April 19, 1955 W. B. LOCKWOOD 2,706,422

METAL ROLLING

Filed May 2, 1947 5 Sheets-Sheet 1

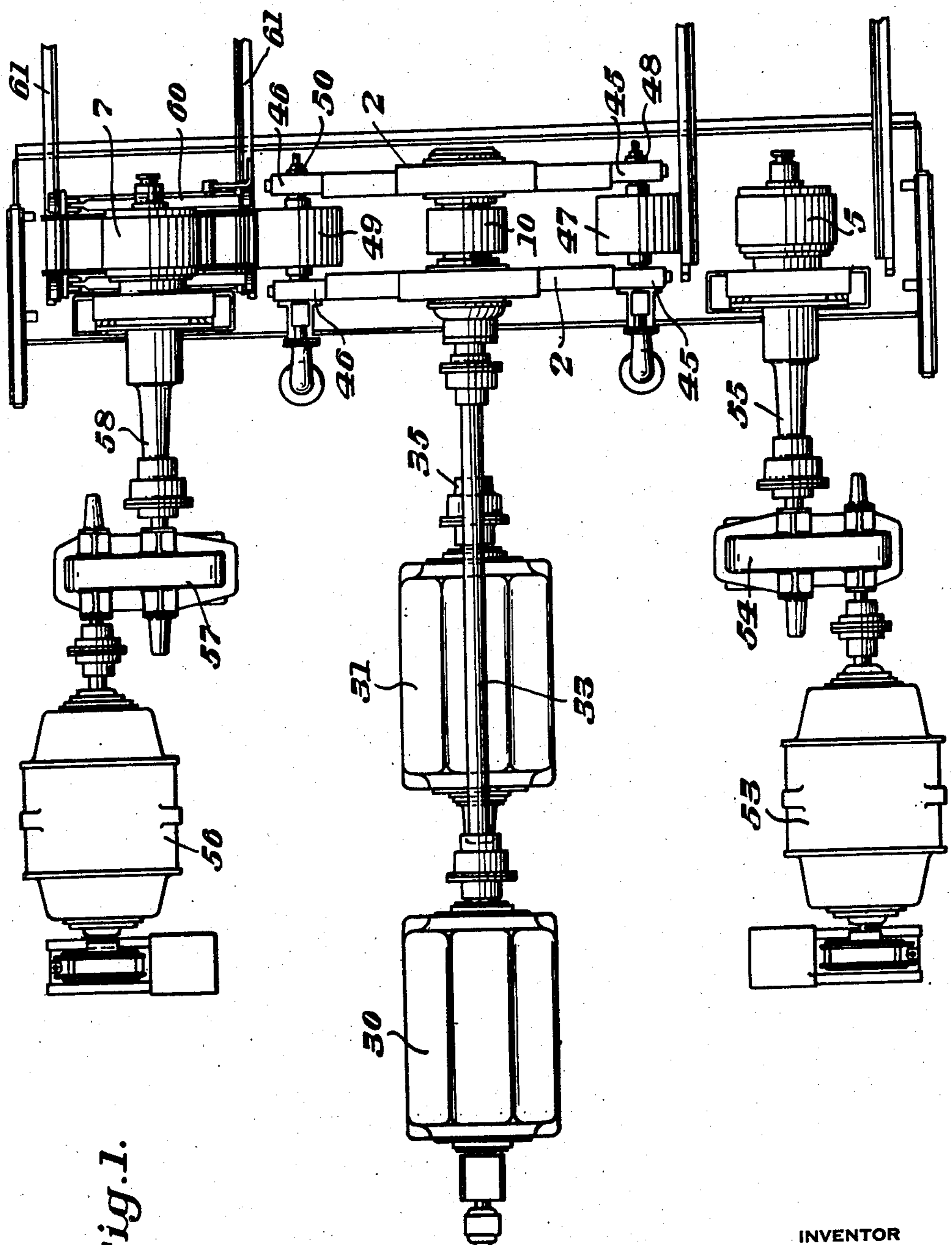

Fig.1.

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5 Sheets-Sheet 2

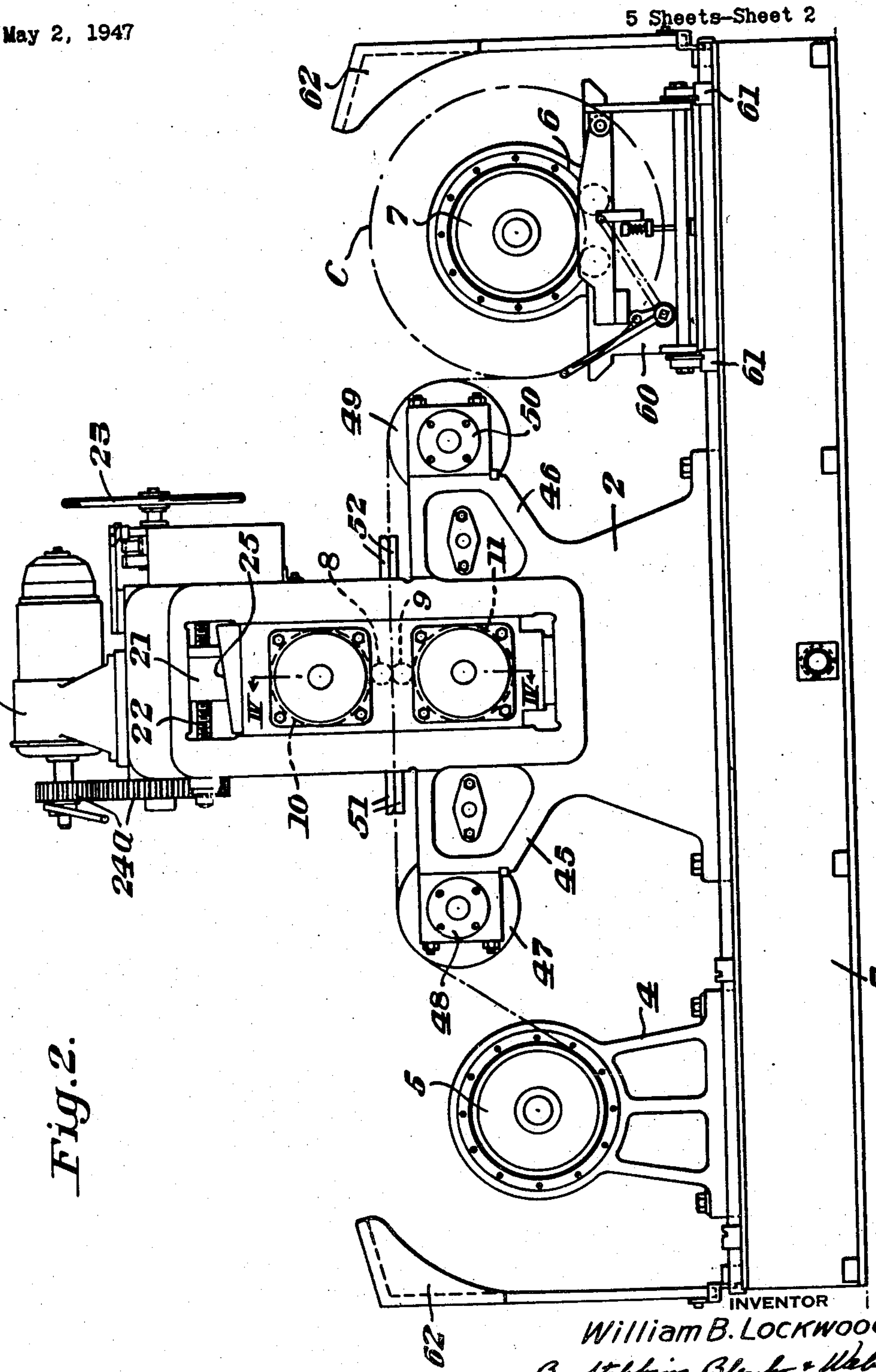

Fig.2.

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METAL ROLLING

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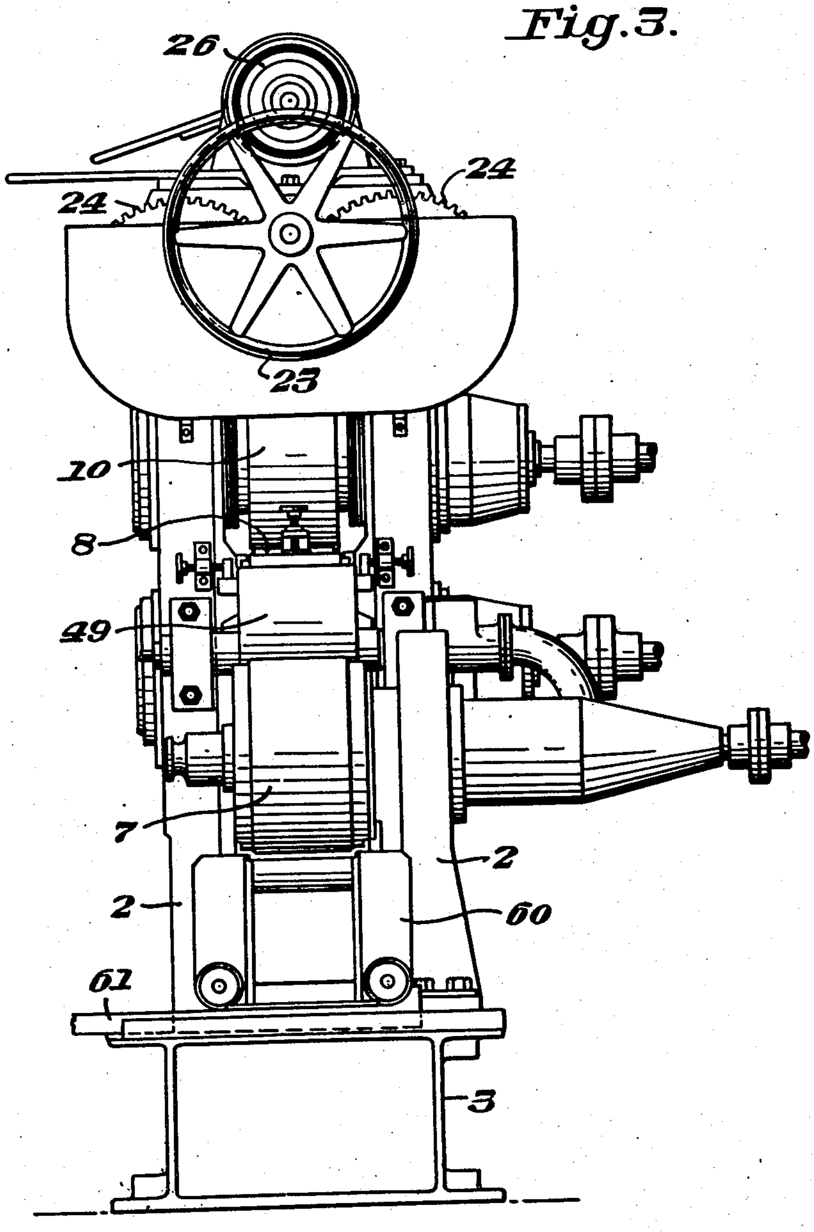
5 Sheets-Sheet 3

Fig. 3.



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METAL ROLLING

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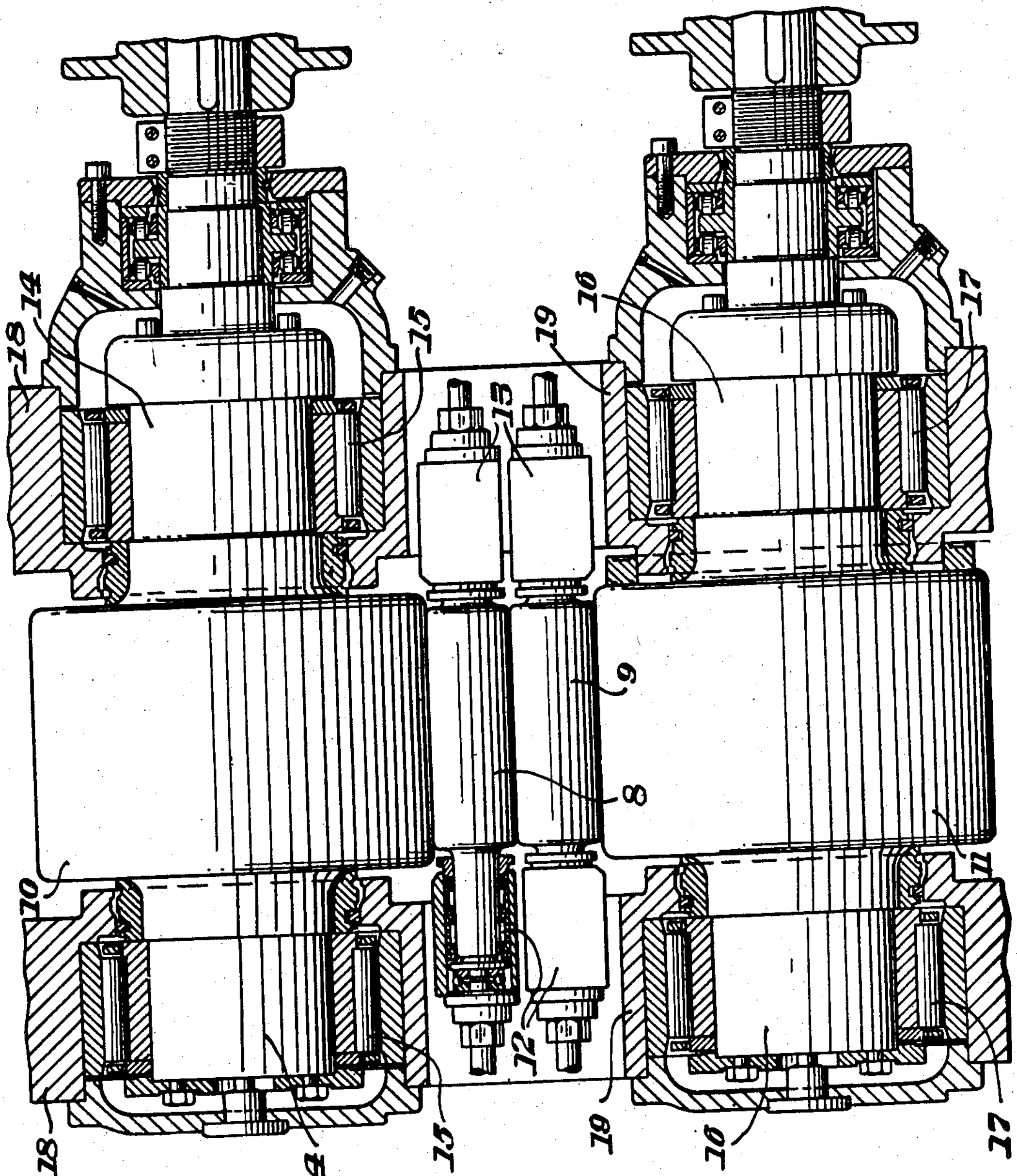

Fig. 4.

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April 19, 1955 W. B. LOCKWOOD 2,706,422

METAL ROLLING

Filed May 2, 1947 5 Sheets-Sheet 5

Fig. 5.

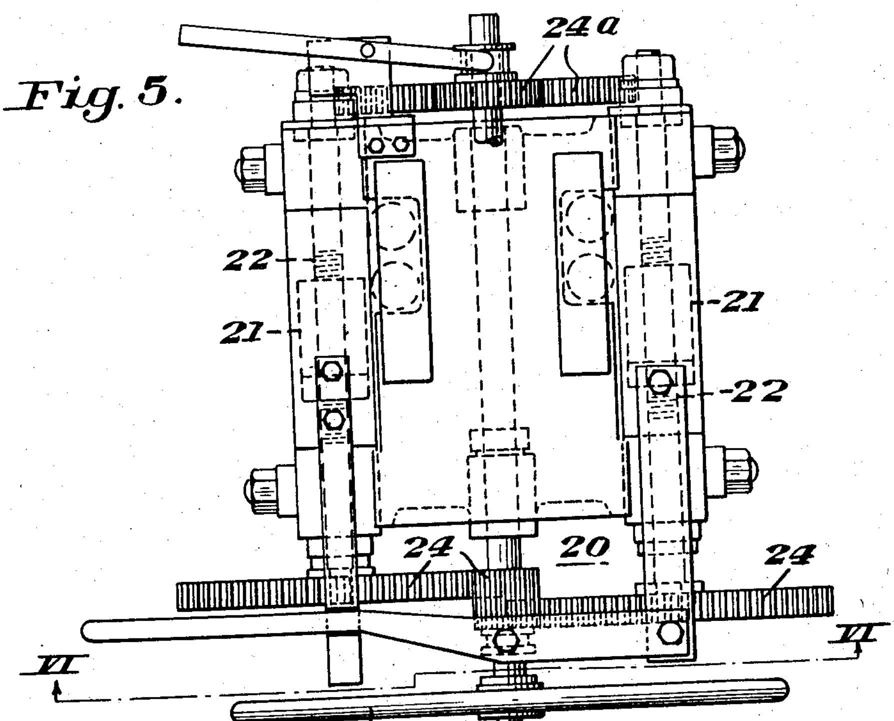
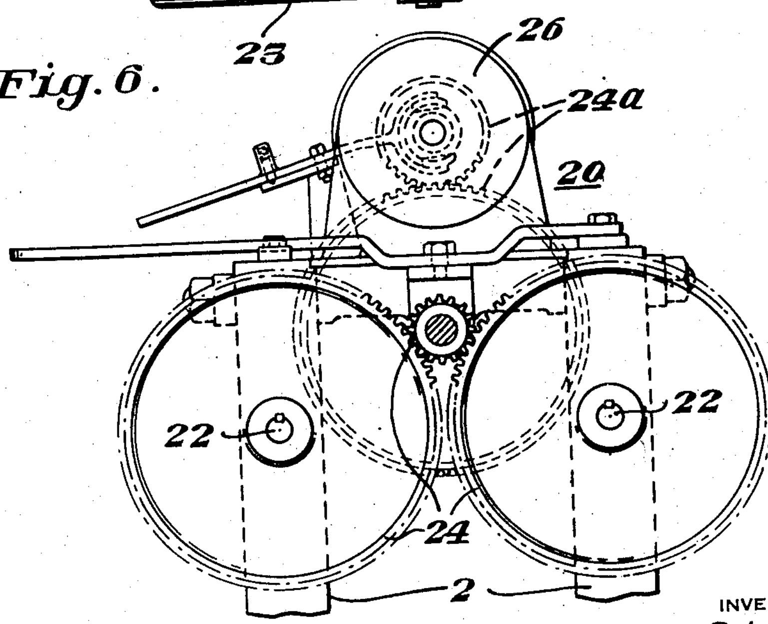


Fig. 6.



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1

2,706,422

METAL ROLLING

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Application May 2, 1947, Serial No. 745,556

9 Claims. (Cl. 80—60)

The present invention relates generally to metal rolling and, more particularly, to the cold rolling of metal in strip form. By my invention I provide a mill and a method of rolling which possess many advantages over any of the presently known types of mills and rolling methods. It is particularly applicable to the cold rolling of thin strip having a relatively high ratio of width to thickness. An important field in which my invention is particularly useful is in the cold rolling of steel such as low carbon steel, high carbon steel and alloy steels, although my invention may be utilized in the rolling of other metals such as copper, brass, other copper alloys, aluminum, magnesium, and aluminum and magnesium alloys, and the advantages mentioned hereinafter as flowing from the use of my invention in the manufacture of cold rolled strip will be realized to a greater or lesser degree.

While I have used the word "strip" herein, I have not used it in the limited technical sense in which that word is frequently employed in the steel industry, but intend that it should include all cold rolled flat products, including those frequently designated in the steel industry as sheets, strip-sheets, etc.

Heretofore in the cold strip rolling art, several different types of mills have been employed. Formerly the 2-high type of mill with ordinary bearings or with antifriction bearings, such as the so-called Morgoil or Mesta bearings, was used in the steel industry, as well as in the brass and copper industry, but that type of mill, particularly for the rolling of thin steel strip, has been largely superseded by other types of mills, because of disadvantages pointed out more in detail hereinafter.

The cluster type of mill in which each working roll is supported in the crotch formed by two backing rolls has also been employed. Various types of bearings have been used on these mills in recent years with varying degrees of success. In general, mills of this type have found their greater usefulness in the rolling of the thicker gauges and have been found to possess serious drawbacks in the rolling of high ratio material, and particularly in the thinner gauges.

Another type of mill which has been used heretofore in the cold rolling of strip is the so-called Sendzimir mill which has two small work rolls and a large number of backing rings for supporting the work rolls against the separating forces caused by the metal passing between the work rolls. It has been found that this type of mill is particularly useful in the rolling of narrow strip having a high ratio of width to thickness, and efforts have been made to utilize this type of mill in the rolling of extremely thin gauges of relatively wide width. However, considerable difficulty has been encountered in the efforts to extend the usefulness of this type of mill to the wider thinner gauges. It is such products that can be rolled relatively easily with the mill which I provide.

Another type of mill which has been utilized heretofore in this field is the so-called 4-high type, in which there are two work rolls which are backed up by backing rolls having a relatively larger diameter as compared with the diameter of the work rolls. Antifriction bearings, such as roller bearings and Morgoil and Mesta bearings have been employed on mills of this character. Such mills have been employed as single stand mills and have also been arranged in tandem. These mills have been powered in several different ways. When employed in tandem, the work rolls at each individual stand have been motor-driven and a motor-driven reel has been employed

2

for receiving the strip as it comes off the last stand. The distribution of power between the several stands has been such that the material is maintained under substantial tension between the stands. In fact, in the cold rolling of the thinner gauges it has been the invariable custom to employ a relatively heavy pull on the strip between the first and second stands, the first stand being driven principally by tension on the delivered strip. When utilized as single stand mills, in some instances all of the power for driving the mill and reducing the metal has been supplied by driving the work rolls, the necks of the work rolls being connected to suitable driving mechanism. In other instances, some of the power has been supplied in the manner just stated and additional power has been supplied through tension on the delivered strip, the tension being imparted to the delivered strip by means of a motor-driven tension reel. In many instances the major portion of the power has been supplied through tension on the delivered strip, while in other instances the major portion has been supplied by driving the work rolls. Back tension has been employed in such mills, the tension on the entering strip being supplied by a reel provided with either a hydraulic brake or a mechanical brake, although in many instances electrical back tension has been employed, the unwinding reel being connected to a generator which serves the same purpose as a brake on the reel and causes the reel to assert a back pull on the strip. This type of mill, either with or without back tension, is known in the trade as the "part-pull, part-drive" mill.

These types of 4-high mills are particularly advantageous in the rolling of strip having a high ratio of width to thickness. In the steel industry, for example, it has been found that many intermediate annealings can be eliminated as compared with the practices prevailing in the art before such mills became known.

Another type of 4-high mill which has been extensively used is the so-called all-pull mill. In this mill the work rolls are not provided with any driving mechanism. The power for driving the mill and reducing the strip is supplied entirely by pull or tension on the delivered strip, the pull or tension being supplied by a winding reel which is motor driven. The reel, of course, is provided with adequate power to not only wind up the strip and subject it to some tension, but is powered so that the pull on the strip is great enough to drive the mill rolls. Back tension has been employed on such mills.

The all-pull type of mill has many advantages over the other 4-high type of mill described above in the rolling of the thinner gauges. The other types are particularly useful as high production mills for rolling such products as sheets and tin plate; but where real accuracy to gauge, extreme flatness, lack of buckles and riffles, and close tolerances are required, and particularly in gauges thinner than approximately .015 inch, the all-pull type of mill is superior. Also, in the rolling of such difficultly rollable materials as high carbon steel and alloy steels, the all-pull type of mill has been found to have numerous substantial advantages over the other type of 4-high mill mentioned above.

Although the all-pull type of mill possesses substantial advantages over the other mills mentioned above in the rolling of the thinner gauges and in the rolling of the more difficultly rollable products such as high carbon steel and alloy steels, it has a number of deficiencies. In rolling steel to the thinner gauges, for example, under .010 inch in thickness, the production is low due to the fact that the reduction which can be taken per pass is small. Edge cracking is frequently troublesome in the rolling of the thinner gauges and this creates a substantial problem in the all-pull type of mill because of the resulting strip breakage. This difficulty is particularly prevalent in the rolling of high carbon steel and certain alloy steels such as stainless steel. The proper shape of the metal cannot be maintained under some circumstances in rolling on this type of mill. The forward tension which is exerted where the entire drive is provided by the mill causes a forward bowing of the rolls and this results in the strip having a thicker center portion than the edges. Uneven elongation of the metal is frequently obtained and this causes buckles where there is an over rolling of the central portion of the strip and riffles where there is an over rolling of the edges. Moreover, the desired tolerances cannot be achieved at times.

The mill which I provide overcomes in large measure these limitations on the all-pull type of mill and the like limitations which are even more accentuated in the other types of mills discussed above.

The mill which I provide is of the 4-high type. It utilizes relatively small work rolls since small work rolls more readily bite into the metal being rolled and lessen the screw pressures and hence the separating forces in the mill. This is particularly true where both forward and back tension are employed, the pressures more nearly becoming concentrated on a line transversely of the strip being rolled. The diameter of the work rolls which I employ are small in relation to the diameter of the backing rolls and in relation to the length of the roll face. For example, in a mill in which the roll face is 10 inches, the work roll diameter may be of the order of from 1¼ inches to 3 or 4 inches. Highly desirable results have been obtained in the use of rolls 1¾ inches in diameter and in the use of rolls 3 inches in diameter.

The work rolls are, of course, too small to be self-supporting and, hence, are backed by backing rolls. The mill which I employ is of the straight 4-high type and there is only one backing roll for each of the work rolls, the backing rolls being considerably larger in diameter than the working rolls. Preferably, the backing rolls are of a diameter several times the diameter of the work rolls, although in some instances the backing rolls may be three, four or five times as large in diameter as the work rolls.

The rolls are supported in suitable housings carrying supporting chocks. The work rolls are preferably of the neck type, although this is not necessary since the mill is not driven through the work rolls. The work rolls are provided with an antifriction mounting, such as antifriction bearings on the necks thereof, if the neck type roll is used. If desired, sliding bearings may be used for supporting the work rolls and this is particularly true where extremely small work rolls are employed. The backing rolls are of the neck type and the necks thereof are supported in antifriction bearings such as roller bearings or pressure lubricated sleeve bearings such as Morgoil or Mesta bearings. These bearings, of course, are mounted in the chocks in the housing and the usual screw-down mechanism is employed for holding the rolls together to provide the desired roll pass.

A reel is positioned on each side of the mill stand and electrical means is provided for driving each reel so that it can function as an unwinding reel or as a winding or tension reel, depending upon the direction of travel of the metal through the mill. The electrical mechanism for each reel is of such character that when the reel functions as an unwinding reel electrical back tensioning will be obtained.

The work rolls of my mill are not driven directly. Each of the backing rolls, however, is driven by a motor either directly or through a gear reducer and suitable connections with the roll neck. While I preferably employ a separate motor for driving each of the backing rolls, a single motor may be used for driving both of the backing rolls. In such a case the drive would be effected through a regular pinion stand. The work rolls are in frictional engagement with the backing rolls and, as the backing rolls are driven, they drive the work rolls in the opposite direction by this frictional engagement. A substantial part of the power required for driving the mill and reducing the metal is supplied in this way, but a substantial portion of the power is also supplied by the forward tension exerted on the delivered material by the reel. Back tension also is preferably employed, since it assists appreciably in the reduction of the screw pressures in the mill. The amount of the back tension desired, of course, must be taken into consideration in the determination of the total power input to the mill.

Thus it will be seen that the entire drive for the work rolls is a frictional drive, that this frictional drive extends throughout substantially the entire length of the roll faces, and that there is a balancing of the torque applied to the work rolls. That part of the power for driving the work rolls supplied through the driving of the backing rolls is transmitted to the work rolls by the frictional engagement of the rolls which extends throughout the roll faces. That part supplied through the pull on the strip is likewise transmitted to the work rolls by the frictional engagement between the strip and the work rolls, and it extends throughout substantially the length of the roll faces. This latter frictional force has a forward component whereas the former force has a rearward component with the result that there is a balancing of forces which serves to hold the small work rolls in line in the mill. All bending of the work rolls is eliminated and, since there is no twisting of the work rolls, such as is encountered when they are directly driven, extreme accuracy can be achieved along with the other advantages mentioned below.

One advantage that this type mill has over the full-pull type of mill and over the part-pull, part-drive type of mill is that smaller, harder work rolls can be employed therein. Tungsten carbide rolls, for example, can be used in the mill which I provide, with a greater degree of satisfaction than in either of the other types of mills. Where carbide rolls are used in the all-pull mill, there is a substantial tendency for them to fracture due to the low bending moment and the strong tendency to bend caused by the excessive forward tension. In the part-pull, part-drive type of mill such rolls cannot be used with any substantial degree of satisfaction because they will not withstand the driving torque required. In the mill which I provide these difficulties are overcome by virtue of the manner in which the power is supplied for driving the rolls and reducing the metal.

I have found that highly desirable results can be obtained where approximately the same amount of power is made available for each of the backing rolls and each of the reels. For example, in a 10 inch mill, I have found that highly desirable results can be achieved by utilizing a 50 H. P. motor for each of the backing rolls and a 50 H. P. motor on each reel, where about 75% of the available back tensioning power is normally employed. Thus, in a normal operation there would be a total of 100 H. P. on the mill, 50 H. P. on the winding reel and 37½ H. P. at the unwinding reel. I have found that each reel should preferably be powered to provide about 20% to 70% of the amount of power supplied to the two rolls combined.

A mill of this character possesses very substantial advantages over the mills discussed above. It is capable of operating at extremely high speeds and large reductions can be made on each pass, thereby reducing the number of passes required in order to reduce the metal to the required thickness. Strip breakage, for all practical purposes, is eliminated. Edge cracking, and particularly the bad effects flowing from edge cracking, is reduced. Work rolls of different diameters can be employed. Smaller rolls can be employed on this type of mill more successfully than on any other type of 4-high mill. Strip steel having a higher ratio of width to thickness can be rolled on the mill than on any other known type of mill. Closer tolerances can be maintained. A proper cross-sectional shape can be obtained and maintained in the metal being rolled. Thinner strip steel can be rolled in single thickness on this mill than on any of the other known mills. In addition, production costs are greatly reduced.

The starting material on this mill, as in the case of other cold rolling mills, is either hot rolled or partially cold rolled strip. The mill in question finds its greatest usefulness in precision rolling of thin strip steel, although it may be used to advantage in the rolling of metal to the heavier gauges. The rolling of heavier gauges can be carried out as advantageously, or more advantageously, on this mill than on some of the other types of mills mentioned above, but as the thickness of the final product decreases, the advantages of my mill over all of the known types of mills increase. While it is not necessary to do so, it is preferable to reduce the metal first on another mill by cold reduction to a thinness of in the neighborhood of .020 inch to about .030 inch. The extent to which the metal will be first cold reduced on some other type of mill, of course, depends on the width and quality of the material being rolled.

In the rolling of low carbon steel, the mill which I provide is capable of a high production as compared to any of the mills mentioned above which are capable of rolling the thinner gauges. When rolling to a thinness of .015 inch, this production is one and one-half times that of the ordinary all-pull type of mill of the same size. When rolling to .010 inch, its production is twice that of the all-pull mill. When rolling to a thinness of .007

inch, its production is three times that of the all-pull mill. In rolling to .005 inch, its production is four times that of the all-pull mill. When rolling to a thinness of .003 inch, its production is five times that of the all-pull mill. And when rolling to a thinness of .0015 inch, its production is ten times that of the all-pull mill. In the rolling of high carbon steel, the production of the mill such as I provide is up to ten times that obtainable on the all-pull type of mill.

One of the reasons why the productive capacity of this mill is so much in excess of that of a similar size all-pull mill which, incidentally, is the best of the old types of mills for rolling to thinner gauges, is that greater drafts can be taken. Low carbon steel, for example, can be rolled to a thinness of .006 inch in 35% reductions per pass. In rolling low carbon steel from .015 inch to .006 inch, three passes only are necessary. On the all-pull type of mill it would not be practicable to roll such material to a thinness of .006 inch with reductions greater than 20% per pass. In rolling such steel from .015 inch to .005 inch, only three passes are required. Seven passes would be required for rolling such material on the all-pull type of mill. In the rolling of material to a thinness of .002 inch, a total of 75% of the passes which would be required on the all-pull mill are eliminated. In rolling to about .005 inch, four or five passes are eliminated. This is approximately one-half of those normally required on the all-pull type of mill. When rolling to lighter gauges on my mill, it is possible to get multiples of the reductions per pass obtainable on the all-pull type of mill.

Sizes such as 18 inches x .004 inch or 18 inches x .003 inch or 18 inches x .002 inch cannot be rolled on part-drive, part-pull mills. Such sizes can be rolled on the all-pull mill but production thereon is only about 10% of the production of such sizes on the mill which I provide. This is due primarily to the fact that strip breakage would be an important factor in the rolling of such sizes on the all-pull type of mill but due to the fact that the amount of forward tension used can be reduced in the mill which I provide, strip breakage can be avoided. If attempts are made to roll below .008 inch or .009 inch on the part-pull, part-drive mill, trouble either in the form of strip breakage or lack of proper shape is encountered.

One of the important reasons for the advantages mentioned is that a proper roll pass is maintainable at all times, even though extremely small work rolls are employed. As stated, the backing rolls are driven. The backing rolls, where they contact the working rolls, rotate in a direction opposite to the direction of rotation of the work rolls at the roll pass and, as a consequence, the backing rolls not only provide for the frictional driving of the work rolls, but they hold the work rolls in axial alinement with each other and in axial alinement with the backing rolls against the forward tension supplied by the winding-up reel. Where small rolls are used in the all-pull type of mill, there is always a tendency for the work rolls to bow forward, but in my mill this tendency is counteracted by the backing rolls, and those rolls also provide a substantial part of the driving force required for operating the mill. Of course, where back tension is employed proper adjustment between the forces exerted on the metal must be made so as to not cause the small rolls to bow in the direction opposite the direction of travel. Such a situation is an unusual one and will not be encountered where the mill is powered in the manner suggested above.

Thus it will be seen that the mill which I provide possesses substantial advantages over the mills known and used generally at the present time.

In the drawings, I have shown for purposes of illustration only a preferred embodiment of my invention. In the drawings,

Figure 1 is a view partly in section and partly in plan taken along the horizontal center line of the mill;

Figure 2 is a side elevational view partly in section;

Figure 3 is an end view looking toward the left as shown in Figure 2;

Figure 4 is an enlarged vertical sectional view taken along the line IV—IV of Figure 2;

Figure 5 is a partial plan view showing a part of the screw-down mechanism; and

Figure 6 is a side elevation taken along the line VI—VI of Figure 5.

In the mill shown in the drawings, the housings **2** are bolted to the bed plate **3**. This bed plate not only carries the housing for the mill, but also carries the support **4** for the reel **5** and the support **6** for the reel **7**.

The mill is provided with an upper work roll **8** and a lower work roll **9**. The upper work roll **8** is in frictional engagement with and is backed up by the backing roll **10**. The work roll **9** is in frictional engagement with and is backed up by the lower backing roll **11**. The work rolls **8** and **9** have necks thereon so as to enable them to be supported in suitable antifriction bearings such as the roller bearings **12** and **13**, respectively. The backing rolls are likewise of the neck type. The necks **14** of the upper backing roll **10** are mounted in bearings **15**. The necks **16** of the lower backing roll **11** are mounted in bearings **17**. These bearings for the backing rolls, as illustrated in the drawings, are of the roller type, but pressure lubricated sleeve bearings, such as the Mesta and Morgoil types, likewise may be employed.

The upper backing roll bearings are mounted in chocks **18** and the lower backing roll bearings are mounted in chocks **19**. The upper chocks, of course, are mounted for vertical movement so that the pass and the pressure exerted on the metal by the rolls may be regulated through a screw-down mechanism indicated generally by the reference character **20**. As illustrated in the drawing, the screw-down mechanism is of the wedge type, a wedge **21** being mounted on a screw **22** which is rotated by means of a hand wheel **23** and suitable gearing **24**. Rotation of the hand wheel results in the wedge being moved along an inclined surface **25** to raise or lower the upper chocks carrying the bearings for the bearing rolls.

The screw-down mechanism, as is indicated in the drawings, may be of the electrical type commonly employed in the rolling mill industry. In this type of screw-down, the screw is actuated through the gearing **24a** by means of a motor **26**.

As is stated above, the work rolls are not driven except through (*a*) the frictional engagement with the backing rolls and (*b*) the frictional engagement between the rolls and the metal. The upper backing roll **10** and the lower backing roll **11** are driven by motors **30** and **31**, respectively. The motor **30** is connected to the upper backing roll through a wobbler connection **33**. Likewise, the motor **31** for the lower backing roll is connected to the roll through a wobbler connection **35**. In the mill illustrated in the drawing, which is the one in which the work rolls are from 1½ inches to 3 inches in diameter and with a roll face of 10 inches, each backing roll was driven by means of a 50 H. P. motor.

Each housing has an extension **45** which projects toward the one reel, which is illustrated as the unwinding reel in the drawing, and an extension **46** projecting toward the winding reel. Between the projections **45** a cooling drum **47** is mounted, the drum **47** being supported in suitable bearings **48** carried by the extensions **45**. The cooling drum **49** is likewise carried in bearings **50** supported on the projections **46**. The drums **47** and **49** may be water-cooled so as to extract from the metal some of the heat which is imparted to it as the result of the reductions being made thereon. The drums are of a suitable diameter to provide for horizontal travel of the metal between the drums and the pass formed by the two work rolls.

As is customary in rolling mills for rolling thin products, guides for accurately guiding the metal into the roll pass are employed. While such guides need not be used, I preferably employ them in the mill shown in the drawings. Wooden guides **51** and **52** are shown on opposite sides of the mill. Of course, the reason for having guides on opposite sides is that the mill illustrated is of the reversing type, the metal being rolled first in one direction through the mill and then in the other.

The reel **5** (which is the unwinding reel as illustrated in the drawings) may be of the collapsible type, although I prefer a solid type of reel having a transverse slot therein for receiving the end of the strip for gripping it when it is being placed on the reel. Provision is made for driving the reel **5** when it is used as the winding reel and for driving a generator so as to provide back tension on the strip when it is being used as the unwinding reel. The reel **5** is connected to the motor or generator **53** through a gear reducer **54** and a wobbler connection **55**. The reel **7** is of the same type as the reel **5**, having a transverse slot for gripping the end of the strip to assist in wrapping it on the reel without slippage. This reel, like the reel 5, is connected to a motor or generator 56 through a gear reducer 57 and a wobbler connection 58. When the coil C on reel 7 has been given the final pass and is ready to be removed from the reel, it may readily be transferred to a coil carriage 60 which is movable upon rails 61.

Oil, of course, is supplied to the strip during the rolling operation and, as a consequence, it is desirable to provide oil guards 62 adjacent each of the reels so that the oil will not be strewn about the room or sprayed on the workmen.

In the mill illustrated in the drawings, each of the reels was powered by a 50 H. P. motor.

In the rolling of metal on this mill, the partially reduced strip is placed on the reel 5 and is threaded through the mill to the reel 7, the end thereof being gripped by the gripper arrangement mentioned above. Power is supplied to the backing rolls for driving them, and power is also supplied to the reel 7 for driving it. The motor, which is connected to the reel 5, is rotated by the pull on the strip and this provides an adjustable electric back tension. The forward reel provides tension on the strip which is sufficient to assist in driving the mill and reducing the metal. Power is supplied to the work rolls through the frictional engagement between the work rolls and the backing rolls. A substantial proportion of the total power required for carrying out a rolling operation is supplied in this way.

After the metal has been given one pass through the mill in the manner mentioned, the one end is connected to the reel 5 through the gripper arrangement described above, and the operation is reversed, the metal being passed from the reel 7 through the mill and on to the reel 5. Any suitable number of passes may be employed to give the desired results.

As is stated above, I have found that the mill which I provide will make reductions which cannot be made satisfactorily on any of the presently known types of mills. In the rolling of low carbon steel in accordance with my invention a production of from one and one-half to ten times that obtainable on the all-pull type of mill can be obtained. In the rolling of high carbon steel, approximately ten times as much can be produced on this mill, for any given time, than on the all-pull type of Steckel mill. This results in a tremendous lowering of production costs.

While I have shown and described a preferred embodiment of my invention, and the preferred method of rolling on such a mill, my invention is obviously not limited thereto, but may be otherwise embodied or carried out within the scope of the appended claims.

I claim:

1. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a backing roll for each work roll, the work rolls and the backing rolls being arranged in frictional engagement with each other and in alignment with their longitudinal axes in substantially the same vertical plane, which comprises the steps of passing the strip back and forth between the work rolls to effect a substantial reduction in the thickness of the strip, applying a forward tension on the delivered strip of sufficient magnitude to supply a substantial portion of the power required to move the metal between the rolls and reduce it in thickness, and at the same time positively driving the backing rolls and thereby driving the work rolls by the frictional engagement between the backing rolls and the work rolls to thereby supply a substantial part of the power required to reduce and deliver the strip.

2. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls, each of which is too small to be self-supporting, and a single backing roll for each work roll in frictional engagement therewith, which comprises passing the strip back and forth between the work rolls to effect a substantial reduction in the thickness of the strip by applying a forward tension on the delivered strip and at the same time driving the backing rolls directly and the work rolls indirectly through the frictional engagement between the backing rolls and the work rolls, the forward tension on the delivered strip being of sufficient magnitude to supply an appreciable portion of the power required to reduce the metal and the power supplied through the driving of the backing rolls also being sufficient to provide an appreciable portion of the total power required for reducing the metal.

3. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls, each of which is too small to be self-supporting, and a single backing roll for each work roll in frictional engagement therewith, which comprises passing the strip back and forth between the work rolls to effect a substantial reduction in the thickness of the strip by applying a forward tension on the delivered strip and at the same time driving the backing rolls directly and the work rolls indirectly through the frictional engagement between the backing rolls and the work rolls, the forward tension on the strip being of sufficient magnitude to provide approximately 50% of the power required for reducing and delivering the strip and the remaining portion being supplied by said frictional driving of the work rolls by the backing rolls.

4. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls, each of which is too small to be self-supporting, and a single backing roll for each work roll in frictional engagement therewith, which comprises passing the strip back and forth between the work rolls to effect a substantial reduction in the thickness of the strip by applying a forward tension on the delivered strip and at the same time driving the backing rolls directly and the work rolls indirectly through the frictional engagement between the backing rolls and the work rolls, the forward tension on the delivered strip being of sufficient magnitude to supply approximately 20% to 70% of the total amount of power applied to the rolls.

5. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a single backing roll for each work roll in frictional engagement therewith, which comprises positioning the strip between the work rolls and driving the work rolls first in one direction and then in the reverse direction entirely by frictional forces exerted on said rolls by applying a substantial forward tension on the delivered strip and by positively driving the backing rolls, which, in turn, drive the work rolls by the frictional engagement therebetween, a substantial portion of the power required for reducing and delivering the strip being supplied by the forward tension on the strip and a substantial portion being supplied through the frictional driving of the work rolls by the backing rolls.

6. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a single backing roll for each work roll in frictional engagement therewith, which comprises positioning the strip between the work rolls and driving the work rolls first in one direction and then in the reverse direction entirely by frictional forces exerted on said rolls by applying a substantial forward tension on the delivered strip and by positively driving the backing rolls, which, in turn, drive the work rolls by the frictional engagement therebetween, the power for reducing and delivering the strip supplied through tension being approximately 20% to 70% of that supplied through the driving of the backing rolls.

7. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a single backing roll for each work roll in frictional engagement therewith, which comprises positioning the strip between the work rolls and driving the work rolls first in one direction and then in the reverse direction entirely by frictional forces exerted on said rolls by applying a substantial forward tension on the delivered strip and by positively driving the backing rolls, which, in turn, drive the work rolls by the frictional engagement therebetween, each of said drives for the rolls supplying approximately 50% of the power required to reduce and deliver the strip.

8. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a single backing roll for each work roll in frictional engagement therewith, which comprises positioning the strip between the work rolls and driving the work rolls entirely by frictional forces exerted on said rolls by applying a substantial forward tension on the delivered strip and by positively driving the backing rolls, which, in turn, drive the work rolls by the frictional engagement therebetween, a substantial portion of the power required for reducing and delivering the strip being sup-

plied by the forward tension on the strip and a substantial portion being supplied through the frictional driving of the work rolls by the backing rolls.

9. The method of cold reducing metal in strip form in a mill of the 4-high type having a pair of work rolls and a single backing roll for each work roll in frictional engagement therewith, which comprises positioning the strip between the work rolls and driving the work rolls entirely by frictional forces exerted on said rolls by applying a substantial forward tension on the delivered strip and by positively driving the backing rolls, which, in turn, drive the work rolls by the frictional engagement therebetween, the power for reducing and delivering the strip supplied through tension being approximately 20% to 70% of that supplied through the driving of the backing rolls.

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