April 8, 1941. T. SENDZIMIR 2,237,794

DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 1

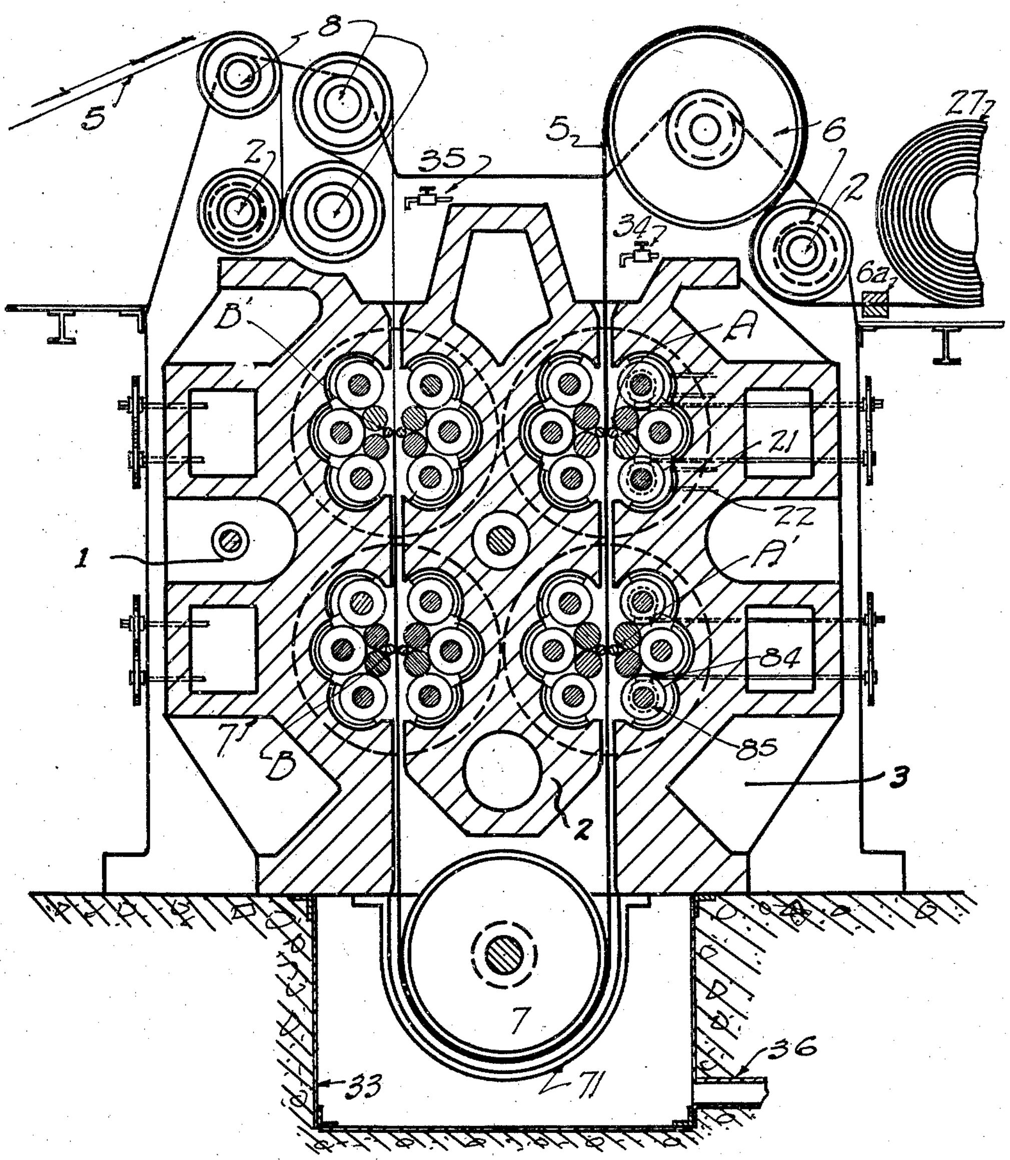


FIG. 1.

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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 2

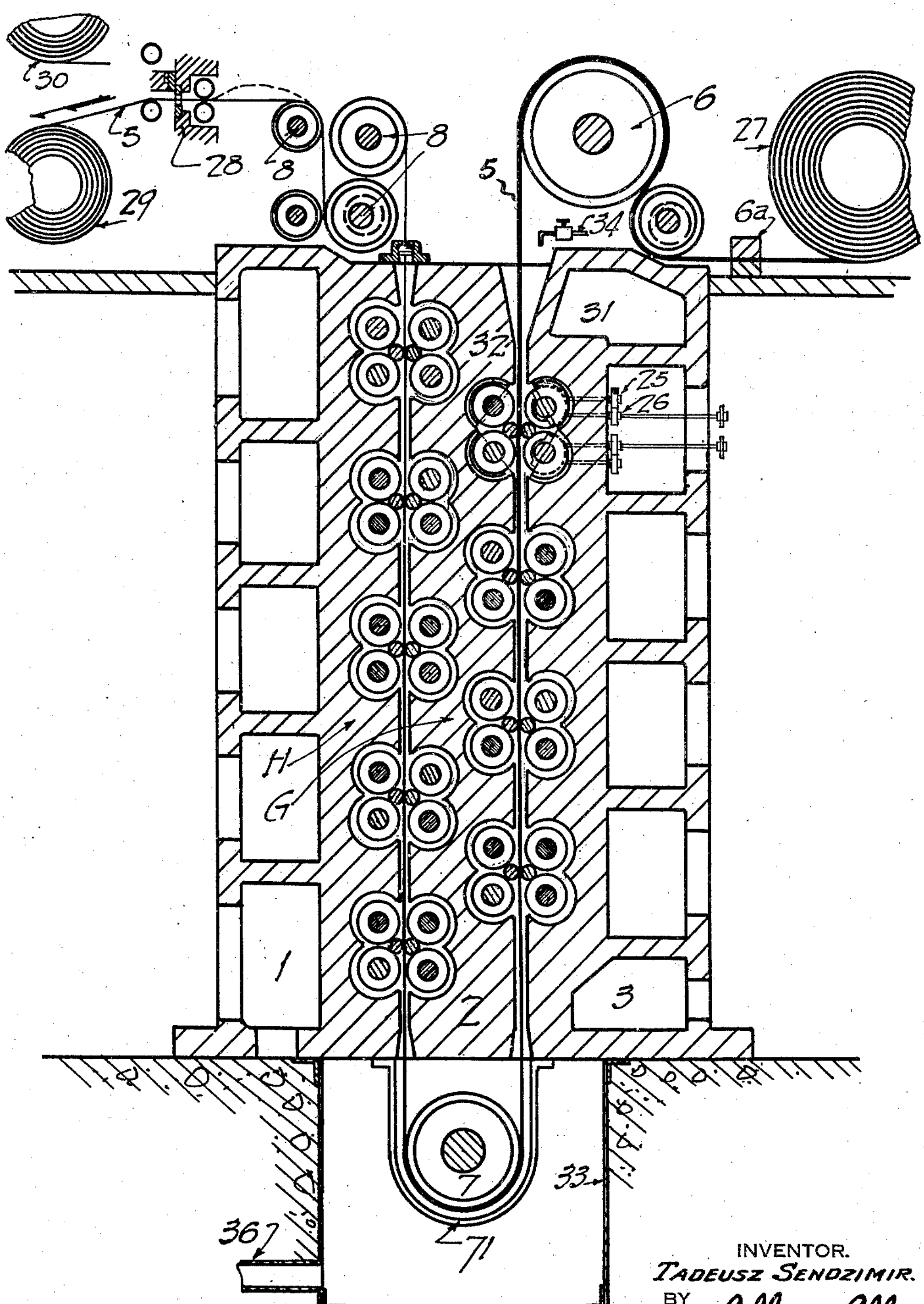


FIG. 2.

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DEVICE FOR REDUCING SHEET METAL

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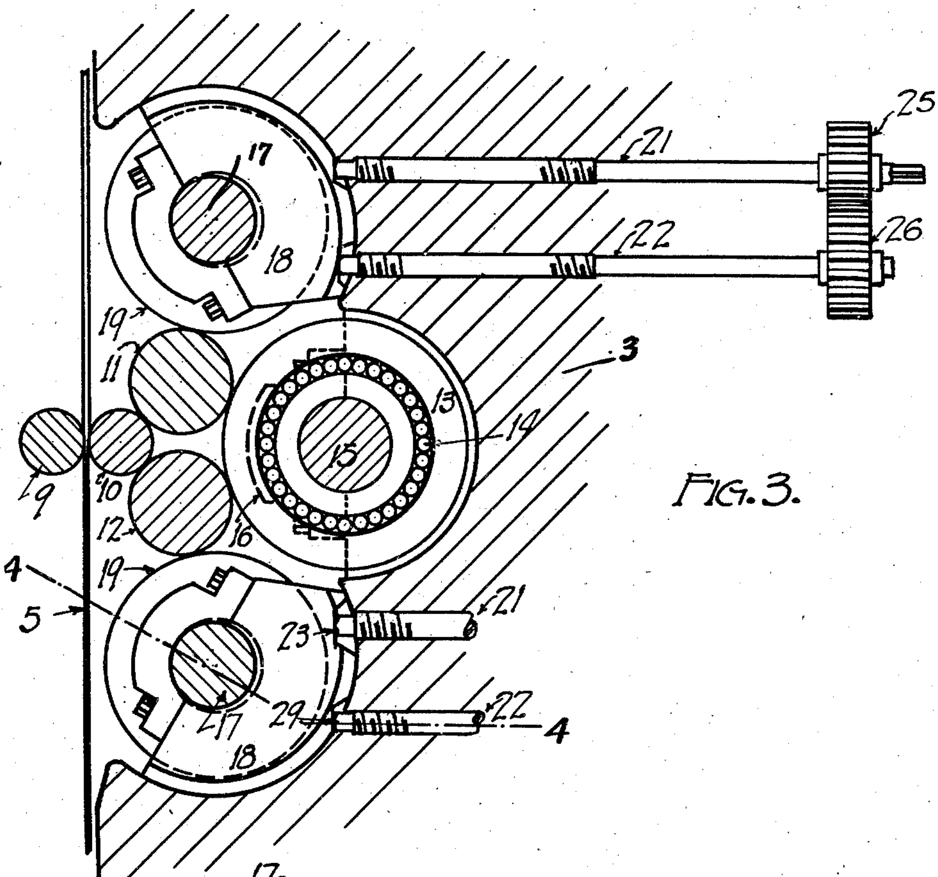


FIG. 3.

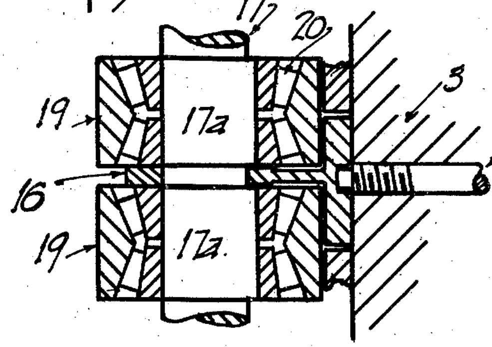


FIG. 4.

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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 4

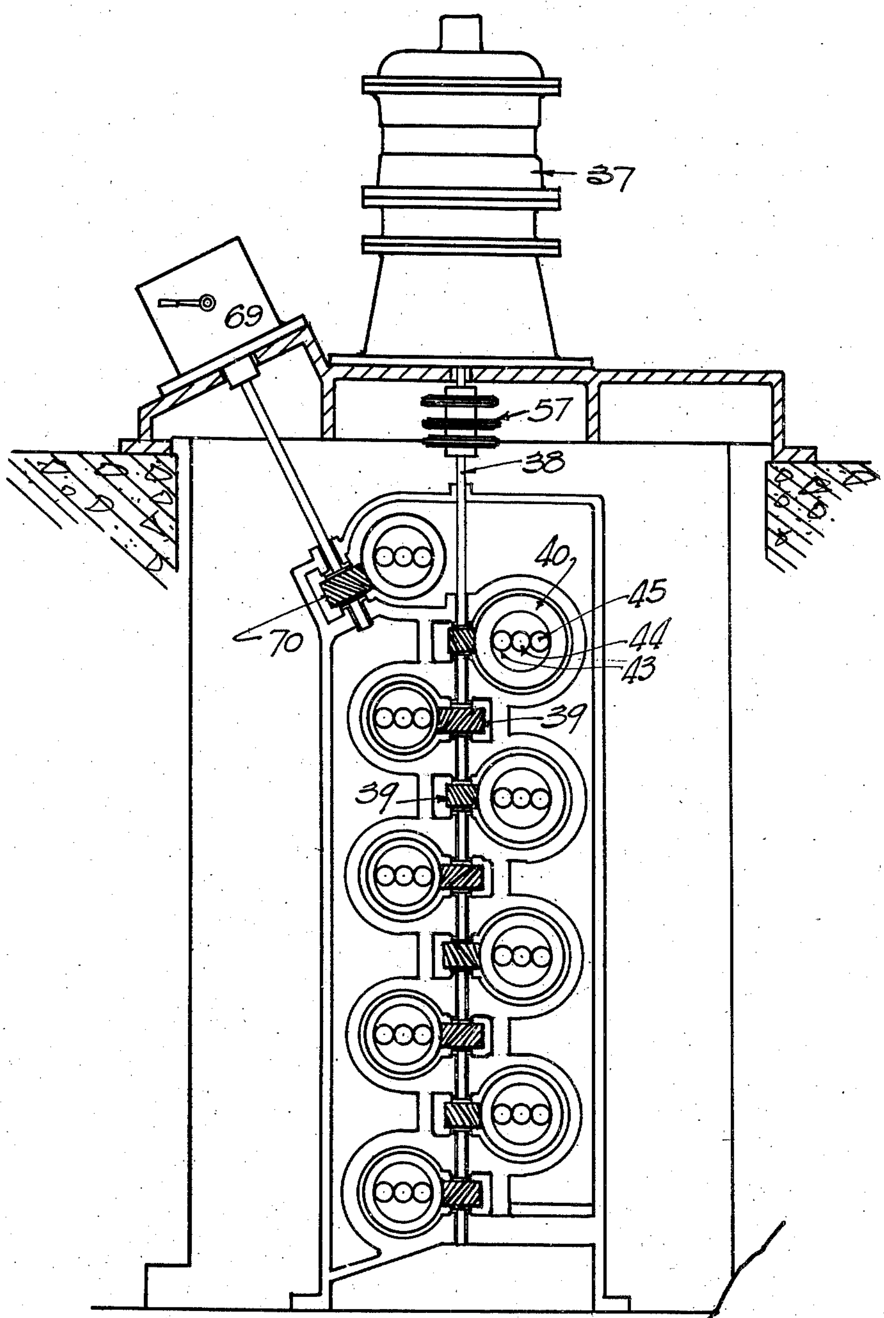


FIG. 5.

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April 8, 1941. T. SENDZIMIR 2,237,794

DEVICE FOR REDUCING SHEET METAL

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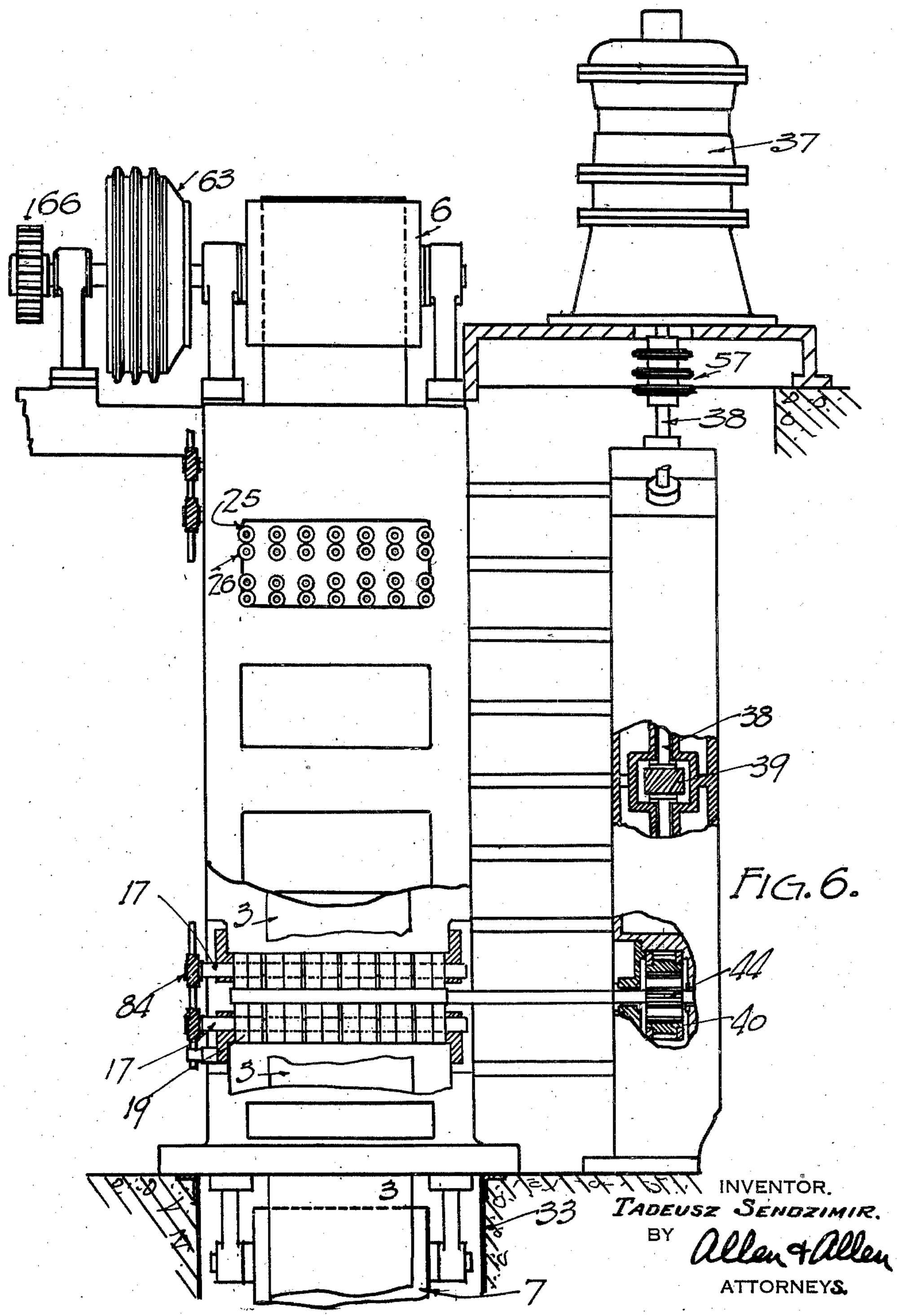


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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 6

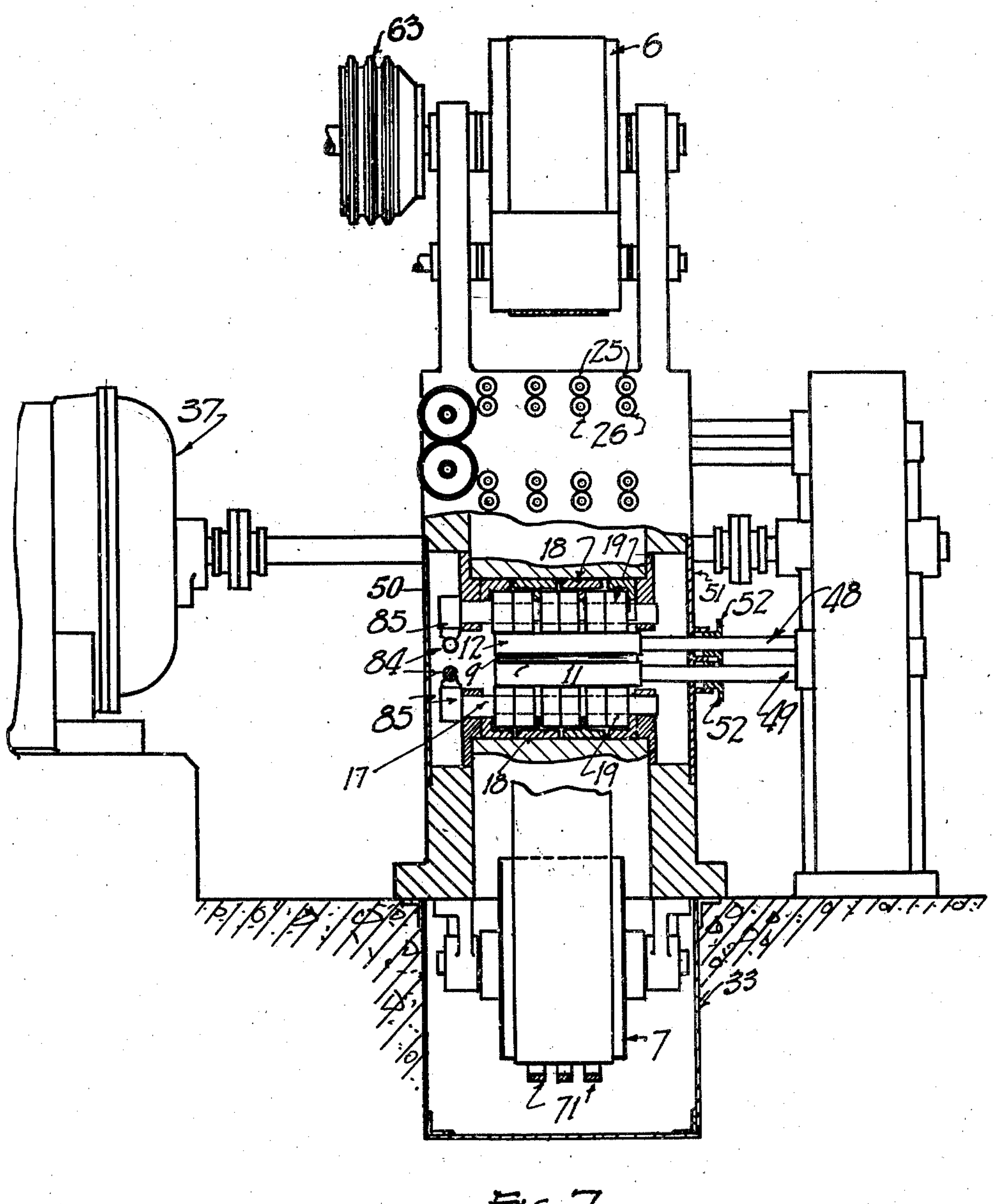


FIG. 7.

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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 7

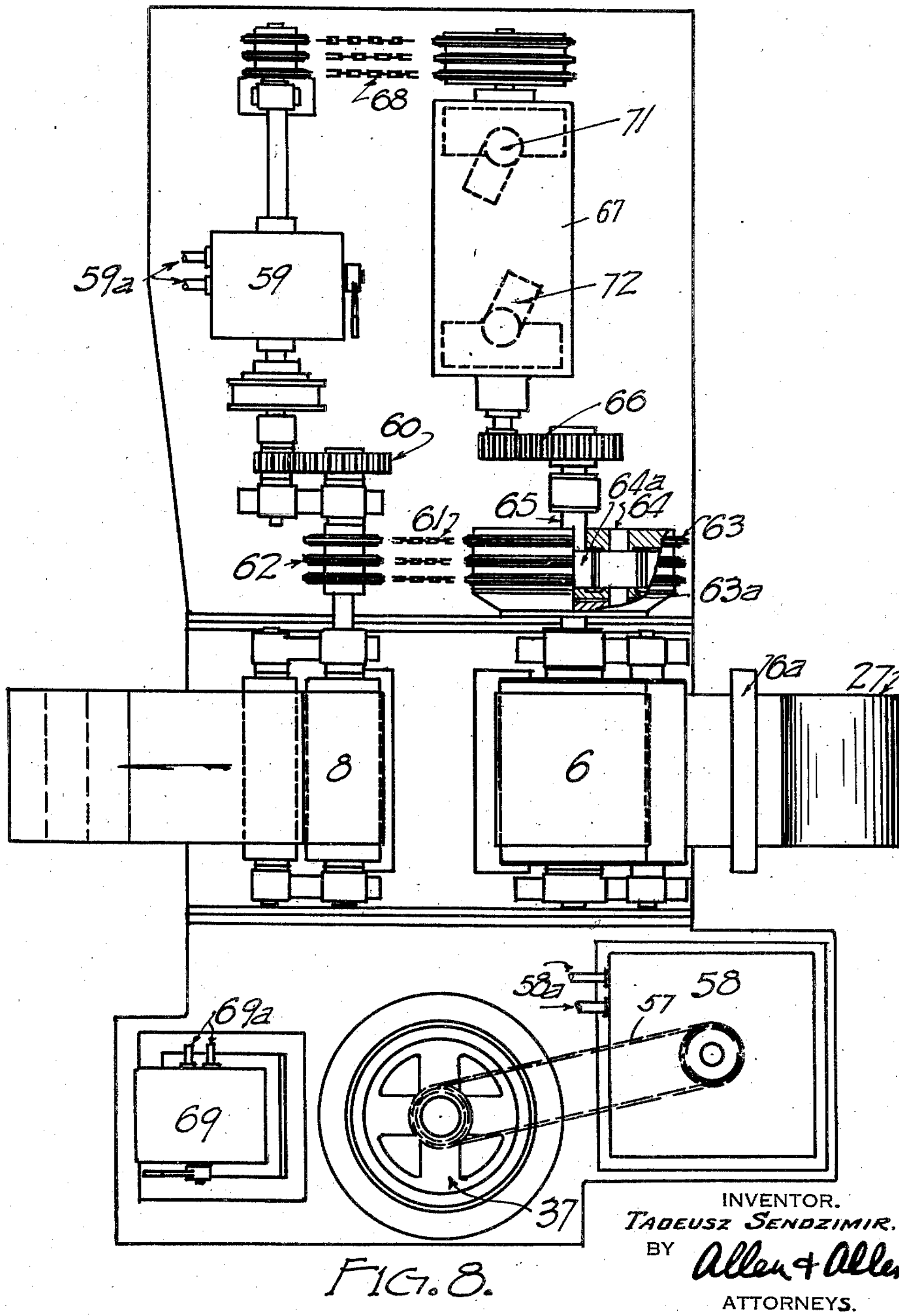


FIG. 8.

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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 8

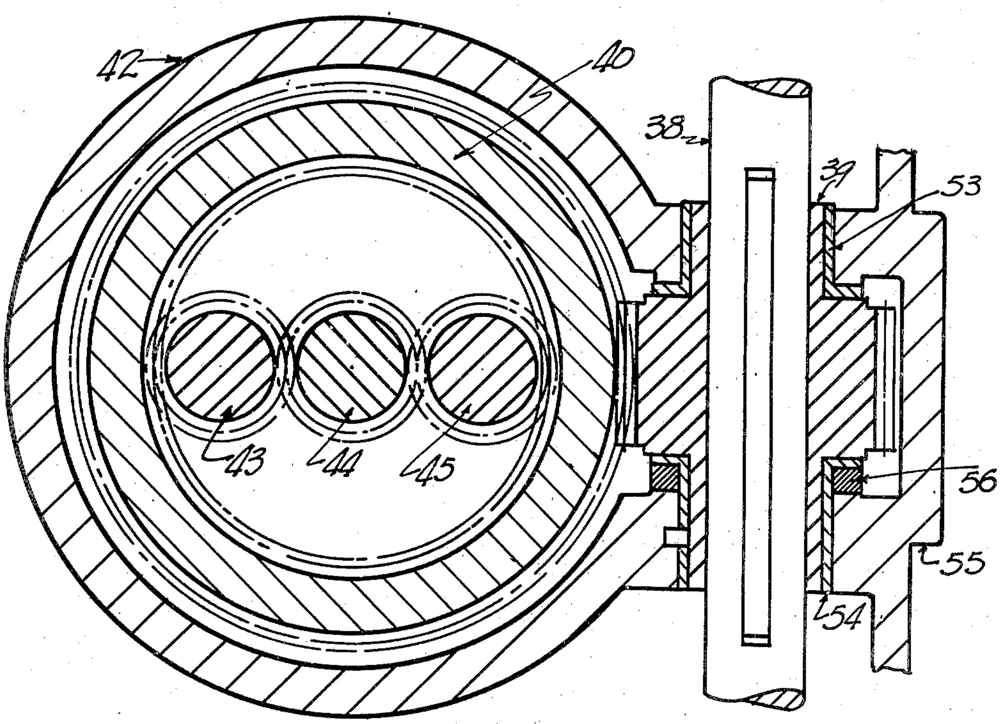


FIG. 9

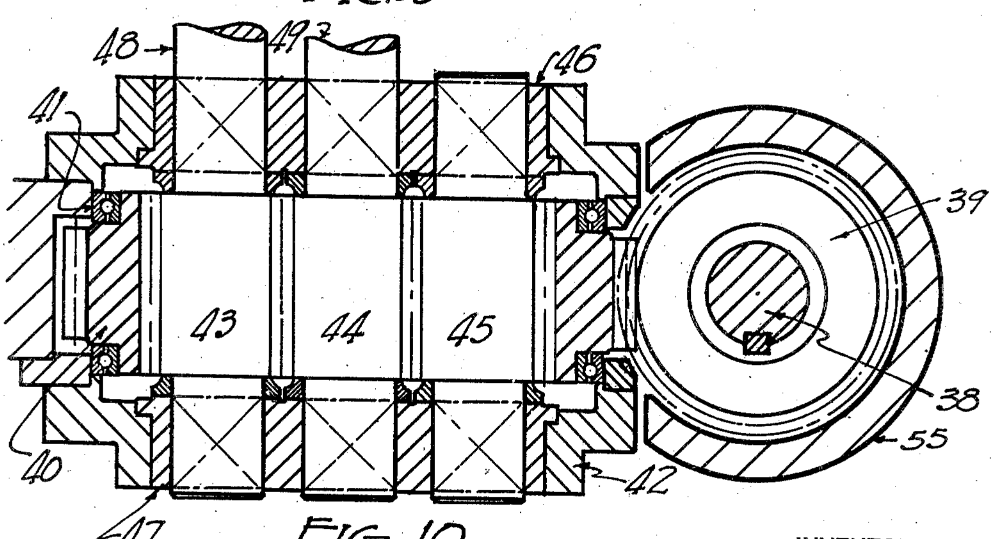


FIG. 10.

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DEVICE FOR REDUCING SHEET METAL

Filed May 12, 1937 9 Sheets-Sheet 9

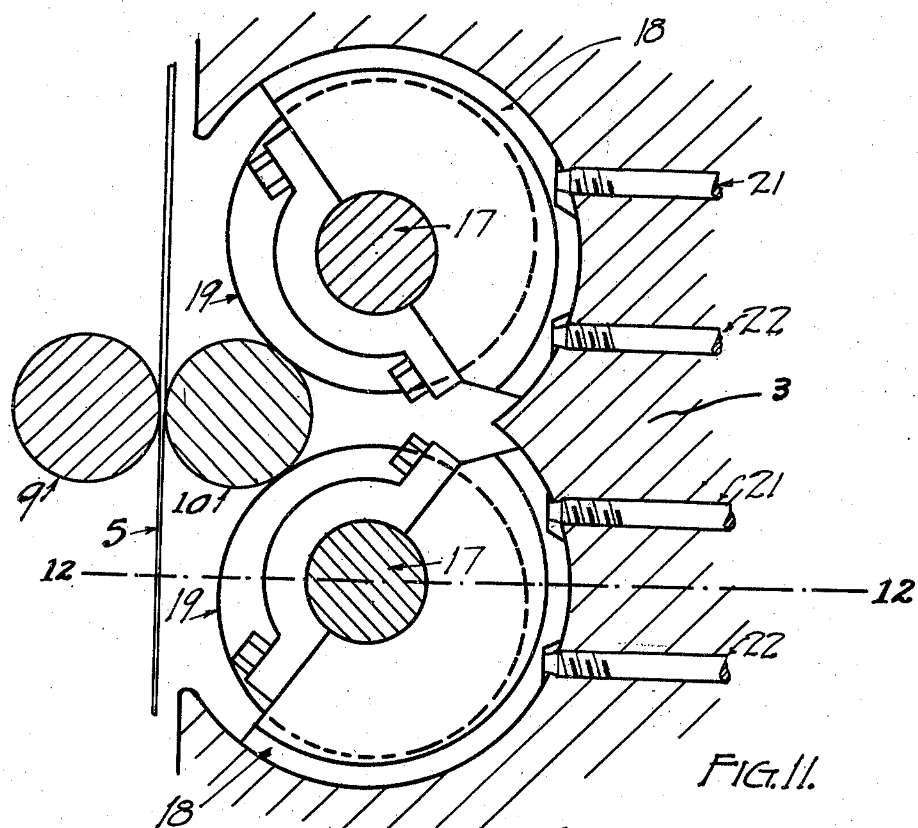


FIG. 11.

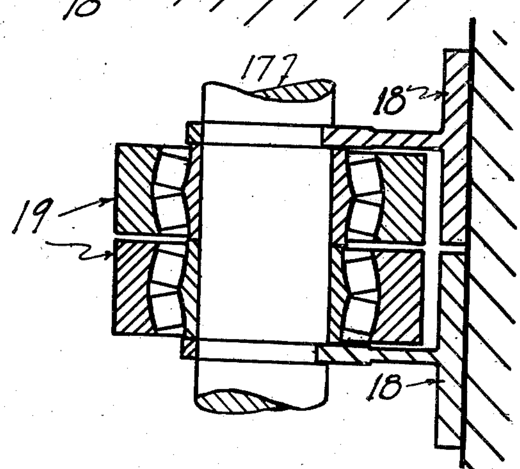


FIG. 12

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Patented Apr. 8, 1941 2,237,794

# UNITED STATES PATENT OFFICE

2,237,794

## DEVICE FOR REDUCING SHEET METAL

Tadeusz Sendzimir, Paris, France, assignor to The American Rolling Mill Company, Middletown, Ohio, a corporation of Ohio

Application May 12, 1937, Serial No. 142,217

19 Claims. (Cl. 80—35)

My invention relates to means for reducing metal by rolling and comprises in part a mechanism which is automatic or semi-automatic in operation and in which the metal is treated a plurality of times in succession. This, together with the securing of various advantages of a rolling operation of this type, together with the provision of a suitable and effective mechanism for the purpose all, as will more fully be set forth hereinafter, constitute the fundamental objects of my invention.

The type of rolling apparatus, so far as the individual rolling unit is concerned, is similar to that set forth in my co-pending applications, Serial No. 742,075 filed August 30, 1934; Serial No. 31,697 filed July 16, 1935; Serial No. 31,698 filed July 16, 1935; and Serial No. 83,534 filed June 4, 1936. In these applications I have described a certain process of rolling strip material, wherein the rolling operation, the elongation of a strip may be maintained constant in spite of variations of temper and gauge and wherein certain means driven in a predetermined relationship with the mill provide a predetermined, but controllable feeding-in speed for the strip, as well as a predetermined and controllable feeding-out speed, thus permitting, in conjunction with the use of working rolls of very small diameter and rigidly supported ultimately by means of the mill frame, the rolling of strip with great flatness and extreme accuracy in spite of the variations in the rolling pieces which have been mentioned.

These teachings may be employed in connection with the present invention, but are not necessarily limitations thereon, as will be clearly set forth hereinafter.

In constructing a mill of the character to which the present invention relates, two or more stands of working rolls may be combined in one frame. Regarding the several stands as constituting a train of working instrumentalities, it will be seen that as to any particular mill a preceding mill can act as a positive feeding-in means, while a suceeding mill can act as a positive feeding-out means and the advantages of the former invention secured with less over all apparatus. A difference in the process lies in this that in the system of my former application the feeding-in and feeding-out devices were essentially devices having no reducing function, whereas in the present case, as respects some of the pairs of working rolls at least, the feeding-in and feeding-out devices have a reducing function, so that compensations in rolling conditions can produce under the influence of varying tensions, a constant rate of elongation, which compensations may be occurring simultaneously at more than one stand of working rolls.

It must be recognized that the action of a pair of reducing rolls, especially of a small diameter, is not exactly the same as that of a feeding device having substantially no reducing function. This is due to the slippage of the strip within the roll bite which varies both with the tension of the strip in front and after the rolls, as well as with the pressure.

What is meant here is that it will act as such for this purpose, that is for feeding the metal at constant predetermined proportion of velocities so that the strip will elongate uniformly and be independent of irregularities in thickness, temper and other characteristics of the raw material.

However, with a mill as described in this application, the reducing rolls act on the strip in succession and it will be clear that if a plurality of reducing rolls are considered, their action on the strip resembles very closely the action of a non-reducing feeding device, as they pull the strip jointly and jointly neutralize any cause (such as a thick spot on the strip) which may affect accurate and uniform reduction.

I have found that by combining in one frame or stand two or more pairs of working rolls of the character described, I obtain very valuable economies in the weight and size of the mill, since the supporting beams or structural framework can be made to support simultaneously two or more working rolls, the reaction of which at least partially counteract each other. The resultant force in the beam is therefore smaller than it would otherwise be and the structure of the mill does not need to be unduly heavy.

An obvious economy lies in the fact that, in such a device the feeding-in and feeding-out devices which do not have a reducing function are required, so that in most instances but one feeding-in and one feeding-out device need be provided.

Still another important simplification and advantage lies in the driving means for a plurality of mills. In a machine of the type described a certain percentage of reduction may be first decided upon for each pair of rolls, and a common rigid geared drive may then be provided for all of them, this drive being suitably connected with the feeding-in and feeding-out devices. Applicant prefers for this purpose, to adopt a percentage of reduction comfortably below the best reduction which could be obtained in each pass, so as to be able to accomplish it irrespective of the quality of the rolling piece and the other variable factors which must be taken into account. An exception to this procedure may be made in the last stand of rolls which can, with advantage, be driven separately and finally for the purpose of obtaining any final gauge desired.

It will be readily understood that with a mechanism in which the rigid drive is correctly adjusted, the same general rolling principles will apply as those set forth in the co-pending applications above enumerated. Thus tension of a high order per unit of strip section may exist between the feeding-in and the feeding-out machines and the rolls, and also between each adjacent pair of working rolls. Yet such tension is merely a result of certain proportions of velocities imparted to the strip and is not capable in itself of influencing the velocity of any given working part of the mill. However, elongation may be maintained constantly at a predetermined value, the tensions varying as may be required to accomplish the predetermined elongation. Of course, a condition of correct adjustment would be upset with any such mechanism if any one of the elements should be disturbed. For example, if a pair of working rolls were substituted in any given mill for a pair of larger diameter, the condition of adjustment would not be the same. In my mechanism, however, such mal-adjustment within certain limits can be corrected by the adjustment of the roll pass of one or more pairs of rolls.

I have solved the main difficulty connected with the operation of a system of this sort. This difficulty is to ascertain, during the actual working of the mechanism, which if any of the pairs of rolls needs special adjustment and if it does, how much adjustment is needed. My solution is based upon the fact that when a pair of rolls actually accomplished the reduction it was intended to accomplish, it is bound to require a certain torque to do it. If the ratio of reduction is upset, however, slightly, the tensions both in front of and behind the rolls are altered and so also is the actual work of reduction accomplished by the rolls. All three of these factors tend to change always in the same direction; that is to say they do not counteract each other. Therefore it is possible to provide for each pair of working rolls a simple means to give a constant measurement of the torque transmitted. The operator, in the operation of the mechanism, therefore, has only to see that the measured torques do not vary too far from predetermined values, by suitably adjusting the roll clearance or screw-down so called, on one or more of the pairs of rolls in accordance with the torque measurements. All of this can be done during the continued operation of the mechanism.

Various objects of my invention which have been set forth hereinabove, or will be apparent to one skilled in the art upon reading these specifications, I accomplish by that certain construction and arrangement of parts of which I shall now describe certain exemplary embodiments. For clarity reference is now made to the drawings wherein:

Figure 1 represents a sectional view through a mill embodying my invention.

Fig. 2 is another sectional view through a mill of slightly different character.

Fig. 3 is a sectional view on an enlarged scale of a type of individual mill construction as shown on Fig. 1.

Fig. 4 is a sectional view of a portion thereof taken along the lines 4—4 of Fig. 3.

Fig. 5 is a sectional view through the driving means for a mill of the type shown in Fig. 2.

Fig. 6 is an end elevational view with parts in section of the mill of Figs. 2 and 5.

Fig. 7 is an end elevational view with parts in section of the mill of Fig. 1.

Fig. 8 is a top plan view of the mill of Figs. 2, 5 and 6.

Figs. 9 and 10 are respectively vertical and horizontal sections of a particular type of mill drive which I find advantageous to use.

Figs. 10 and 11 are sectional views, on an enlarged scale, of a type of individual mill construction as shown in Fig. 2.

Fig. 12 is a sectional view taken along line 12—12 of Fig. 11.

By reference to Figs. 1 and 2 it will be noted that my mill comprises in general a housing which can be divided into three parts indicated respectively at 1, 2 and 3. The strip 5 first passes through a feeding-in device indicated generally at 6, then between the parts 3 and 2 over a sheave marked 7, back between the parts 2 and 1 and over a feeding-out device indicated generally at 8. I have shown mills indicated at A, A', B, B', etc. In Fig. 1 four such mills are shown, two operating on the strip 5 during its downward passage and two operating on the strip 5 during its upward passage. In Fig. 2 I have shown nine mills compressed in the same stand.

Now it will be noted, that the member 2 is common to the several mills and supports oppositely directed pressure strains, whereby this part does not need to be so heavy. Moreover it will be noted that the mills are of a type in which the forces applied to the outer mill frame members 1 and 3 are not wholly normal to the axis of the frame members and therefore in part counteract each other. The mill frame or housing comprises the parts 1, 2 and 3 and is either made of one piece of metal, or of several parts which are solidly and rigidly fastened together in any way desired.

As to the mills themselves, I prefer to use such constructions as are shown in greater detail in Figs. 3 and 4 and 11 and 12. Modifications in these structures may be made without departing from the spirit of my invention. The various structures in general are described and claimed in my co-pending applications referred to above. They differ from each other in various ways, such as in the number of elements which back up the working rolls and in the manner of actuation of the elements for pass adjustment, i. e., for gaining the effect of screw-down. For the purposes of this application, I shall describe but the two structures, namely, the structures set forth in Figs. 3 and 4 and 11 and 12, it being understood that those particular structures do not constitute a limitation upon my invention as hereinafter claimed.

I have shown in these figures a mill, having a housing portion 3. A pair of working rolls 9 and 10 are indicated as operating upon the strip 5. In the particular mill shown on Figs. 3 and 4, the roll 10 is backed up by a pair of intermediate rolls 11 and 12 which in turn contact three parallel rows of backing rings 19, mounted on shafts 17, 15, 17, and interspaced with disc-like bearing members 18 resting directly in circular channels provided in the beam 3 of the mill stand. Clamps 16 are bolted to said bearing members 18 jointly forming a bore for the necks of shafts 17 and 15.

In this way, shaft 17 is journaled in said bearing members 18, while on its eccentric necks are mounted backing rings 19, coaxial for each shaft 17 and 15; such backing rings 19 have an outward appearance of a roller bearing with a thick outside ring, in order to distribute the contacting pressure, of the intermediate roll 11, 12 over a number of rollers 20. They may be roller bearings, with rollers 20, as illustrated or, ball, needle bolt or sliding type of a bearing.

The bearing members 18 may be interspaced between such bearing rings 19 so that one, two or more bearing rings 19 comes between two bearing members 18, but always so that the deflection of the reducing roll 9, 10, produced by the rolling pressure, between each two supporting bearing members 18, is considerably less than what would impair either the accuracy of the rolled product or the process of rolling. The central row of supporting bearings may be mounted on a plain shaft 15, but I prefer to make this shaft also excentric so as to make certain hand adjustments possible.

Two intermediate rolls 11 and 12 rest each on a pair of rows of supporting rings 19, so that the central row supports both rolls 11 and 12 at the same time. The load on it will not be greater, however, than on the other two rows of bearings, as the forces partly offset themselves. The reducing roll 10 is, in turn, supported by the two intermediate rolls 11 and 12.

The roll pass adjustment, that is the adjustment of the distance between the two rolls of each pair, is obtained by adjusting the angular position of the excentric shafts 17 which may be done by means of worms 84 and worm sectors 85, (Fig. 7). Worms 84 may be mounted on one common shaft and engaged singly or in groups by suitable clutches. A possibility of adjustment in groups is very important since an adjustment of one pair of rolls in most cases, calls also for an adjustment of all pairs that come after it. The bearing members 18 (Figs. 3, 4, 11 and 12) are excentric and by adjusting their angular position, as by turning the screws 21, 22 which are joined between themselves by gears 25, 26 and thus form pairs of screws, one for each bearing member. Said screws 21, 22 engage into suitable recesses in the bearing member 18 and when one screw moves forward, the other is forced to turn in the opposite direction by the pair of gears and therefore recedes the same distance, so that, as a result of such adjustment, the angular position of the bearing member 18 is altered. The bore of the bearing member 18 being excentric with its outer diameter, such alteration of the angular position also alters its effective height, as a support, and by such adjustment the working rolls may be made to press more in the center than at the sides of the strip, or vice-versa, and, in fact, any effect corresponding to what is called "crown" or barrel-shaped form on ordinary two- or four-high mills, can be produced instantaneously and, if necessary, even while the mill is running. A similar adjustment, with ordinary mills, necessitates taking out the rolls and grinding them to a different crown. Minor adjustments, on existing mills, can be made by applying gas or other flames to the surface of the rolls or supporting rolls, which also is a lengthy and uncertain operation, as compared to this one requiring practically no time and being extremely precise. This form of roll support is only given by the way of example and any type of roll support where working rolls rest upon beams or other parts of the frame, either directly or through suitable intermediate rolls, bearings, rings or the like may be used with the present invention.

In my mills the shape of the piece can be very accurat ly determined by the adjustment of the several supporting means along the length of the working rolls or working roll supports and the various types of adjustments set forth in my co-pending applications may be employed here. I have not illustrated these nor the mechanical interconnection between the adjustment means since this does not form a necessary limitation upon the invention herein claimed.

The mill construction as illustrated in Figures 11 and 12 is of a more simple design there being only two rows of supporting rings 19 and contacting with one reducing roll 9. Each row of supporting rings corresponds to the construction as described in connection with Figures 3 and 4. That is to say semi-circular channels are provided in the beam 1 of the mill stand and in each channel there is an excentric shaft 17 and in each supported, at frequent intervals, by disc-shaped bearing members 18 interspaced with bearing rings 19 which may be of a ball, roller or plane-bearing type and mounted on the bigger diameter next 17a of said excentric shaft.

As shown in this construction, I prefer to employ self-adjusting bearings which in this case can be mounted in pairs, that is to say, two rings 19 between each pair of bearing members 18 can be either type of a bearing, in spite of the reflection of the excentric shaft 17. The support of the working rolls 9 remains uniform and undisturbed, the rings 19 not following the bending of the excentric shaft, owing to this feature of self-adjustability.

The latter is obtained as a rule by having the inner diameter of the supporting ring 19 spherically shaped, the support of the sphere corresponding to the geometrical center of the ring.

Adjustment for roll pass, by changing the angular position of one, or better still of both excentric shafts 17, in this instance, is effected exactly as in the case of Figs. 3 and 4 with the only exception that the position of the rings 19 affects directly the position of the working roll 9, and not through any intermediate rolls like in Fig. 3.

The same applies to the "contour" or "crown" adjustment of the rolls, the two screws 21 and 22 being provided for rocking said bearing member 18 and thereby individually adjusting the shape of the roll contour at a plurality of points along their working length as shown in Fig. 12.

The object of the mill in the present invention will be in most cases of practical use, to roll such stock as can comfortably be produced on a hot mill, say of the order of from one-half to one-eighth inches or even less in thickness and bring it down in one passage through my mill combination to a desired finished gauge. This gauge may be, for tinplate stock for example, as thin as around 1/100 of an inch. The desired total reduction in gauge will determine the number of pairs of rolls in the mill and the reduction per pass.

As shown particularly in Fig. 2 the strip 5 may be uncoiled from a coil 27 and enters the mill through the feeding-in device which has been indicated generally at 5. I have shown this device as consisting of two rolls, but it will be understood that any of the feeding-in devices and appurtenances which I have disclosed in my co-pending case may be employed here. When rolling hot-rolled stock of heavier gauges, such as ½ or ⅜", I prefer to use such feeding-in devices as do not bend the stock, one or more pairs of pinch rolls, for example. Or I may dispense with the use of the feed-in device entirely, as with such heavy stock the several first pairs of reducing rolls taken in conjunction, play the role of a feeding-in device for the finishing group of rolls. Ordinarily the strips are welded together, always the last end of the preceding to the first end of the following coil, as at *6a* to avoid threading the mill each time a coil is finished and secure less interruption in operation.

The feeding-out machine has been indicated generally at **8** and this again may be as shown or it may comprise any of those devices which have been set forth in my co-pending applications hereinabove referred to. The strip may proceed to a shear **28** and may be coiled up alternately into different coils as at **29** and **30**.

Considering the assembly of mills and feeding devices thus far set forth, it will be noted that the first mill in the train is positively fed by the feeding-in device **6** and that each successive mill in the train is fed by the fore-going mill. The mill housings are so constructed as at **31** and **32** as to guide the first end of the strip from one mill to another. It is preferable that from the point of its entry into the first pair of rolls until it emerges from the finishing rolls, the strip will be covered with a bath of oil. The construction of my mill is such that the entire interior of the mill housing may be submerged in oil which not only lubricates and cools all of the bearings and all bearing surfaces, but also lubricates and cools the strip and washes away any foreign material on its surface. To facilitate this, the return sheave **7** is preferably contained in an oil-tight housing or sump **33**. Oil may be delivered to the entrance and exit portions of the mill housing by means indicated at **34** and **35** and will flow down between the housing members **1**, **2** and **3** to the sump **33**, whence it may be withdrawn through a pipe **36**. The oil is, of course, circulated rapidly and may be cooled and filtered outside of the mill after withdrawal from the pipe **33** and before re-delivery to the spouts **34** and **35**. It is preferable to provide means for pumping the oil in and out very quickly so as to avoid loss of time in case an adjustment or repair to the mill or a change of rolls is necessary.

All of the working rolls excepting preferably the last stand, are driven by fixed gearing from one common source of power. This is illustrated best in Figs. 5 and 6 where the main mill motor is indicated at **37** and drives a common shaft **38**. The common shaft is connected by worms **39** to driving means **40** for the several rolls on the train. The particular power transmitting drive is shown in Figs. 9 and 10 where the shaft **38** is shown as slidably keyed to the worm **39**. This worm meshes with the member **40** which is journaled by suitable bearing means **41** in a housing **42**. The member **40** is teethed on its outer surface to mesh with the worm **39**. On its inner surface it carries teeth which mesh with three pinions **43**, **44** and **45**. The purpose of this particular type of gearing is to minimize the conversion of torque to displacement forces on the drive gears. It will be seen that each of the gears **43**, **44** and **45** are driven from both sides. As a consequence they do not need heavy bearings in end members **46** and **47** of the housing **42**. An adjacent pair of gears, e. g. **43** and **44** may be directly connected by shafts **48** and **49** with the working rolls of a mill. By this arrangement side forces are neutralized and only torques are transmitted and I am able to transmit large forces by a gearing which occupies very little space, being particularly limited in this respect as the shafts **48**, **49** have practically the same diameter as the reducing rolls themselves, and the introduction of this type of a gear box greatly improves this mill. With the type of mill as shown on Figs. 1, 3 and 4, I prefer to drive the intermediate rolls **11** and **12** which in turn, drive the working rolls **10** by friction, so as to be able to use working rolls of such a small diameter as would not stand the necessary torque. In Fig. 7 I have shown the shafts **48** and **49** connected directly to the intermediate rolls **11** and **12**. The length of the shafts **48** and **49** will be such as to permit slight displacement of the rolls **11** and **12** and eliminate the necessity for universal joint drives, although such drives may be employed if desired. It will be understood, of course, that where desired, the rolls **11** and **12** for replacement purposes may be provided with separable couplings for attachment to the shafts **48** and **49**. In Fig. 7 it will be seen that I have made my mill oil-tight for purposes hereinabove described by side plate means **50** and **51** and that suitable glands **52** are provided where the shafts **48** and **49** pass through the plate **51**.

In the drives for the mill each of the individual drives connected with the shaft **38** are calculated for the particular speed ratio required for the individual mill taking into account the diameter of the working rolls and the speed of the strip (as determined by previous elongation as well as the entering speed) of such pair of rolls. Since each of the mills in the stand can effect a reduction upon the strip, it will be obvious that each successive mill be geared to operate at a higher speed than the preceding mill.

The diameter of the rolls must also be taken into consideration since the most economical way of using the rolls would seem to be to start with a new pair of working rolls on the first or roughing mill and then as they wear transfer them to successive mills in the train, the finishing mill having rolls always of the smallest diameter, so as to be able to use the reducing rolls to the very end of their useful life, and yet have the range of roll diameter, for each individual reducing mill, within very narrow limits which makes the use of this rigidly geared drive possible.

Referring again to Fig. 9 the worms **39** may be slidably keyed to the shaft **38**. Each worm is supported in radial and thrust bearings **53** and **54** in the housing member **55**. One of the thrust bearings at least is provided with a thrust measuring ring **56**, or pressure indicating ring which may be of any of several known types. Thus it may be a compressor body filled with a liquid or a body containing a piezo-electric crystal or a magnetic stress measuring device or the like. Connected with the ring **56** for each of these drives there will be a pressure indicator not shown, and placed in a position of convenient access to the operator. The pressure indicators described are convenient means for indicating the torque transmitted to each mill by the common shaft **38**, since the indicator pressure will be proportional to the torque as will be clear. However, other torque measuring means may be employed such as means directly measuring the torque in the shaft **38** at various points, the purpose of these torque indicating means being to permit the adjustment of the roll pass while it is running in a way which has been indicated above. Thus in the balanced system of velocities and forces in my mill, if one pair of rolls falls out of adjustment, for example through faulty original adjustment, such a condition will immediately show upon the dial pertaining to the particular transmission for that particular set of rolls. An adjustment of the roll pass can then be made by the operator so as to restore the balance. Also, as will be clear, such an adjustment can be accomplished by automatically acting devices set in motion by the pressure indicating means.

The main motor 37 is also connected with the feeding-in and feeding-out devices 6 and 8 respectively as will be described, and finally may be caused to drive the final pair of working rolls in the stand. Any direct mechanical action between the motor 37 and such devices may be employed. For convenience in the mill illustrated, a piston-hydraulic drive has been adopted which, excepting for a very insignificant amount of leakage of oil past the pistons, is the substantial operating equivalent of a train of gears. In addition to its fixed ratio of drive, however, it can easily be made to have an adjustable stroke and when so made, has the further advantage of being variable by infinitely small stages if necessary. Such a transmission always comprises two parts, the one being a pump, the other a motor. The pump furnishes oil under pressure to the motor so that the motor is bound to turn exactly in proportion with the quantity of oil supplied. Hydraulic transmisson mechanism of this general type is available on the open market and, therefore, is not herein described in detail.

By reference to Fig. 8 it will be seen that the motor 37 drives by means of chains 57, a variable stroke hydraulic pump 58 which furnishes oil to two motors, 59 and 69, each having variable strokes. The particular connections 58a, 59a and 69a between this pump and the several motors have not been carried through on the drawings but will be readily understood by the skilled worker in the art. The first of these motors is a motor 59. This motor is connected with the feeding-out device 8 by means of a pair of gears 60; but is also connected with the feeding-in device 6 through a chain drive 61 the sprockets for which, 62 and 63, are proportioned in size in a way appropriate to the particular elongations desired. The chain sprocket 63 is cut or formed on the outside of a ring gear. The planetary or satellite gear is indicated at 64, the spider of which 63a is connected directly to one of the shafts of the feeding-in device 6. The sun wheel or center wheel 64a of the planetary transmission is connected through a shaft 65 and gears 66 to another hydraulic device indicated at 67. In this device there is combined both a hydraulic motor 72 (which drives the shaft 65 through the pair of gears 66) and a hydraulic pump 71. The pump 71 is driven through a chain drive 68 or other suitable transmission from the motor 59.

It will be clear that with this arrangement, when the pump 71 is set at zero stroke, the sun wheel of the satellite gearing 64 will not turn and therefore the transmission 61 between the feeding-in and feeding-out devices will be entirely rigid as if it were a train of gears.

When an adjustment of this fixed ratio is necessary, the stroke of the pump portion of the hydraulic transmission 67 will be so adjusted as to furnish enough oil to the motor portion of the transmission to make the sun pinion of the planetary gearing 64 turn at a desired speed so as to add to or subtract from the original ratio. However, when such adjustment has been made the new ratio will likewise be positive and unyielding as if it were a train of gears. This system of positive and adjustable transmisison has been discussed in detail in the co-pending applications for Letters Patent, hereinabove referred to.

The second motor is the motor 69. As shown most clearly in Fig. 5 this motor is coupled by means 70 to the last pair of working rolls in the mill combination. For simplicity in this application I have considered the motor 69 as being driven by oil from the pump 58, although in practice it may be simpler to use a separate pump for it. The motor is of exactly the same piston type as has hereinbefore been discussed and has an adjustable stroke. With the same quantity of oil per minute the smaller the stroke the more rapid the motor will turn. The whole drive arrangement which I have shown and described permits one to start with a strip of raw material of the desired gauge, within the limits actually met in practice and to carry it down to substantially any gauge desired, always maintaining the proper velocities and consequently the proper tensions between the feeding-in device and the first pair of working rolls, then between each pair of rolls and the next one and finally between the finishing pair of rolls and the feeding-out device.

The purpose of providing separate drives for the final mill is to permit changes of gauge without over all readjustment. This may be accomplished in my system by eliminating the operating effect of one or more of the latter mills in the train. This can be done by opening up the mills or can be done by removing the working rolls. The final pass is given by the final mill with the separate drive giving a very high degree of flexibility of operation.

While I have described in some detail a certain type of driving means, it will be understood that others can be employed if desired. It is evident that the mill can be made to work with an entirely rigid gear connection for example from the feeding-in device through all the working rolls down to and including the feeding-out device; but the ratio between the feeding-in and feeding-out devices of the mills being thus set at a fixed ratio which cannot be varied, only one definite reduction can be obtained. Thus with a given material it would be possible under these circumstances to roll to but one finished gauge. Where a lighter finished gauge was desired, a thinner starting piece would have to be employed. On the contrary in the arrangement which I have particularly described or an arrangement including some transmission means of equivalent flexibility, I can produce almost any specific reduction desired. This can be accomplished by adjusting the final pass on the finishing rolls and by the omission of the operation of one or more preceding mills as I have indicated. Naturally this adjustment applies only to the making of lesser reductions than the maximum. A certain possible maximum reduction for the mill cannot of course, be exceeded; but the mill may be so constructed as to be capable of a maximum reduction in excess of commercial requirements.

On the other hand, the individual pairs of rolls of my mill may be driven by other flexible means, without departing from my mill frame invention.

They may, for instance, be driven, each pair of rolls, or even each roll (from opposite sides of the mill), by a piston-type hydraulic motor, while the feeding device or devices are similarly driven. In such case, an absolute rigidity of maintaining the speed relationship of all these instrumentalities can still be preserved, while the reduction by each individual pair of rolls can be adjusted at will, same as the tension in front and after the rolls; and so the mill, although more expensive to buy, shall be capable of being utilized better and give a higher reduction than with the gear drive as first described.

Or else individual or group electric motors may be used, employing such speed control means as are available. In this case all the advantages of the frame construction and roll support are there, but the predetermined speed relationship cannot be obtained with the same accuracy and without a lag, and through accelerations and stops, as in the case of the drives hereinabove described. Such electric drive may, however, give tolerably good results for many purposes.

As far as the housing or frame of the mill is concerned it is essentially a one piece housing; but it can also be made of several pieces fastened together by bolts or other means of sufficient strength so that under conditions of full load on all rolls, there is still a considerable pressure on all parts of the surfaces of junction. The frame is characterized by the fact that the roll supporting beams are not loosely connected with the rest of the frame but from one solid body with it, that is to say, the resistance of the bending forces which such beams offer is still further increased by their rigid connection with other parts of the frame. This principle has also been described in the applications referred to. The frame as shown in Fig. 2 shows a staggered arrangement of the working roll assemblies. In Fig. 1 there is an opposite arrangement. On both figures it will be apparent, however, that much metal and space is saved on all beams which support rolls lying on the inside of the mill frame. Not only is one beam in this position enough instead of two, but also such an intermediate beam can be made thinner and lighter than would be possible with an outside beam because the greater part of the forces counterbalance each other. The savings in weight on the outside beams supporting two adjacent rows of backing rings, like the beam H in Fig. 2 is not so pronounced as with the inside beams like G, but still it is quite considerable.

The mill illustrated in Fig. 1 is shown as having only four pairs of working rolls but is indicated as having also the intermediate supporting rolls which have hereinabove been described in detail. The provision of these rolls avoids even the slightest marking that the individual supporting rings might produce on the working rolls as they bore directly against the working rolls. Excepting for this consideration and considerations of space, the number of working rolls in any given mill combination will usually be determined by considerations of the greatest reduction that the mill may be called upon to produce. The arrangement of the rolls in such a way that the strip first passes downwardly through a series of mills then runs around a sheave and goes upwardly again through a series of mills is not essential but it offers some important advantages in itself. First of all it permits the saving of material in the frame. Secondly, it makes it very easy to work in a complete bath of oil as has been described. Thirdly, the bottom pulley gives the strip an opportunity to cool down sufficiently especially near the surface after the roughing treatment and before entering the finishing group of rolls.

Finally there is the important advantage of dividing the mill and its operations into two floors. The mechanics, roll grinders, and adjustment men carry on their operations on the lower floor as illustrated, while the handling of the strip both in raw and finished condition is carried on on an upper floor. Thus the several operations do not interfere with each other.

Although not shown in the drawings, it is, of course, preferable to provide for the welding of the raw strip into one continuous length before it enters the mill. This may be accomplished with any suitable mechanism. However, my mill is not restricted to the rolling of a continuous supply of material and strip stock of finite length may be sent through it if desired. I have already explained how the mills in the frame are caused to be self-threading. For this purpose also I provide in connection with the return sheave 7 suitable guide means 71 for leading the strip from one mill section to the other.

Modifications may be made in my invention without department from the spirit of it. Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A method of reducing strip metal which consists in passing it successively through two or more pairs of reducing rolls while driving said reducing rolls at a fixed ratio of speed to each other, controlling the rate of feed of the strip metal to the first pair of reducing rolls by a non-reducing, positive feeding instrumentality and controlling the rate of withdrawal of the metal from the last pair of reducing rolls by a non-reducing, positive instrumentality, so that the feeding-in and feeding-out of the metal to the several pairs of reducing rolls bears a fixed ratio of speed to the speed of the reducing rolls.

2. That method of reducing strip metal which consists in passing a strip successively through a feeding-in apparatus having substantially no reducing function, then through at least two pairs of reducing rolls, and finally through a feeding-out apparatus having substantially no reducing function and causing the speeds of all of the mentioned instrumentalities to bear a certain predetermined constant relationship to each other.

3. That method of reducing strip metal which consists in passing a strip successively through a feeding-in apparatus having substantially no reducing function, then through at least two pairs of reducing rolls, and finally through a feeding-out apparatus having substantially no reducing function and causing the speeds of all of the mentioned instrumentalities to bear a certain predetermined constant relationship to each other, and during the continuation of said process adjusting the roll passes of the several pairs of reducing rolls to control the amount of work done at each pass irrespective of the speed of operation of said rolls.

4. In a rolling mill assembly a housing, a plurality of interspaced rolling means in said housing, a non-reducing, positive feeding-in apparatus and a non-reducing, positive feeding-out apparatus, and positively acting mechanical mo-

tion transmitting means connecting all of said instrumentalities.

5. In a rolling mill assembly a housing, a plurality of interspaced rolling means in said housing, a non-reducing, positive feeding-in apparatus and non-reducing, positive feeding-out apparatus, and positively acting mechanical motion transmitting means connecting all of said instrumentalities, and means for varying the ratio of transmission between certain at least of said several instrumentalities.

6. In a rolling mill, a single housing, interspaced pairs of working rolls located in said housing, said housing comprising a plurality of beams for supporting said working rolls throughout their length, one at least of which beams is located to act as a supporting means common to interspaced pairs of working rolls.

7. A continuous rolling mill comprising a housing, a plurality of pairs of reducing rolls located in said housing, said housing having portions acting as a common support for interspaced pairs of said reducing rolls substantially throughout their working length, said reducing roll pairs so arranged in said housing that a strip of material being acted upon first passes through said housing in one direction between at least one pair of reducing rolls and then passes in the opposite direction through said housing between one other pair of reducing rolls.

8. A continuous rolling mill comprising a housing, a plurality of pairs of reducing rolls located in said housing, said housing having portions acting as a common support for interspaced pairs of said reducing rolls substantially throughout their working length, said reducing roll pairs so arranged in said housing that a strip of material being acted upon first passes through said housing in one direction between at least one pair of reducing rolls and then passes in the opposite direction through said housing between one other pair of reducing rolls, said mill also comprising a feeding-in device, a feeding-out device and a sheave over which said material runs intermediate its passages through the housing.

9. A common drive for several pairs of reducing rolls situated in one housing and comprising a single drive shaft with a plurality of pinions keyed thereto, a plurality of gears meshing with said pinions, each gear being connected to a pair of working rolls in said housing, and a device for continuously indicating the torque transmitted by it fitted to each of said pinions.

10. In a continuous rolling mill a plurality of pairs of reducing rolls, a common drive for said pairs of reducing rolls, said drive operating to maintain a fixed ratio of speeds between said several pairs of reducing rolls, and means for measuring the torque transmitted by said common drive to each of said several pairs of reducing rolls, whereby in accordance with such measurements, adjustment of the roll passes may be made.

11. In a continuous mill a non-reducing, positive feeding-in device, a plurality of pairs of working rolls, and a non-reducing, positive feeding-out device and means for transmitting torque to said several instrumentalities continuously at predetermined speed ratios.

12. In a continuous mill a non-reducing, positive feeding-in device, a plurality of pairs of working rolls and a non-reducing, positive feeding-out device, means for transmitting power to each of said instrumentalities excepting the last mill at predetermined speed ratios in spite of variations in load, and means for separately driving the last pair of working rolls.

13. In a rolling mill a housing comprising beams parallel to the working rolls, a plurality of interspaced working rolls mounted in said housing and supported in their length by said beams for rolling a strip passing therethrough, said beams being shaped intermediate said pairs of working rolls to lead a strip of material being operated upon from one pair of working rolls to the next.

14. In a rolling mill a housing comprising beams, a plurality of working rolls located in said housing and supported in their length by said beams in interspaced parallel series whereby a strip of material to be operated upon can be caused to pass twice through said housing in opposite vertical directions in said interspaced series of working rolls, said beams being shaped intermediate said working rolls to lead said strip of metal from one pair of working rolls to the other, a sheave mounted to conduct said strip from one series of working rolls to the next, and guide means for conducting said strip about said sheave.

15. A method of reducing strip metal, which consists in passing it successively through two or more pairs of reducing rolls in tandem, said pairs of rolls being backed up throughout their length on stationary supporting means, the said stationary means serving fixedly to interspace said pairs of rolls and maintaining the contour of the said reducing rolls in spite of substantial variations of rolling pressures, and driving said reducing rolls at a fixed ratio of speed to each other during the rolling operation.

16. A method of reducing strip metal, which consists in passing it successively through two or more pairs of reducing rolls in tandem, said pairs of rolls being backed up throughout their length on stationary supporting means, the said stationary means serving fixedly to interspace said pairs of rolls and maintaining the contour of the said reducing rolls in spite of substantial variations of rolling pressures, driving said reducing rolls at a fixed ratio of speed to each other during the rolling operation, controlling the rate of feed of the strip metal to the first pair of reducing rolls by a non-reducing, positive feeding instrumentality, and controlling the rate of withdrawal of the metal from the last pair of reducing rolls by a non-reducing, positive feeding instrumentality, while driving said feeding instrumentalities at a fixed ratio of speed to the speed of the several rolls.

17. In a single housing rolling mill, containing a plurality of pairs of working rolls, arranged to operate as a tandem mill, a housing, comprising beams supporting said working rolls substantially throughout the working length thereof, and members connecting said beams, at least one of said beams being located so as to act as a support to more than one working roll, said workir~ rolls so supported being located in such manne_ that the pressures applied thereby to said beam are in part at least, mutually opposed.

18. In a single housing rolling mill, containing a plurality of pairs of working rolls, end frame members, parallel supporting members located between said end frame members, and acting as supporting means throughout the length of at least one roll of a plurality of pairs, so that said supporting members are each common to a plurality of pairs of rolls, and so that the passage of strip material is between said supporting

members through a plurality of pairs of working rolls.

19. In a single housing rolling mill, containing a plurality of pairs of working rolls, end frame members, parallel supporting members located between said end frame members, and acting as supporting means throughout the length of at least one roll of a plurality of pairs, so that said supporting members are each common to a plurality of pairs of rolls, and so that the passage of strip material is between said supporting members through a plurality of pairs of working rolls there being at least three of said parallel supporting members so that the passage of said strip material is at least twice through said mill between said end frame members in opposite direction.

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