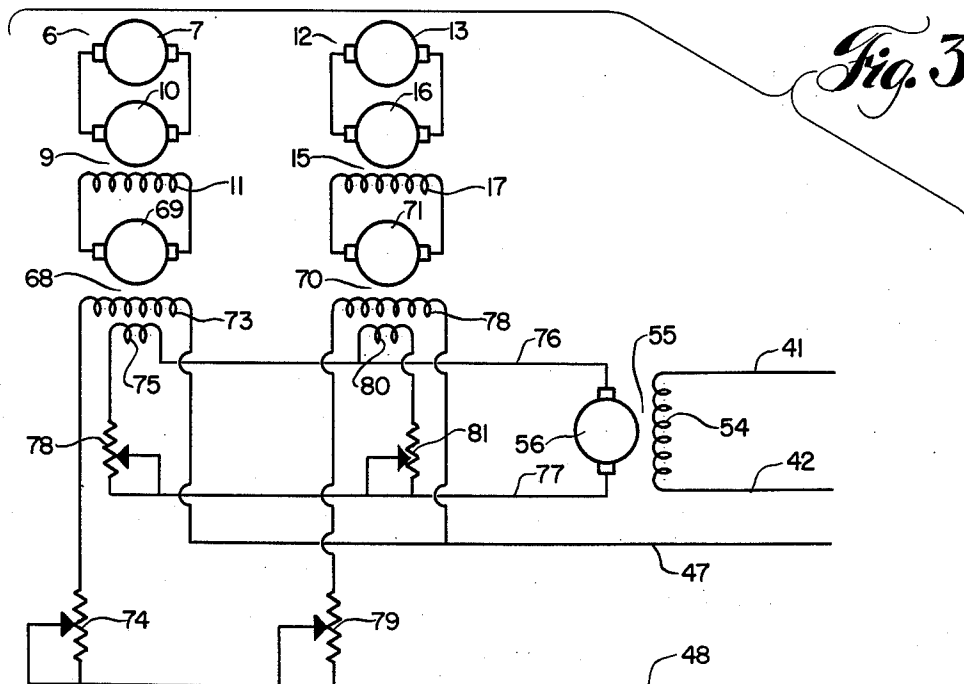
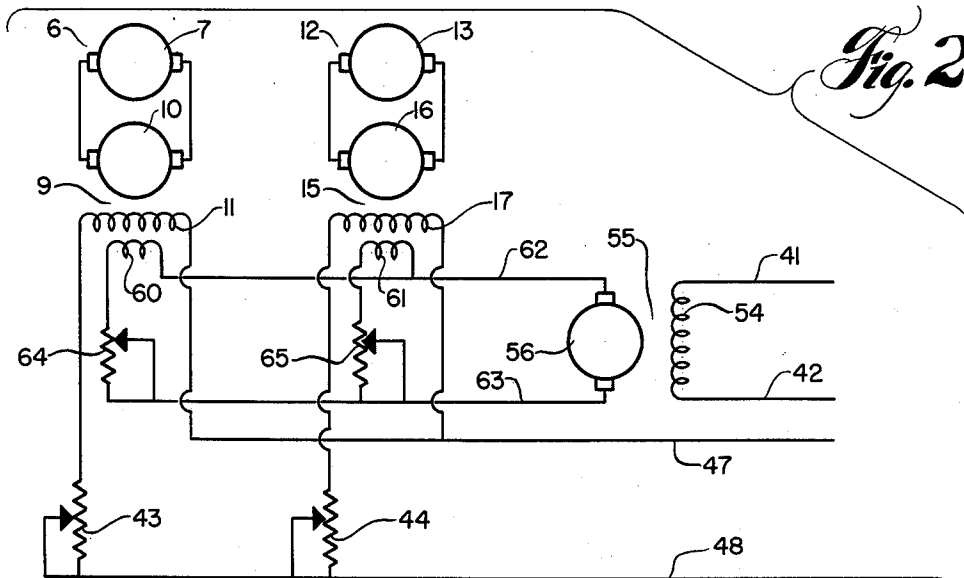
O. C. GOCHENOUR

3,030,836

CONTINUOUS STRIP GAUGE CONTROL MEANS

Filed July 8, 1957

2 Sheets-Sheet 2



INVENTOR.
OLIN C. GOCHENOUR

BY

L.R. Harris
ATTORNEY

1

3,030,836

CONTINUOUS STRIP GAUGE CONTROL MEANS
Olin C. Gochenour, Thornburg, Pa., assignor to Jones & Laughlin Steel Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

Filed July 8, 1957, Ser. No. 670,433

4 Claims. (Cl. 80—35)

This invention relates to a tandem reducing mill for the rolling of metal strip adapted to effect close control of the gauge of the material rolled. My invention is particularly adapted to tandem mills for cold rolling steel strip for tinplate and similar applications, but is also applicable to mills for rolling other metal strip material.

In the rolling of thin metal strip material, such as steel strip, it is of great importance to produce a product of uniform gauge. Various devices have been developed for continuously indicating the gauge of the strip as it leaves the mill and various schemes have been devised for using the indications of these devices to bring about automatic adjustment of the mill to compensate for variations in the gauge so measured. All such apparatus known prior to my invention, however, required an appreciable time to effect compensation for non-uniformity in gauge, with the result that a considerable amount of off-gauge product was produced before the mill could be properly readjusted. In a mill rolling strip of tinplate gauge at 3600 feet per minute, which is not uncommon, a few seconds' delay in correcting for gauge variation results in the production of hundreds of feet of off-gauge material.

It is the principal object of my invention, therefore, to provide apparatus for rolling thin strip of uniform gauge which rapidly compensates for gauge variations in the final product so as to minimize the amount of off-gauge product. It is another object of my invention to provide such apparatus which is readily adapted to modern high-speed strip mills. Other objects of my invention will appear in the course of the following description thereof.

It is well known that the gauge of strip being rolled can be controlled in two ways—either by controlling the pressure on the rolls of one or more stands, or by controlling the tension maintained in the strip. My apparatus acts to control strip tension between one or more pairs of stands in a tandem mill and effects the control of tension by the adjustment of the speed of one or more stands. Modern tandem strip mills are provided with separate drive motors for each stand and, in some cases, with a separate motor generator for each drive motor. My invention is adapted to a tandem mill having at least one stand preceding the exit stand provided with a separate drive motor and a separate motor generator therefor. The drive motors for the other stands may be supplied by separate generators or from a common power source. My invention comprises, in brief, conventional means for determining the gauge of the material leaving the exit stand of a tandem mill and field current supply means controlled by the automatic gauging means for supplying field current to the generator or generators for one or more stands preceding the exit stand so as to vary the speeds of those stands and so vary the tension between the controlled stand or stands and the next following stand.

An embodiment of my invention and two modifications thereof presently preferred by me are illustrated in the figures to which reference is now made.

FIG. 1 is a schematic diagram of the apparatus of my invention adapted to a four-stand tandem mill.

FIG. 2 is a schematic diagram of a portion of the apparatus of FIG. 1 modified in accordance with a modification of my invention.

FIG. 3 is a schematic diagram of a portion of the appa-

2

ratus of FIG. 1 further modified in accordance with another modification of my invention.

In FIG. 1 the four stands of my mill are designated, left to right, as stands 1, 2, 3 and 4. Strip 5 moves through these stands from left to right and is continuously reduced thereby. Stand 1 is driven by an electric motor 6 having an armature 7 and a field 8. Motor 6 is supplied with armature current by generator 9 having an armature 10 and a field 11. Stand 2 is driven by motor 12 having an armature 13 and a field 14 and motor 12 is supplied with armature current by generator 15 having an armature 16 and a field 17. Stand 3 is driven by motor 18 having an armature 19 and a field 20. Motor 18 is supplied with armature current by generator 21 having an armature 22 and a field 23. Stand 4 is driven by motor 24 having an armature 25 and a field 26. Motor 24 is supplied with armature current by generator 27 having an armature 28 and a field 29.

Strip 5 after leaving stand 4 is automatically gauged by thickness gauge 30, which may be an X-ray gauge of the type known to the art. Such a gauge consists of an X-ray source 31 positioned on one side of the strip and X-ray detecting means 32 positioned on the other side of the strip opposite X-ray source 31. The output of detecting means 32 is a voltage which may be applied through conductors 33 to an indicator 34. Detecting means 32 are also connected to a discriminator 35 which supplies a direct current of reversible polarity to the field 36 of an amplidyne 37. The armature 38 of amplidyne 37 is connected to rheostat 39 and vernier rheostat 40 and from these rheostats through conductors 41 and 42, respectively, to field 54 of an auxiliary generator 55. The armature 56 of generator 55 is connected in circuit with conductors 47 and 57, the latter of which is connected to one terminal each of fields 11 and 17 of generators 9 and 15. Field 11 through an adjustable resistor 43 and field 17 through a like adjustable resistor 44 both connect to conductor 48.

Field 23 of generator 21 is connected through adjustable resistor 45 to conductors 47 and 48. Field 29 of generator 27 is likewise connected through adjustable resistor 46 to these same conductors. Conductor 47 is connected to rheostat 49 and from it through conductor 50 to a source of field supply voltage which is not shown. Conductor 48 is connected to the same source. The moving contacts of rheostats 39 and 49 are mechanically connected together. Fields 8, 14, 20 and 26 of motors 6, 12, 18 and 24 are connected to conductors 51 and 52, which in turn are connected with a source of field excitation for the drive motors which is not shown. The drive motors are direct current motors requiring direct current both for armatures and fields.

FIG. 2, which illustrates a modification of my invention, shows only the drive motors and apparatus associated therewith for stands 1 and 2 of a four-stand tandem mill. The apparatus shown in FIG. 2 which is common to FIG. 1 carries the reference characters which have previously been applied to that apparatus. The principal difference between the apparatus of FIG. 2 and that of FIG. 1 is that generators 9 and 15 are each provided with an auxiliary field winding. Auxiliary field winding 60 is carried by generator 9 and a like auxiliary field winding 61 is carried by generator 15. One terminal of each of these field windings 60 and 61 is connected to conductor 62, which in turn is connected to a terminal of armature 56 of auxiliary generator 55. The other terminal of field winding 60 is connected through adjustable resistor 64 to conductor 63, which in turn is connected to the other terminal of armature 56 of auxiliary generator 55. The other terminal of field winding 61 is likewise connected through adjustable resistor 65 with conductor 63.

FIG. 3 illustrates a further modification of my invention. It shows only the drive motors for stands 1 and 2 of my four-stand tandem mill together with the apparatus of my invention for supplying armature current to those motors. Again, the apparatus common to FIG. 1 carries the reference characters which have been applied thereto. In FIG. 3 field 11 of generator 9 and field 17 of generator 15 are each supplied by separate generator exciters designated 68 and 70, respectively. Generator exciter 68 has an armature 69 which is connected across field 11. It is also provided with a first field winding 73, one terminal of which is connected to conductor 47. The other terminal of field 73 is connected through adjustable resistor 74 to conductor 48. Generator exciter 68 is also provided with an auxiliary field winding 75, one terminal of which is connected to conductor 76. The other terminal of auxiliary field winding 75 is connected through adjustable resistor 78 to conductor 77. Conductors 76 and 77 are connected to armature 56 of generator 55. Generator exciter 70 has an armature 71 which is connected across field 17, and a first field winding 78, one end of which is connected to conductor 47. The other end of field 78 is connected through adjustable resistor 79 to conductor 48. Generator exciter 70 is also provided with an auxiliary field winding 80, one end of which is connected to conductor 76 and the other through adjustable resistor 81 to conductor 77.

I shall now describe the operation of my apparatus as shown in FIG. 1 and described herein. I do not deem it necessary to describe the operation of a continuous X-ray thickness gauge as these gauges are well-known to the art and as such form no part of my invention. Likewise, I do not deem it necessary to described the operation of discriminator 35, other than to say that it provides direct current to field 36 of my amplidyne 37, this current being of one polarity when the strip being gauged is thicker than desired and the other polarity when the strip being gauged is thinner than desired. Apparatus of this type is also well-known to the art. An X-ray thickness gauge and discriminator suitable for my invention are shown in U.S. Patent 2,653,247 granted to W. N. Lundahl on September 22, 1953.

Let it be supposed that strip 5 leaving the stand 4 of my mill is exactly the thickness desired. In that case, discriminator 35 supplies no current to field 36 of my amplidyne 37, and the amplidyne under these conditions supplies no current to field 54 of auxiliary generator 55. Therefore, fields 11 and 17 of generators 9 and 15, respectively, are supplied with current at the same voltage as is applied to fields 23 and 29 of generators 21 and 27, except for the voltage drops through the adjustable resistors in series therewith. Now let it be assumed that strip 5 gauges heavier than is desired. Discriminator 35 then sends direct current through field 36 of my amplidyne 37 in a direction such that amplidyne 37 supplies current to field 54 of a polarity such that generator 55 generates voltage opposing that across conductors 47 and 48. Under these conditions the voltage applied to fields 11 and 17 of generators 9 and 15 is reduced, and these generators supply lower armature voltages to motors 7 and 13. These motors, therefore, slow down correspondingly. If the speed of stand 2 is reduced but the speed of stand 3 remains unchanged, it is seen that the tension in the strip between the stands 2 and 3 will necessarily increase, and this increase in tension stretches the strip and reduces its thickness somewhat. By adjustment of resistors 43 and 44, stand 1 can be slowed down to a somewhat greater extent than stand 2 so that the tension in the strip between stands 1 and 2 is also increased and its thickness decreased. Therefore, my apparatus has corrected for the undesired increase in gauge of the strip as detected by the continuous thickness gauge 30. If the strip 5 leaving stand 4 is under gauge, discriminator 35 furnishes direct current to field 36 in a direction to reverse the current

which amplidyne 37 supplies to field 54 of auxiliary generator 55. The voltage supplied by that generator then adds to the voltage across conductors 47 and 48, motors 6 and 12 thereupon increase in speed, and the tension between stands 2 and 3, as well as stands 1 and 2, is reduced so that the reduction of gauge in the strip between these stands is lessened. The mill can be brought to a stop or brought up to full speed by operation of rheostat 49 which varies the currents in the fields of all the generators supplying the mill motors. As has been mentioned, the moving contact of rheostat 49 is mechanically connected to that of rheostat 39 so that manual operation of rheostat 49 also varies the resistance between the amplidyne 37 and the field 54 of generator 55. Rheostat 39 has a resistance selected to provide at any setting the voltage output of generator 55 required for proper speed change at the voltage and speed determined by the corresponding setting of rheostat 49. Rheostat 40 may be varied manually to effect desired changes in the relation between the voltage supplied by generator 55 and that between conductors 47 and 48. Adjustable resistors 45 and 46 are set to adjust the speeds of stands 3 and 4 relative to each other and to that of stand 2.

The operation of the embodiment of my invention illustrated in FIG. 2 will be readily understood in the light of the foregoing description. Generator 56 furnishes current to auxiliary fields 60 and 61 of generators 9 and 15 instead of to their main fields 11 and 17. The provision of two fields each on generators 9 and 15 permits the larger portion of the current required for field supply to be obtained from the same source which supplies field current to the other generators. The auxiliary windings only are supplied from generator 55, the output of which is varied in accordance with the measurement of the thickness of the strip being rolled. As the variation of speed required to compensate for gauge changes is normally only a small percentage of the normal speed of the mill, the power required from generator 55 in this modification of my invention is relatively small. Field windings 60 and 61 may be formed of relatively small diameter wire so that generator 55 is required to furnish relatively small currents only. By adjustment of resistors 64 and 65 stand 1 can be caused to vary in speed to a greater extent than stand 2 so that the tension in the strip between stands 1 and 2 is varied in the same manner as the tension in the strip between stands 2 and 3.

The operation of the embodiment of my invention illustrated in FIG. 3 is likewise readily grasped in view of the foregoing descriptions of the operation of the apparatus shown in FIGS. 1 and 2. In FIG. 3 the dual field windings are found on generator exciters 69 and 71 rather than the much larger generators 9 and 15. Thus the amount of power required to be supplied by generator 55 is even smaller for the arrangement of FIG. 3 than for that of FIG. 2. Adjustable resistors 78 and 81 have the same functions in the apparatus shown in FIG. 3 as adjustable resistors 64 and 65 in FIG. 2.

I find that it is undesirable when rolling thin steel strip to vary any conditions of stand 4, the final stand of my mill. Variation in conditions of the last stand tend to influence unfavorably the flatness of the strip. Therefore, I prefer not to control stand 3, as any change in the speed of this stand will necessarily change the tension in the strip between stands 3 and 4. In a four-stand mill, as is shown in my FIG. 1, I obtain best results by controlling stands 1 and 2. It is desirable to control all stands preceding the last controlled stand because otherwise a reduction in the tension of the strip between the controlled stand and the next following stand would be accompanied by an increase in the tension of the strip between the controlled stand and the next preceding stand which would partially offset the effect desired. The stand next preceding the final controlled stand may be controlled so as to maintain constant the tension in the strip between it and the final controlled stand, or, as I

have mentioned, it may be controlled so as to reduce that tension when tension in the strip between it and the final controlled stand is reduced, and vice versa. This adjustment for the mill shown in the figure is accomplished by adjusting resistors 43 and 44.

My apparatus responds quickly to changes in gauge of the strip. Amplidyne 37 in response to the current supplied to its field 36 by discriminator 35 rapidly applies a voltage aiding or opposing that normally supplied to the fields of my controlled generators and by proper choice of amplidyne characteristics I may make this voltage as large as is necessary to secure rapid current change in generator fields 11 and 17. I find that in one installation of my invention in a mill with which I am familiar, the maximum voltage which the amplidyne need supply is only about plus or minus 3% of the normal field supply voltage for generator fields 11 and 17. This installation corrects for any normal operating variation of strip gauge in from a half to two-thirds of a second.

Although I have illustrated and described my invention as applied to a four-stand tandem mill, it will be understood that my invention is not limited to a mill of four-stands but may be applied to tandem mills having a larger or smaller number of stands.

I claim:

1. In a tandem reducing mill, a drive motor driving the second stand preceding the exit stand and no following stands, a generator supplying armature current for the drive motor only, means for supplying field current to the generator, means positioned at the exit end of the mill for continuously measuring the thickness of the material rolled, auxiliary field current supply means for supplying field current to the generator and to no generator for any following stand, and control means for the auxiliary field current supply means actuated by the thickness measuring means so that measurement of increased thickness causes a decrease in the speed of the drive motor and measurement of decreased thickness causes an increase in the speed of the drive motor.

2. In a tandem reducing mill, a separate drive motor for each stand, a separate generator supplying armature current for each separate drive motor, means for supplying field current for the separate generators, means positioned at the exit end of the mill for continuously measuring the thickness of the material rolled, auxiliary field current supply means for supplying field current to the separate generator for the second stand preceding the exit stand and to no generator for any following stand, and control means for the auxiliary field current supply means actuated by the thickness measuring means so that measurement of increased thickness causes a decrease in the speed of the drive motor for the second stand preceding the exit stand, and measurement of decreased thickness causes an increase in the speed of that drive motor.

3. In a tandem reducing mill, a first drive motor driving only the second stand preceding the exit stand, a second drive motor driving the third stand preceding the exit stand and no following stands, a generator supplying armature current for the first drive motor only, a second

generator supplying armature current for the second drive motor, means for supplying field current to the first and second generators, means positioned at the exit end of the mill for continuously measuring the thickness of the material rolled, auxiliary field current supply means for supplying field current to the first and second generators and to no generator for any following stand, first and second current adjusting means in circuit with the auxiliary field current supply means and the first and second generators, respectively, and control means for the auxiliary field current supply means actuated by the thickness measuring means so that measurement of increased thickness causes a decrease in the speed of the first and second drive motors and measurement of decreased thickness causes an increase in the speed of the first and second drive motors, the first and second current adjusting means being adjusted so that changes in speed of the second drive motor are proportionately greater than changes in speed of the first drive motor.

4. In a tandem reducing mill, drive motor means for the exit stand and the first stand preceding the exit stand, generator means for supplying armature current for the drive motor means, a separate drive motor for the second stand preceding the exit stand, a separate generator supplying armature current for the separate drive motor, means for supplying field current to the generator means and the separate generator, means positioned at the exit end of the mill for continuously measuring the thickness of the material rolled, auxiliary field current supply means for supplying field current to the separate generator, control means for the auxiliary field current supply means actuated by the thickness measuring means so that measurement of increased thickness causes a decrease in the speed of the separate drive motor and measurement of decreased thickness causes an increase in the speed of that motor, first manual control means in circuit with the means for supplying field current to the generator means and the separate generator, second manual control means in circuit with the auxiliary field current supply means, and a mechanical connection between first and second manual control means whereby they are varied together to increase or decrease the speed of the mill without change in strip tension.

References Cited in the file of this patent

UNITED STATES PATENTS

2,210,708	Cook	Aug. 6, 1940
2,295,399	Hanna	Sept. 8, 1942
2,342,767	Stoltz	Feb. 29, 1944
2,544,467	Michel	May 6, 1951
2,586,412	Winchester	Feb. 19, 1952
2,626,376	Harder et al.	Jan. 20, 1953
2,851,911	Hessenberg	Sept. 16, 1958
2,949,799	Walker	Aug. 23, 1960

FOREIGN PATENTS

533,162	Great Britain	Feb. 7, 1941
774,373	Great Britain	May 8, 1957