April 27, 1937. E. B. HUDSON 2,078,711

ROLLING UNDER TENSION

Filed April 26, 1933 8 Sheets-Sheet 1

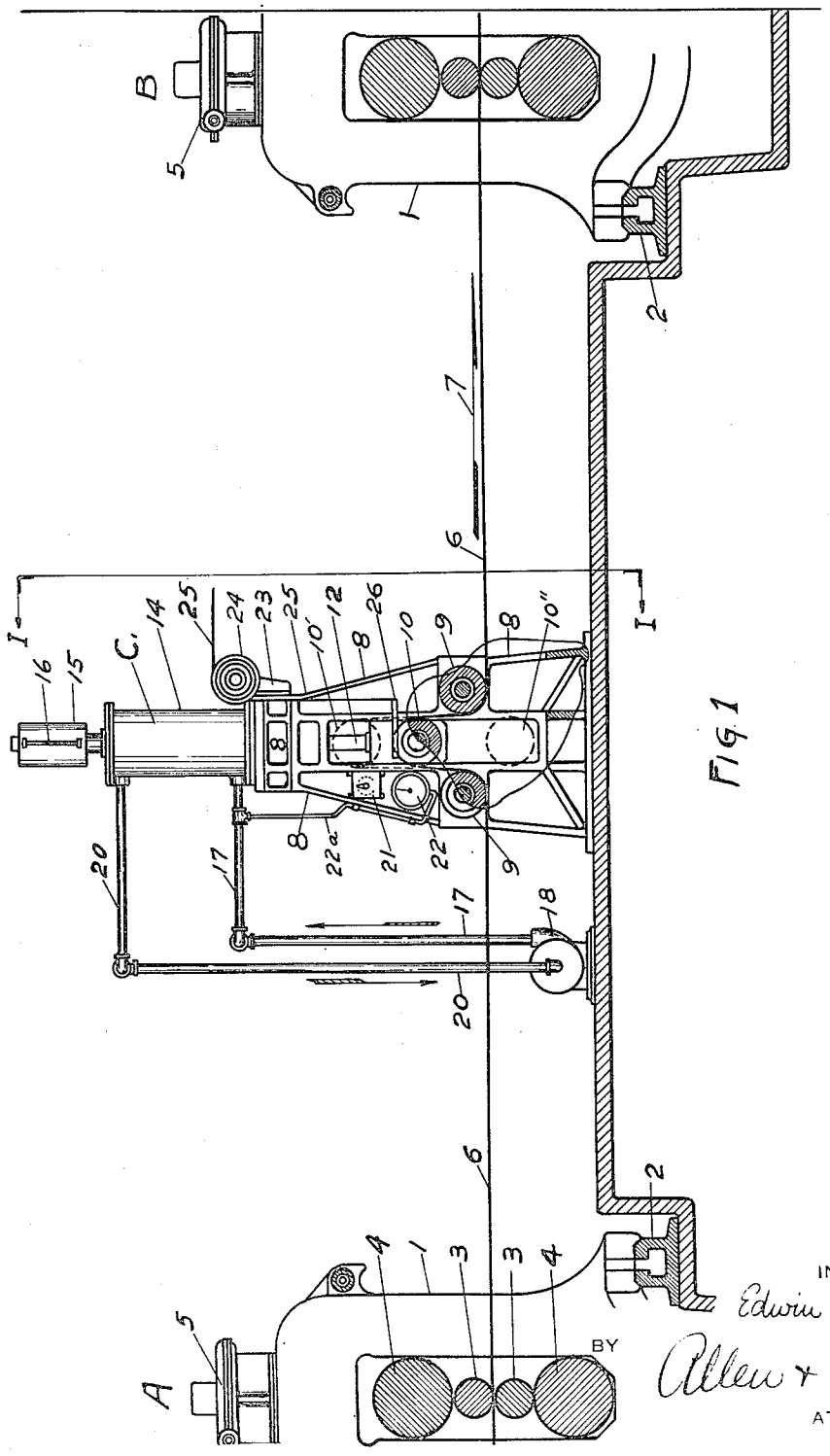


FIG 1

INVENTOR.
Edwin B. Hudson
BY
Allen & Allen
ATTORNEYS.

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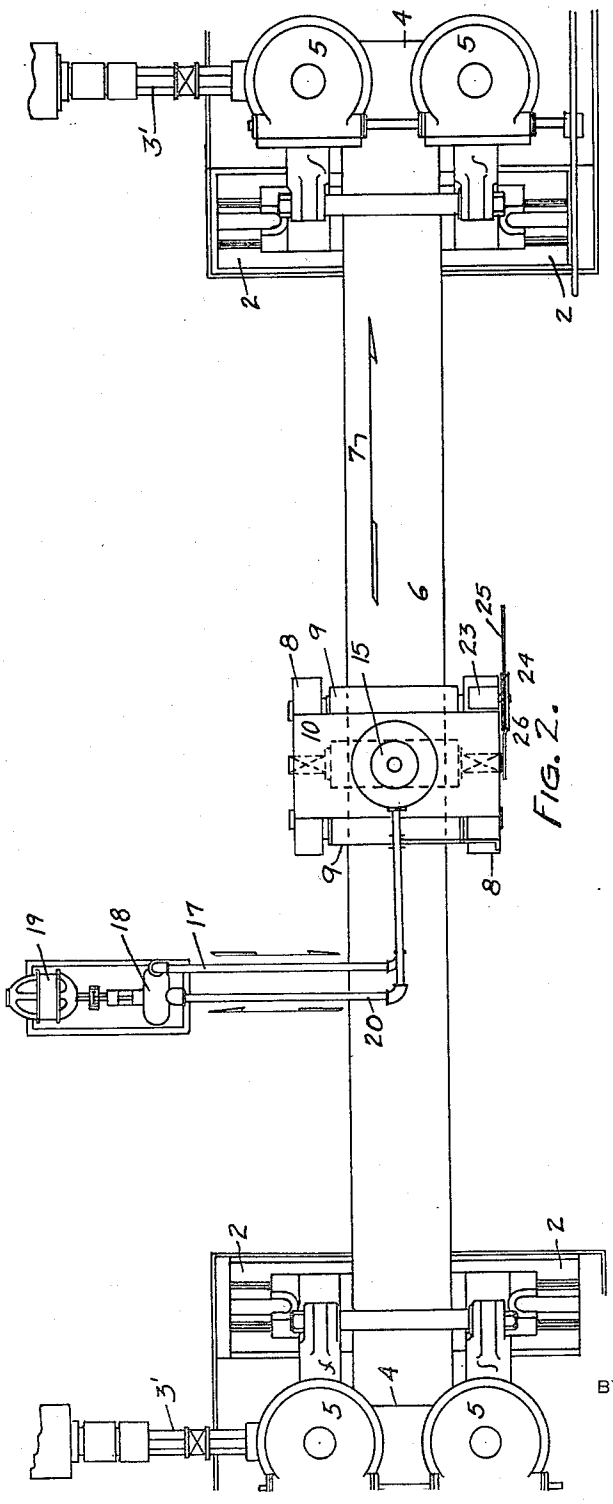


FIG. 2.

INVENTOR.
Edwin B. Hudson
BY Allen & Allen
ATTORNEYS.

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ROLLING UNDER TENSION

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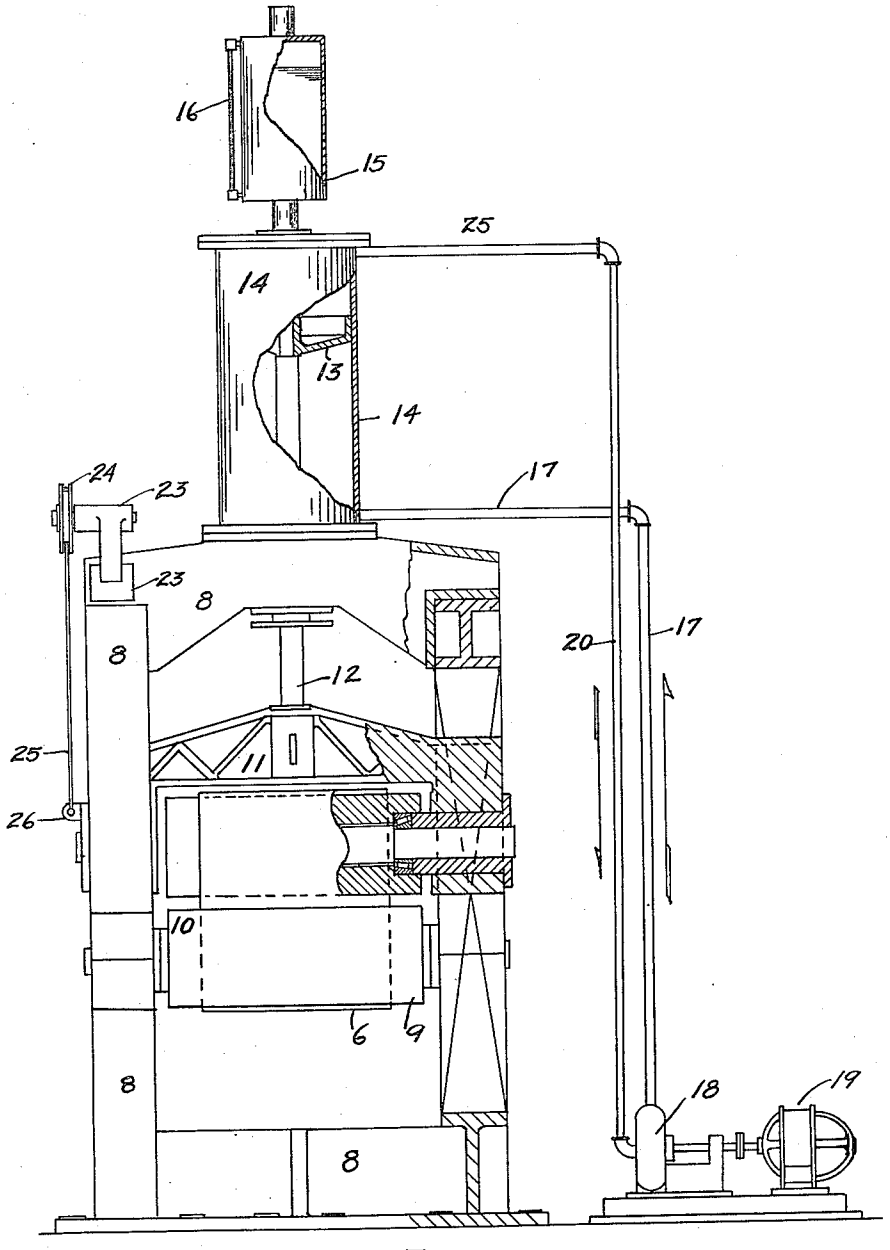


FIG. 3.

INVENTOR.
Edwin B. Hudson
BY Allen & Allen
ATTORNEYS.

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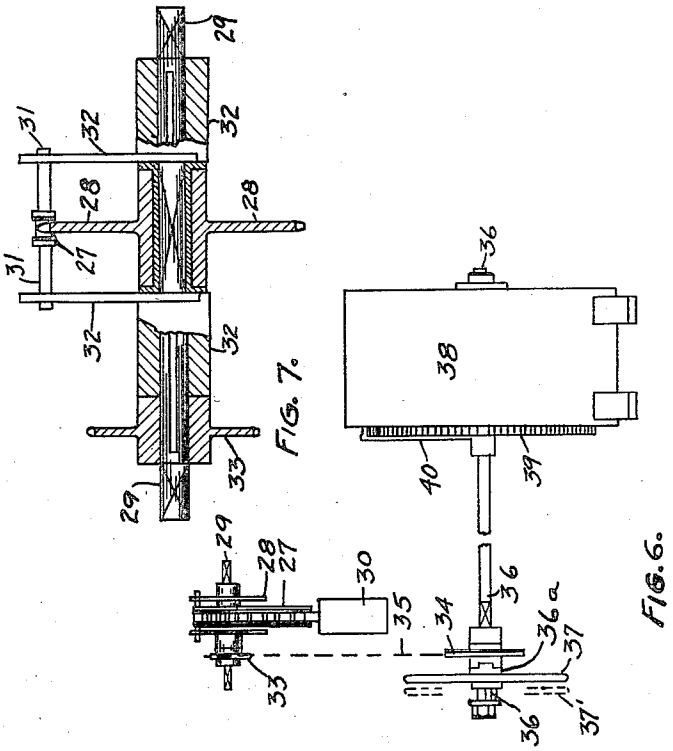


FIG. 7.

FIG. 6.

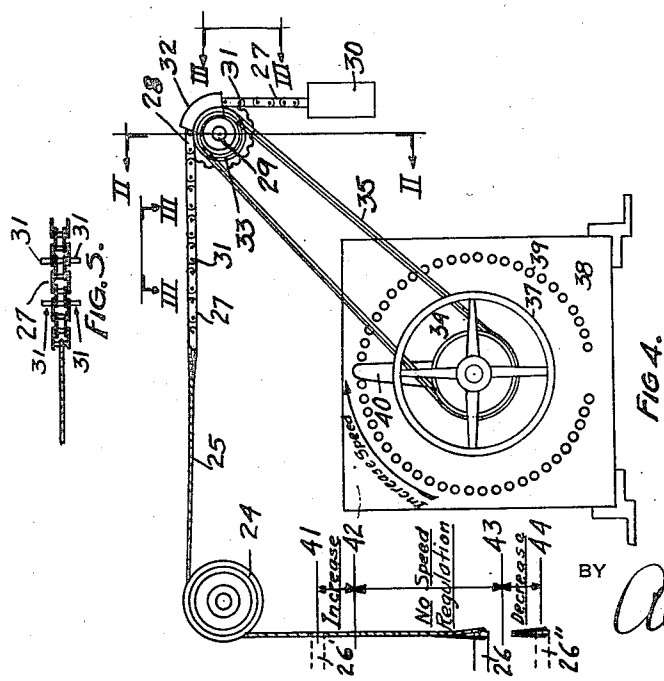


FIG. 5.

FIG. 4.

INVENTOR.
Edwin B. Hudson
BY
Allen & Allen
ATTORNEYS.

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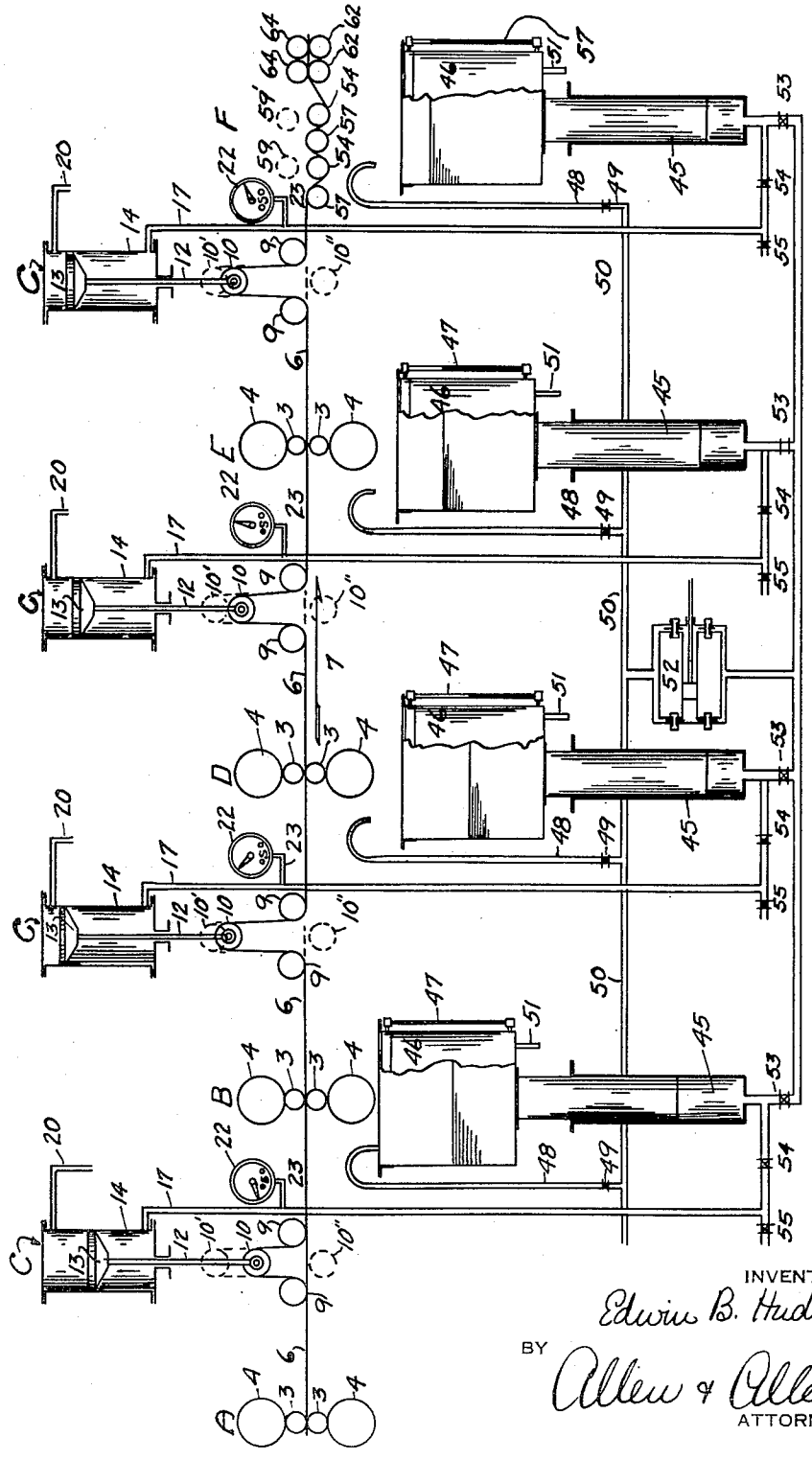


FIG. 8.

INVENTOR.
Edwin B. Hudson
BY
Allen & Allen
ATTORNEYS.

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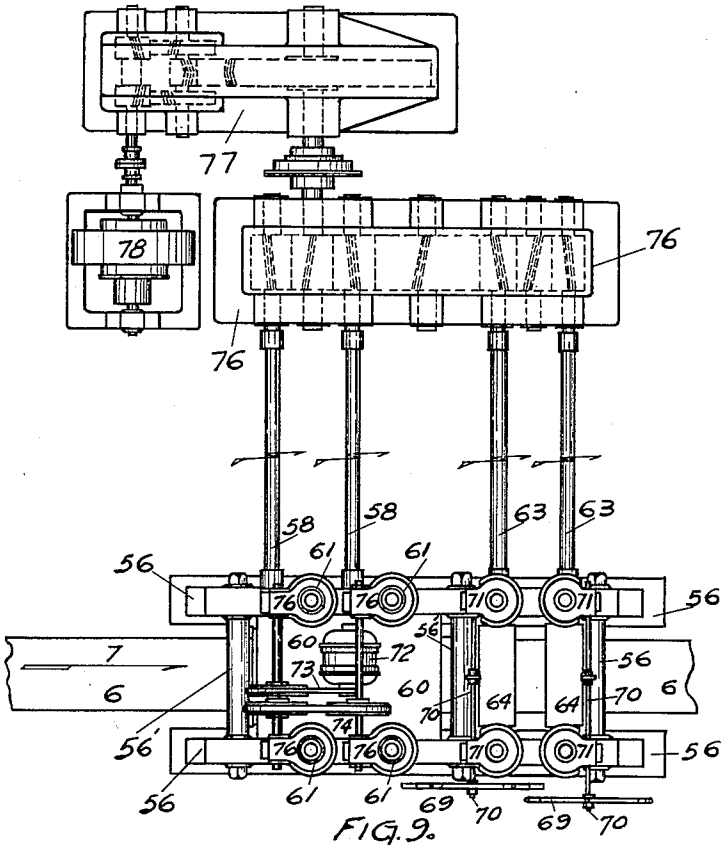


FIG. 9.

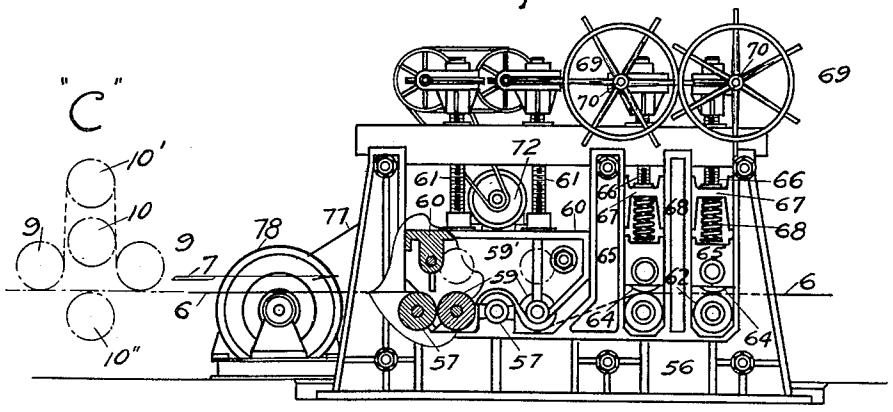


FIG. 10.

INVENTOR.
Edwin B. Hudson
BY
Allen & Allen
ATTORNEYS.

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ROLLING UNDER TENSION

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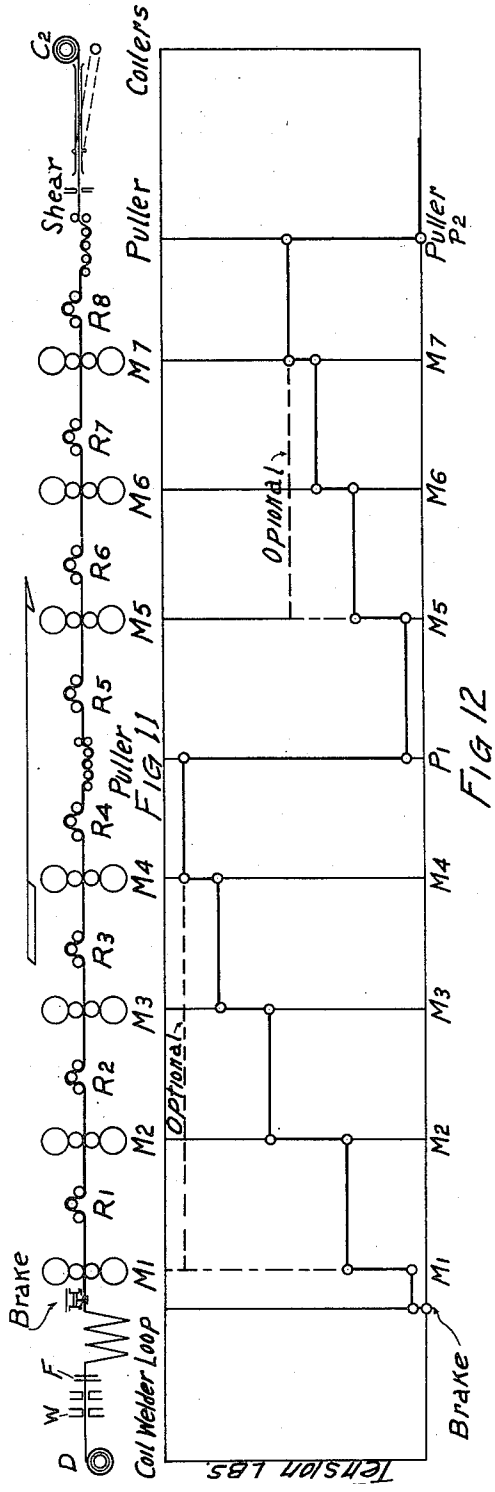


FIG 12

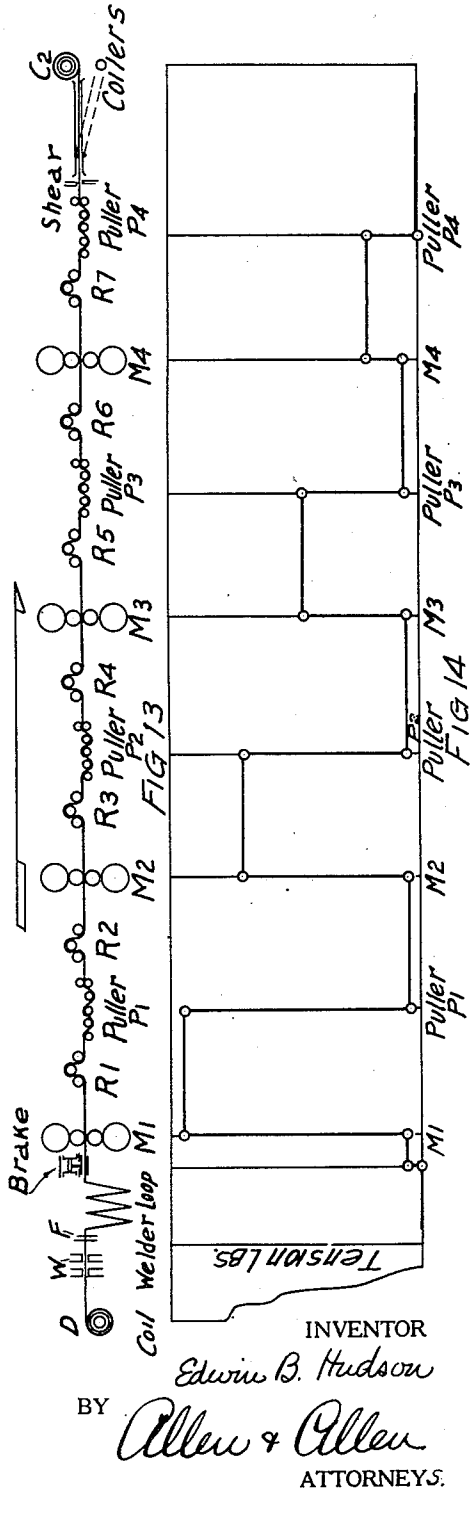


FIG 13 FIG 14

INVENTOR
Edwin B. Hudson
BY Allen & Allen
ATTORNEYS.

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ROLLING UNDER TENSION

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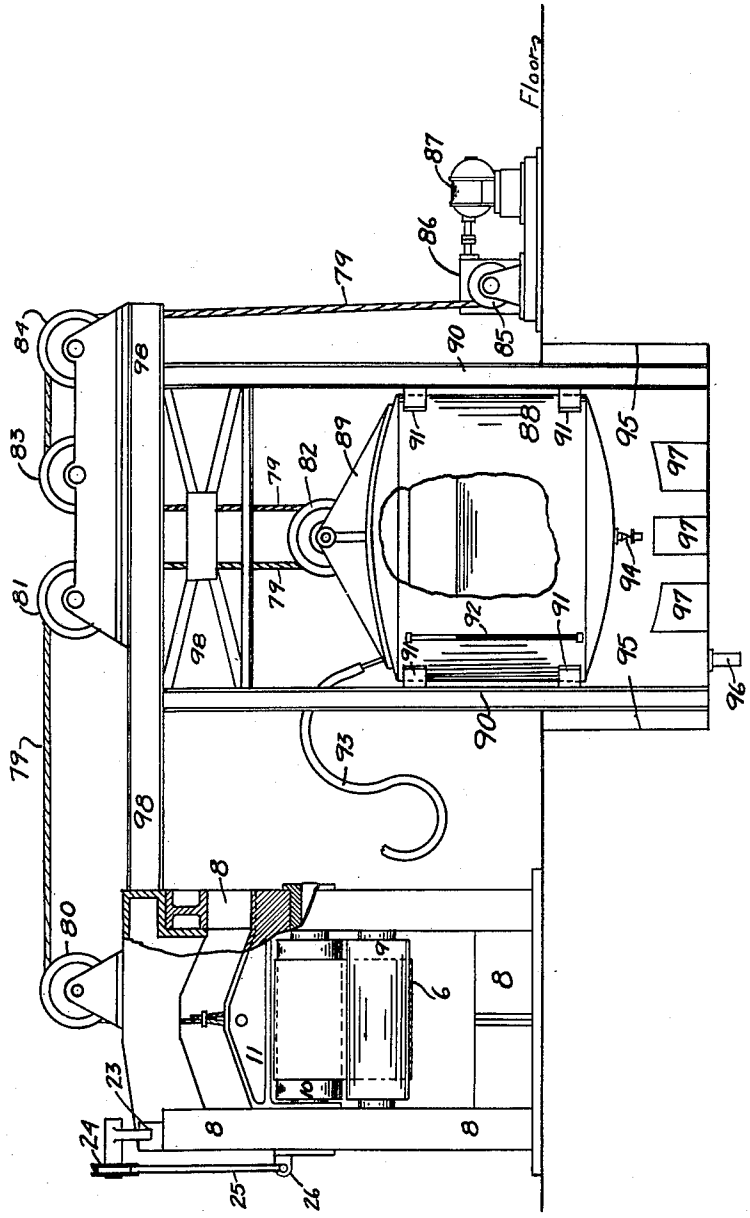


FIG. 15

INVENTOR.
Edwin B. Hudson
BY Allen & Allen
ATTORNEYS.

Patented Apr. 27, 1937

2,078,711

UNITED STATES PATENT OFFICE

2,078,711

ROLLING UNDER TENSION

Edwin B. Hudson, Middletown, Ohio, assignor to The American Rolling Mill Company, Middletown, Ohio, a corporation of Ohio

Application April 26, 1933, Serial No. 668,100

6 Claims. (Cl. 80—35)

My invention relates to rolling metal strips under tension. It is the object of my invention to provide for an effective method of supplying tension to metal strips which differs over prior efforts in this regard in essential principle.

I have applied my invention primarily to a certain set of optimum conditions, and from said optimum conditions I derive a mode of practice which may be varied within the scope of my invention to get less than optimum results, which results are, however, much superior to results which could be obtained previously.

The optimum conditions to which I refer are the tension rolling of cold metal strip by a series of passes in mills having baby working rolls (backed up mills), where the rolls are set to drafts which would result in the mills of themselves being unable to move the piece effectively at the tension, percentage reduction and speed desired. Less optimum conditions would be attained for example, by the use of less draft than the optimum on one or more passes so that its tractive force is increased, or the use of large rolls, all of which variations may still fall within my invention.

Again the optimum results are attained by arranging the tension pull on the piece so that there is a greater pull at the outlet of each mill than that mill is called upon to exert on the piece as it emerges from the previous mill. In this way the tension in each pass will be advancing, in the direction of rolling.

In order to maintain a tension system which will keep the piece taut or under tension throughout a train of mills, with a force which is constant, it is necessary for me to supply a loop of strip metal between each pass, and between the last pass and whatever instrumentality it is that applies pull to the piece. This loop of metal must have sufficient scope to serve for engaging a measured tension control which keeps the piece under a constant, predetermined, static tension between each pass and after the final pass, by acting on the power means so as to maintain a proper relative speed of all driven elements.

Since tension applied unequally to different parts of each piece in the same pass will not give a uniform product, the requirement for optimum results is to secure the strips together to supply an endless strip to be worked upon, and to eliminate threading operations. This in addition requires a pulling device which is not a coiler because the coiler will be limited in its continuous operation. It also calls for a welder ahead of the first mill of the series.

I have stated that to obtain optimum results it is desired that the piece be actually pulled between the rolls of each mill at a greater force than the mill itself applies to the piece as it emerges from the preceding mill. There must accordingly be an increase in static tension on the piece after each pass. Thus it follows that the static tension device at the end of the last stand of any series of mills, and between it and the puller acting at the end of the series, must be capable of maintaining a static tension which is equal to the pull on the piece into the first mill of the series, plus all of the increments by which this pull is increased in each pass. Furthermore, the pull which this puller must exert cannot be enough to break the piece.

It has been suggested that a strip of cold metal can be drawn by force applied to its end through a series of rolling mills acting as roller dies on the piece. This is not possible with any efficiency because the force necessary, where economical roll spacing or draft is employed, to pull the piece through a series of stands of rolls, will break the piece.

It has, of course, been suggested that rolling under tension is an efficient practice, but mere rolling under tension without the other features of my invention serves only to keep the piece taut, and does not facilitate the employment of efficient drafts.

Merely driving the rolls to a certain degree in the roller die system does not satisfy the requirements;—to secure the results of my invention the roll system must be controlled, and static tension must be maintained between each pass. If the rolls are driven too fast they will jump and spin on the piece. If they are driven too slow they will act as a brake.

My method requires the maintenance of a constant static tension between passes, and this static tension must be regulated to be greater in the direction of rolling as to each mill than the static tension that precedes the mill, or at least that no mill be called upon to exert more tension on the piece than the static tension succeeding it.

The more general aspects of my invention over the art, are set forth in my copending application of even date.

While my invention is not limited to any specific mechanism and while a wide variety of mechanisms could be employed to carry out my process, I propose to describe a complete mill installation and a set of optimum conditions

which will give the advantageous results to which I have referred.

In the drawings:—

Figure 1 shows an elevation of the mill speed and tension control device located between two mills of a cold mill tandem train.

Fig. 2 shows a plan of the mill speed and tension control equipment and mills shown in elevation in Fig. 1.

Fig. 3 is a front elevation of the preferred mill speed and tension control equipment, with parts in section.

Fig. 4 shows the devices by which the mill motor rheostat of the mill immediately following the speed and tension control equipment is actuated.

Fig. 5 shows a portion of the chain controlling the position of the mill motor rheostat (Sec. III—III).

Fig. 6 is an end elevation of the apparatus of Fig. 4.

Fig. 7 is an enlarged detail of a part of the apparatus shown in Figs. 4 and 6.

Fig. 8 shows in diagram an alternate method of actuating the mill speed and tension equipment shown in Figs. 1, 2, and 3, utilizing hydraulic accumulators.

Fig. 9 is a plan view of the pulling or tensioning device, and the drive therefor.

Fig. 10 is a side elevation of the tensioning device.

Fig. 11 is a diagrammatic representation of a train of seven tandem four-high mills and associated mechanisms including a puller at the end of the train, and a puller intermediate the fourth and fifth mills.

Fig. 12 is a tension diagram showing an optimum tension control in the system of Fig. 11.

Fig. 13 is a diagrammatic representation of a train of tandem four-high mills with pullers intermediate each mill and beyond the final mill.

Fig. 14 is a tension diagram showing one operation of the system of Fig. 13, and indicating how in each pass the tension upon the strip as it leaves the rolls may be maintained greater than the tension upon the strip as it enters the rolls, irrespective of the tension levels in the several passes.

Fig. 15 shows a static tension device of a slightly different type, namely one actuated by gravity.

The particular embodiment chosen by me for the purpose of an exemplary showing herein, is a train of tandem four-high mills for cold rolling metal strip of sheet width to thin gauges, such as tin mill gauges. The four-high mills in this instance are mills with small working rolls and large backing up rolls. It will be understood that this embodiment is exemplary only, and is not limiting upon my invention.

It is possible, by means of the four-high mills illustrated in this embodiment, to apply such great drafts and operate the mills at speeds which would not permit them to impart to a strip being rolled the higher tensions which many of the mills are carrying as shown by the tension diagram hereto appended, when the piece leaving each mill is at a still higher tension than in the preceding mill. Thus, a pulling machine freed of rolling requirement and capable of exerting a very high tension on the strip is a necessity in the particular embodiment, and under the exemplary conditions herein shown. Because the pulling machine can exert a great tension upon the mill just preceding it, it enables that mill to maintain a high tension on the next preceding mill. This in turn enables that mill to exert a high tension upon its predecessor, and so on. The only limits to the arrangement of a desired tension in each pass is the ability of the piece to withstand the pull of the pulling machine. Hence, pulling machines are employed by me at such intervals as the strength of the piece and the desired "advancing impulse" in each pass makes necessary.

In the exemplary embodiment herein described, I employ a plurality of stands of four-high mills, one or more pulling devices, and take-up devices between the several mills and/or between the mills and the pulling devices.

The particular take-up and tension control device hereinafter described is the joint invention of myself and John B. Tytus, and is claimed in a co-pending application Serial No. 670,930, filed May 13, 1933. While I prefer to use this device, other mechanism may be substituted therefor.

In Figure 1, a four high-mill in a train is indicated generally at A, and the succeeding mill is indicated at B. The mills are identical, and like numbers are employed for like parts. The mill comprises mill housings 1, resting on mill shoes 2, the working rolls 3, which are driven by mill spindles 3^1, (in Fig. 2), and the back up rolls 4. The mill is provided with suitable screw-down mechanism 5. The rolling piece 6 is passed through the mill A, thence through the mill speed and tension control apparatus indicated generally at C, thence through mill B in the direction of the arrow 7.

The mill speed and tension control C comprises a suitable frame 8 in which two stationary rolls 9 (capable of rotation) are mounted, preferably so that the bottom periphery is at the same elevation as the mill pass between mill rolls 3—3. A movable roll 10 is mounted in yoke 11 with suitable bearings. The yoke is slidably mounted, as shown, in ways on the frame 8. The roll 10 is thus vertically movable with respect to the frame 8. In several of the figures a high position is indicated at 10', and a low position at 10''. The mills of the train may be initially threaded with the roll in the position 10''.

The yoke 11 is connected to a piston rod 12, bearing a piston 13, operating in a hydraulic cylinder 14 which is mounted on the housing 8. A reservoir tank 15 may be provided to retain an extra supply of oil. A gauge glass 16 can be used to indicate the oil level. I have shown an oil pump 18 driven by a variable speed motor 19. Pipe 17 conveys the high pressure oil from the pump 18 to the lower side of piston 13, and another pipe 20 conveys the oil from the upper side of piston 13 to the inlet side of pump 18. The pump motor is controlled as to speed by a motor rheostat 21; and the resultant oil pressure under piston 13 may be indicated on a pressure gauge 22 (Fig. 1) which is connected to the pipe 17 as at 22a. I prefer to calibrate the gauge 22 in pounds of tension upon the strip 6 instead of in pounds per square inch.

Mounted on a bracket 23 is a pulley 24, over which a cable 25 passes. The cable is connected to the yoke 11 by a bracket, or the like, 26. The highest position of the connection 26 is shown at 26^1 and the lowest at 26''. The cable 25 is used to transmit to a rheostat for the succeeding mill of the train, a controlling motion based upon the position of the movable roll 10, to effect the automatic regulation hereinabove referred to.

Figures 4, 5, 6, and 7 disclose means for controlling the mill motor rheostat or the pulling machine rheostat as the case may be. The cable 25, connected as described to the yoke 11, and passing over the pulley 24, is connected to a sprocket chain 27. The links of this chain engage the teeth of a sprocket 28 mounted idly on a shaft 29. The chain 27 may be connected to a weight 30. Extended pins 31 and 31', shown in Figures 4 and 5, are mounted on the chain and are arranged to engage a segment 32 keyed to the shaft 29. Mounted and keyed to shaft 29 is a sprocket 33 which drives the rheostat sprocket 34 through a chain 35. The sprocket 34 idles on the rheostat shaft 36 and can only drive this shaft through hub jaws which engage cooperating jaws of a handwheel 37, which is keyed to shaft 36 and is slidably mounted thereon so that the jaws can be disengaged, making hand regulation of the rheostat possible. Handwheel 37 is disengaged when in position of 37^1 and can be held in either position by suitable detents (not shown). The jaw or clutch construction is shown at 36a in Figure 6.

The shaft 36 is mounted in the rheostat 38; and bears the usual contactor arm 40, which engages the usual contact buttons 39. The movement of the movable roller 10 in our exemplary device is divided into three ranges, viz., a range of increased speed from point 41 to 42, a range of no speed regulation 42 to 43, and a range of reduced speed 43 to 44 (Fig. 4). When the movable roller enters the increase-speed range at 42, the extended pins 31 engage the segment 32 (as the weight 30 descends), rotating the shaft 29 in a clockwise direction. This motion is transmitted from sprocket 33 through chain 35 to sprocket 34. Thence through the clutch 36a, the motion is transmitted to the hand-wheel 37 and the shaft 36, which cuts out resistance in the motor circuit increasing the speed of the mill motor or the pulling machine. This in turn operates to pull the movable roller out of the increase speed range 42—43. Should the movable roll 10 descend below 43 into the 43—44 range the action will be the reverse of that described for the acceleration of the mill motor. The extended pins 31^1 will engage the opposite edge of the segment 32, and the rheostat will be regulated to increase the resistance in the motor circuit. The automatic control of the mill motor or pulling machine rheostat 38 will keep the movable roll 10 within a desired range. Such strip capacity as the movable roll 10 can take up or pay out insures the maintenance of strip tension while the mill motor rheostat 38 is being regulated, and until the motor responds, to regulate the desirable length of strip that is to be maintained between stands.

Thus the function of the mill speed and tension control equipment C is to maintain at all times a predetermined tension in the strip 6 between mills A and B not only by automatically regulating the speed of the mill B, or a pulling machine, as the case may be, but also by taking up and paying out the strip under a predetermined force. The predetermined tension in strip 6 is maintained by the regulation of the oil pressure under piston 13. A rheostat 21 may be provided to control the speed of the pump motor 19.

When the piston 13 is exerting the desired pressure upon the strip 6, the value of the tension is indicated on a gauge 22; and as long as no slack is introduced into the strip 6, the pump 18 will maintain the necessary oil pressure, although slippage will occur in the pump. Should some slack be introduced into strip 6, due to mill slippage or asynchronism, the oil pressure will drop slightly as the upward movement of piston 13 occurs; but this condition will be corrected as soon as the movement of piston 13 is arrested.

The exemplary embodiment of my invention contemplates placing a mill speed and tension controlling device between all the mills of the mill train and between the last mill and the pulling machine. On extremely thin gauges, such as tin plate, where seven mill stands may be required, an additional pulling machine may be used between the fourth and fifth mill as well as beyond the seventh stand.

The tension between the various mills will be so adjusted that the tension in the piece will be greater on the exit side of each mill than on the entering side; all differential tension being in the direction of rolling to facilitate the gauge reduction of the strip. With this invention all mills will be working under the most favorable conditions and will be capable of a greater rate of gauge reduction than is possible without my invention, assuming that a satisfactory pulling device is provided.

Figure 8 discloses another apparatus suitable for the practice of my invention, in which a hydraulic system using variable loaded accumulators 45 is used. I have shown, for each of the control units C, a separate accumulator, whereby the tension on each mill may be individually adjusted. Mills A, B, D, and E are arranged in tandem; and after the mill E, a pulling machine F is provided to pull the strip 6 in the direction of arrow 7. The tension between mill E and pulling machine F is, in this instance, greater than the tension between mills D and E; and between each set of mills the tension is reduced so that each mill will be operating under a favorable "effective tension".

The water load accumulator tanks are indicated at 46. The different levels to which water rises in these accumulator tanks is indicated by the water gauges 47. The accumulator tanks may be filled from lines 48 by opening valves 49 from the mill water supply line 50. The tension introduced into the strip is indicated by gauges 22. The accumulator tanks can be drained by valves 51. The accumulators are charged by a hydraulic pump 52 which takes its water from the mill water supply line. For this purpose valves 53 and 54 are opened and valves 55 are closed. After the accumulators are charged, the valves 53 are closed and the pump 52 is stopped. When threading the strip 6 through the mills, the movable rolls 10 can be lowered to position 10'' by closing the valves 54 and opening the valves 55. The pipe 20 will carry away any leakage of water past the piston 13.

Figures 9 and 10 show my pulling machine. This machine is designated by the letter "F" on Figure 8, and comprises two similar housings 56 stayed by separators 56^1, carrying bottom pulling rolls 57. These are driven by shafts 58 from a suitable source of power. Idler rolls 59 are carried in an adjustable housing 60, which is moved in a vertical direction by screws 61. The housings 56 also carry driven pinch rolls 62 which are driven by shafts 63, and idler pinch rolls 64 which are carried in vertically adjustable bearings 65. An adjustment of pinch rolls 62 is provided by a screw 66, spring blocks 67 and springs 68. The screws 66 may be operated by handwheels 69 on shafts 70, and by worm gears (not shown) in a worm gear housing 71.

The adjustable housing 60, which carries the rolls 59, is adjusted by screws 61 which are driven by a motor 72 through chains 73 and 74, as shown, driving shafts 75 and worm gears (not shown) in a worm gear housing 76. The adjustable rolls 59 can be raised to a position shown at 59^1 by the motor 72, when threading the machine. The pulling rolls 57 and 59 may be provided with cork inserts or other means to increase the friction upon the strip.

The strip 6 is shown passing through the machine in the direction of the arrow 7, leaving the outgoing end of strip 6 free for shearing or coiling without releasing the tension in the strip 6 on the ingoing side, and permitting the tensioning device to be used upon endless lengths of strip.

The driving shafts 58 and 63 may be connected to a secondary gear drive 76, with various gears to give the proper spacing, speed and direction to shafts 58 and 63. This in turn may be driven by a primary drive 77 as shown, connected to a variable speed motor 78. The speed of motor 78 is controlled by the final control unit "C".

In my pulling device the material is wrapped around a plurality of rolls indicated at 57 and 59, and then is caught by pinch rolls, which assures sufficient tension on the strip after it leaves the rolls 57 and 59 to provide a tight frictional contact with the strip. It is an advantage of my pulling device that a continuous strip may be handled therein. Upon this strip may be exerted as much tension as desired within the limit of the ultimate strength of the reduced strip.

It will be obvious that I may, if desired, employ means to retard and/or tension the strip as it enters a train of rolls.

In an exemplary set up for rolling iron or steel to tin mill gauges, I may provide seven mills operating continuously upon the same strip and divided into two groups, a first group comprising four mills, followed by a pulling device, and a second group comprising the remaining three mills, followed by another pulling device. I have indicated in Fig. 11 such an organization of parts. Here strip metal is uncoiled or decoiled as at D. Adjacent strips are welded together as at W, any surplus material at the weld being removed by a flash cutter indicated at F. In order to provide for the discontinuous character of the welding operation the material may be looped as at L. The mills of the train are indicated at M^1, M^2, etc. The various take-up devices are indicated at R^1, R^2, etc. A brake, so marked, may be employed to tension the strip prior to its entry into the first mill M^1. Static tension devices R^1, etc. are located between each of the mills, on each side of the puller P^1, and between the final mill M^2 and the puller P^2. The general operation of this organization of parts will be clear from the description hereinabove. Beyond the puller P^2 the material may be cut apart by a shear, so marked, into sheets, or into lengths suitable for coiling at C^2. The tension diagram, Fig. 12, shows in solid lines the tension effective in the several passes. It will be noticed that in the solid line showing there is a positive differential of tension in the piece as it leaves and enters each mill, and that the tension progressively increases in the passes represented by mills 1 to 4, inclusive, and to the puller P^1. The tension likewise increases in the portion of the train comprising mills 5 to 6, inclusive, in a progressive manner, to the puller P^2. This tension diagram is illustrative of a preferred practice only. In carrying out my invention there may be less of a positive differential of tension in each pass than that shown, or the tension may even be maintained in such a way as to be not less on the outgoing side of each pass than on the incoming side, as indicated by the dotted lines marked optional.

In Fig. 13 I have shown a mill train in which the mills are again indicated at M^1, M^2, and etc., but in which a puller P^1, P^2, etc. is located between each stand of mills, or beyond the final mill in the train. The other mechanisms are indicated in Fig. 13 by the same indicia. Fig. 14 is a tension diagram showing one mode of operating the instrumentalities of Fig. 13. Here a positive differential of tension may be maintained with respect to each pass, but the tension may be varied with respect to each pass in any degree desired. I have shown not only a greater total tension on the piece as it leaves mill 1 as compared with the condition in other passes, but also a greater differential in tension in mill 1 than in other passes. The greater thickness of the piece being rolled in mill 1 will permit the placing thereon of a greater effective tension without danger of breaking the piece than is possible when the piece is thinner. Again, however, the tension diagram of Fig. 14 is exemplary only and not limiting. The organization of parts shown in Fig. 13, while it entails the use of more apparatus to a given number of mills, is more flexible in that it permits a variation of tension within the limits of my preferred teaching from the same tension on the incoming and outgoing sides of each pass to any desired positive differential tension within the limits of practicability, irrespective of the total tension or differential tension in any other pass.

Fig. 15 illustrates a type of static tension device which is actuated by gravity. This is advantageous under a number of circumstances, primarily in that the force applied to the tensioning device can be maintained more constantly at the desired value. The device acting upon the strip is the same as the most of its parts, and like parts in Figure 15 have been indicated by like indicia. In this modification, however, the yoke member 11, in which the upper roll 10 is journaled, is not actuated by a hydraulic cylinder, but instead is drawn upwardly by a cable 79, acted upon by a weight of constant though adjustable magnitude. A framework comprising uprights 90 and a cross head 98 is provided at some convenient point, and a weight indicated at 88 is slidably mounted on brackets 91, so as to move vertically on the standards 90. This weight has been indicated in the form of a tank for containing water, or other fluid, provided with a gauge 92 which may be calibrated, if desired, in pounds of tension on the strip. The liquid level may be raised by adding liquid through the conduit 93, or lowered by draining through the outlet valve 94. In order to provide for sufficient vertical movement of the weight 88, the lower part of the framework may be located in a pit 95, having drainage means 96, if desired. Blocks 97 are located in the bottom of the pit. The weight at its lowermost position rests on these blocks. Where a tank is employed as illustrated, it will preferably be attached to a suspension member indicated at 89, in which is journaled a sheave 82. The cable 79, attached to the yoke 11 of the strip tensioning device, passes over a sheave 80 mounted upon the cross head 8, thence over a sheave 81

above the weight, and downwardly to engage the sheave 82. The cable returns to a position above the cross head 98 to pass over sheaves 83 and 84, whence it passes downwardly to a motor driven reeve indicated at 85. The motor 87 drives this reeve through a gear box 86, having a worm and gear arrangement which is self-locking.

This arrangement is capable of exerting a constant and invariable force upon the yoke member 11. It will be obvious also that the distances of movement of the various parts are scaled down. Since the strip 6 passes over the upper roller 10 in a loop, the vertical movement of the yoke 11 in taking up a given length of strip is half only of the length of strip so taken up. Likewise, since the cable 79 makes a loop over the sheaves 81 and 83 to engage the sheave 82 of the weight, the vertical movement of the weight is but half of the movement of the yoke 11 produced thereby. This, while it necessitates the application of a force of considerable magnitude upon the yoke 11 and necessitates the use of a very heavy weight, yet minimizes the effects of inertia and makes for the steadier application of the constant force.

In operation, when it is desired to thread up the tensioning device, the motor 87 is rotated so as to pay out cable from the reeve 85. This lowers the weight 88 until it rests upon the blocks 87. A further paying out of the cable 79 will result in a lowering of the yoke 11 to the desired level. When the machine has been threaded with the strip, the motor 87 is rotated in the opposite direction, taking up the cable 79. This results in the application of force against the strip 6, and when the yoke 11 has been raised to such a point as to take up any slack in the strip, the further taking up of the cable 79 will raise the weight 88. In this way the level of the weights 88 may be adjusted with respect to the level of the yoke 11.

It will be obvious that instead of the single cable 79, a plurality of cables may be used, and it will be equally obvious that instead of a weight in the form of a tank filled with liquid, a container filled with shot, or the like, may be employed, or instead of either of these, a frame or carriage may be journaled on the uprights 90, and may be loaded with removable weights to the desired total weight. Provision is thus made for weight adjustment; but the application of force to the yoke 11 is not dependent upon the transmission of fluid through conduits, or upon the action of a fluid cylinder.

In the specifications and the claims which follow, the word "constant" as applied to tension or tension value, should be construed as implying that the tension for any given setting of the machine, is not characterized by substantial variations from a predetermined value, and is used in this sense to distinguish from conditions in which the tension sporadically varies by substantial amounts, and also to distinguish from conditions in which the tension while substantially varying, nevertheless has its variations so controlled or compensated for as to have what might be termed an average or mean value of constant character.

It will be obvious that modifications may be made in the particular instrumentalities combined to this end without departing from the spirit of my invention.

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

1. In combination with a tandem train of driven cold mills, a pulling device located beyond the final mill and capable of exerting a tension upon a strip being rolled which is not less than the sum of differences in tension between the entering and leaving portions of the strip in all preceding mills, and means between each of the mills in said train and between the final mill and said pulling device for taking up said strip under a predetermined force, said devices being controlled to maintain a positive cumulative difference in tension in the direction of rolling.

2. In combination with a tandem train of driven cold mills, a pulling device located beyond the final mill in said train and capable of exerting a tension upon a strip being rolled which is not less than the sum of differences in tension between the entering and leaving portions of the strip in all preceding mills, and means intermediate said pulling means and said final mill and intermediate said mills for varying the speed of said instrumentalities in accordance with measurements of the length of said strip between said instrumentalities, and for taking up said strip under a predetermined force, said devices being controlled to maintain a positive cumulative difference in tension in the direction of rolling.

3. In combination with a tandem train of driven cold mills, a pulling device located beyond the final mill in said train and capable of exerting a tension upon a strip being rolled which is not less than the sum of differences in tension between the entering and leaving portions of the strip in all preceding mills, and means intermediate said pulling means and said final mill and intermediate said mills for varying the speed of said instrumentalities to maintain the predetermined tension in said strip, and for taking up said strip under a predetermined force, said devices being controlled to maintain a positive cumulative difference in tension in the direction of rolling, said last mentioned means comprising a looping device having a movable roll and a pressure means tending to move said roll, and means for causing the movement of said roll to control the speed of a succeeding instrumentality.

4. In combination with a tandem train of driven cold mills, a pulling device located beyond the final mill and capable of exerting a tension upon a strip being rolled which is not less than the sum of differences in tension between the entering and leaving portions of the strip in all preceding mills, and means between each of the mills in said train and between the final mill and said pulling device for maintaining a predetermined tension by taking up said strip under a predetermined constant force, said devices being controlled to maintain a positive cumulative difference in tension in the direction of rolling, said pulling device comprising a plurality of driven rolls about a substantial portion of the periphery of which said strip is passed, and pinch rolls located in the direction of movement of said strip beyond said first mentioned rolls.

5. A process of cold rolling metal strip in a tandem train of driven rolling mills which comprises the steps of passing the strip through the mills of said train and pulling upon said strip beyond the final mill, while, between each mill in the train and between the final mill and the

pulling device, taking up said strip in a variable loop under constant force so as to make the tension in the strip independent of variations in elongation produced by said mills, and constant as between each of the mills and each adjacent mill and between the final mill and the pulling device, and so proportioning the forces so applied that the tension is cumulative in the strip, each mill having a positive differential in tension in the strip on the outgoing side as compared with the tension in the strip on the incoming side.

6. A process of cold rolling metal strip in a tandem train of driven rolling mills which comprises the steps of passing the strip through the mills of said train and pulling upon said strip beyond the final mill, while, between each mill in the train and between the final mill and the pulling device, taking up said strip in a variable loop under constant force so as to make the tension in the strip independent of variations in elongation produced by said mills, and constant as between each of the mills and each adjacent mill and between the final mill and the pulling device, and so proportioning the forces so applied that the tension is cumulative in the strip each mill having a positive differential in tension in the strip on the outgoing side as compared with the tension in the strip on the incoming side and controlling the speeds of said mills in accordance with the length of said loops so as to maintain the system in equilibrium in spite of variations in elongation produced by said mills.

EDWIN B. HUDSON.