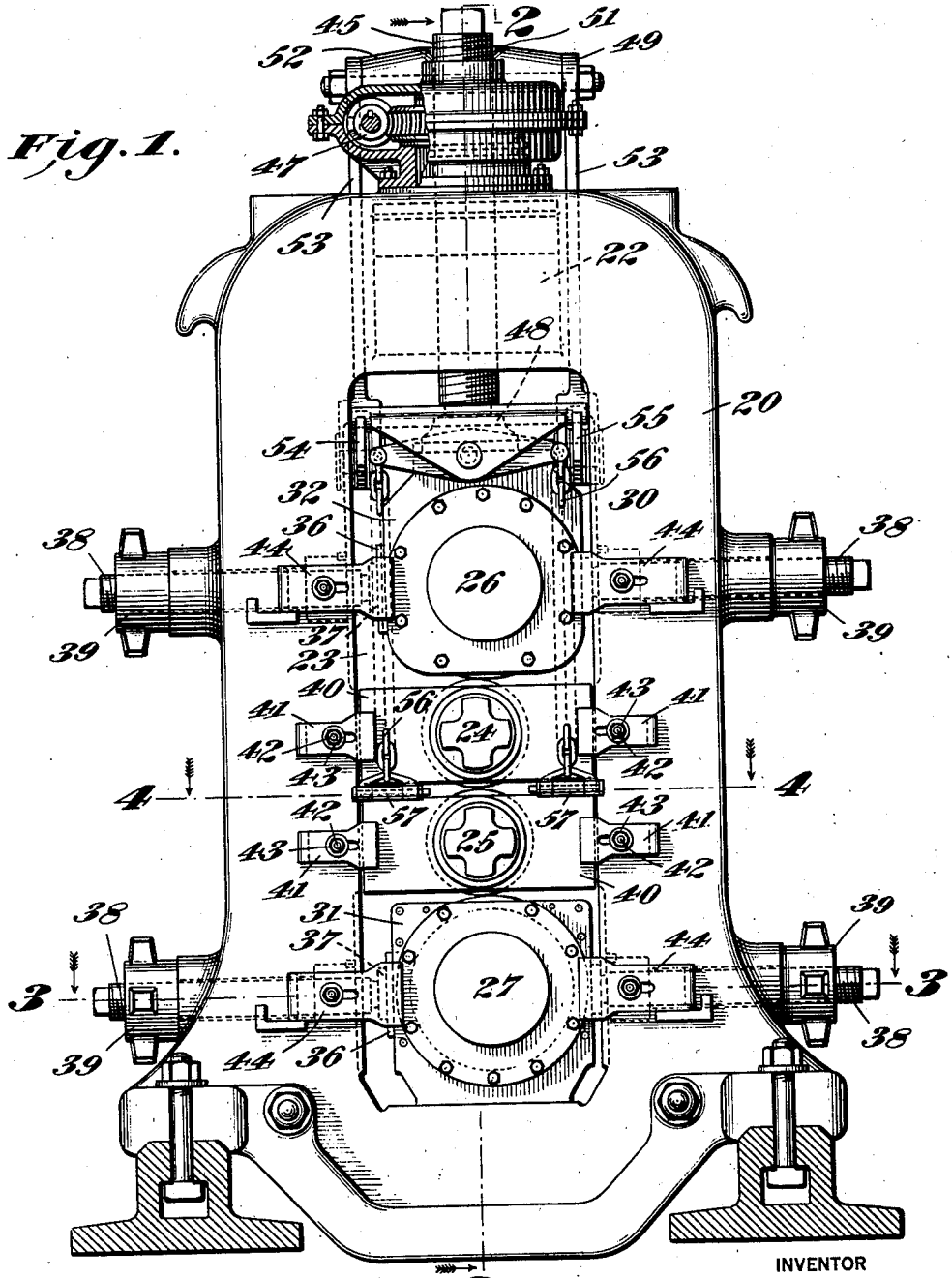
May 31, 1932. A. T. KELLER 1,860,931

ROLLING MILL

Filed Feb. 23, 1928 4 Sheets-Sheet 1

Fig. 1.



INVENTOR

Albert T. Keller.

BY

R. S. & C. Dougherty.

ATTORNEY

May 31, 1932. A. T. KELLER 1,860,931

ROLLING MILL

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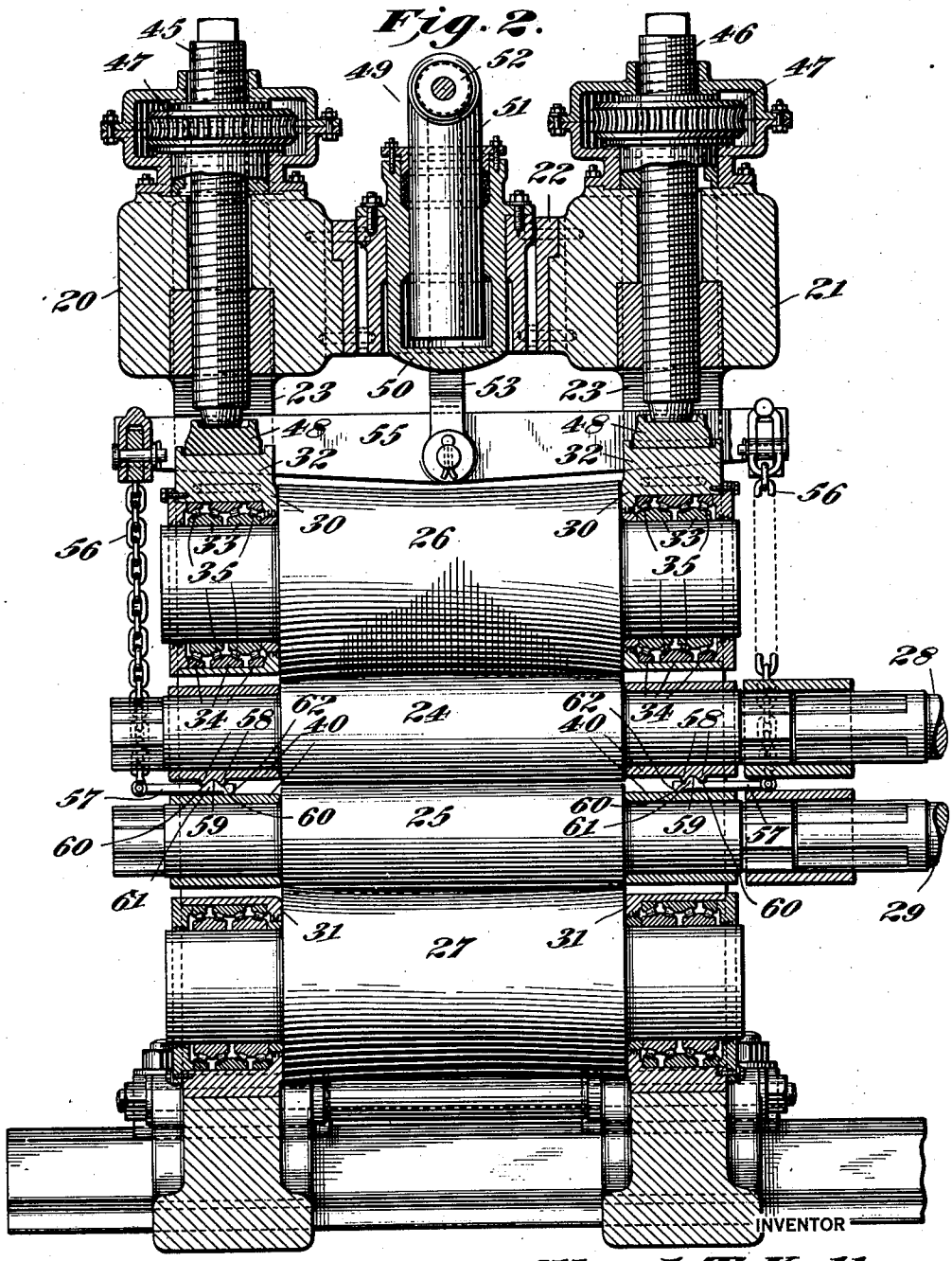
Fig. 2.



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May 31, 1932. A. T. KELLER 1,860,931

ROLLING MILL

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Fig. 3.

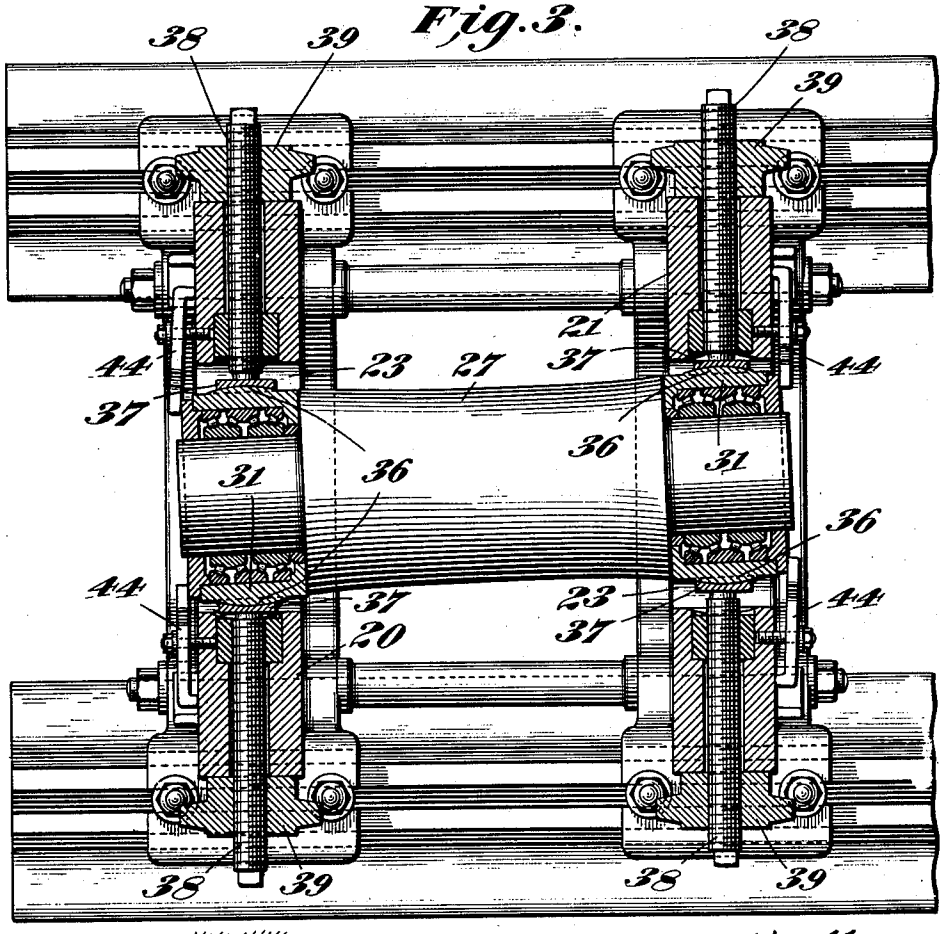
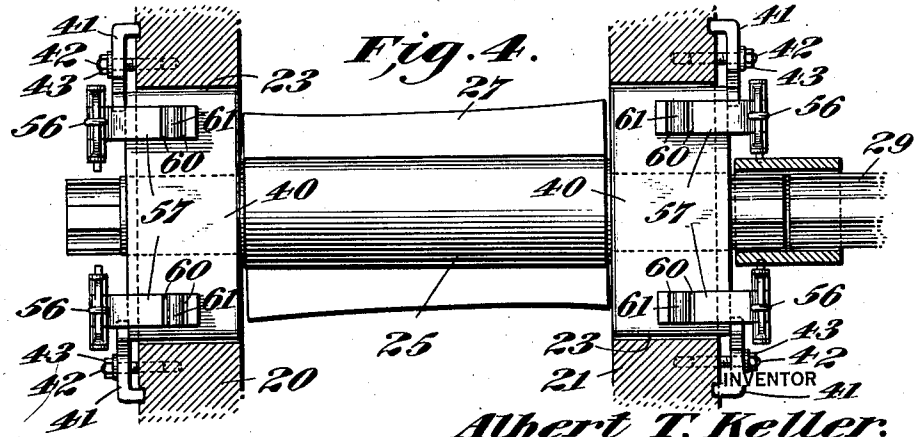


Fig. 4.



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May 31, 1932. A. T. KELLER 1,860,931

ROLLING MILL

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Fig. 5.

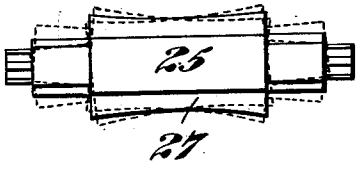


Fig. 6.

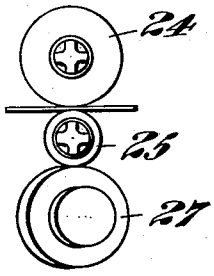


Fig. 7.

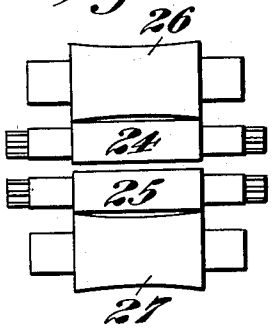


Fig. 8.

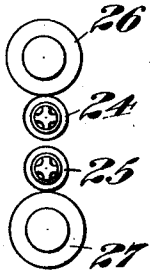
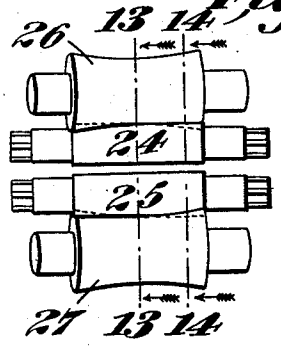


Fig. 12.



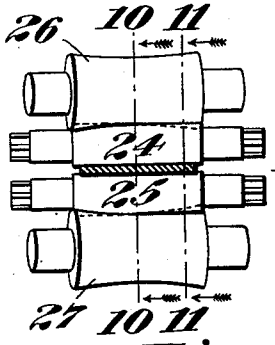


Fig. 9.

Fig. 13.

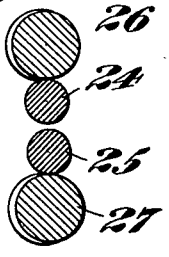


Fig. 14.

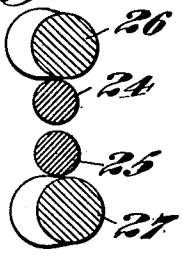


Fig. 10.

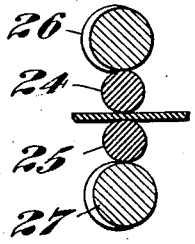


Fig. 11.

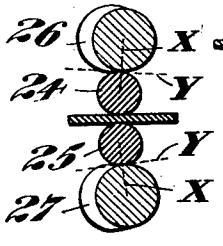


Fig. 15. Fig. 16. Fig. 17.

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Patented May 31, 1932 1,860,931

UNITED STATES PATENT OFFICE

ALBERT T. KELLER, OF BETHLEHEM, PENNSYLVANIA, ASSIGNOR TO BETHLEHEM STEEL COMPANY, A CORPORATION OF PENNSYLVANIA

ROLLING MILL

Application filed February 23, 1928. Serial No. 256,270.

My invention relates to rolling mills and particularly to mills for rolling sheet materials.

When rolling hot or cold metal sheets, it has been found that, within certain limits, the smaller the diameter of the working roll in contact with the work, the greater the reduction that may be made in a single pass for a given expenditure of power. However, in rolling mill practice, high pressures are encountered, so it is usual, when employing working rolls of comparatively small diameter, particularly when rolling relatively wide thin sheets, to back or support the working rolls by separate rolls of large diameter to prevent excessive springing of the working rolls and provide the required strength and rigidity.

It should be understood that in order to obtain a sheet of uniform thickness and to prevent wrinkling or buckling of the work, it is necessary to accurately control the shape of the roll pass, and compensate for the spring in the rolls occasioned by the working pressure and for any variation in the diameter of the rolls which may occur throughout their length due to heating. Even though at the outset of the rolling operation the mill reduces the work uniformly, it is very difficult to maintain this condition for several reasons. For instance, one important reason is that, whether or not the work is hot or cold, the rolling operation causes the rolls to heat up and expand irregularly.

In the attempt to ameliorate the latter condition it has heretofore been the practice in hot rolling to shape the profile of the rolls so that, when they are heated up in the stand preparatory to the actual rolling operation, they will expand to form a pass that will produce a usable sheet. However, with this practice, the shape of the roll and the amount of preliminary heating necessary to form the desired pass is more or less empirical and is predicated on the experience of the mill operators and is not sufficiently accurate when rolling thin material. It is almost impossible to predict the changes which occur to the shape of the pass in the rolling operation. Apart from the irregular wear, which may occur to the rolls, the shape of the pass may change due to several factors, some of which are the heating up of the roll necks and the flexing of the rolls under the working pressure. The pressure developed at the roll necks generates heat and expands the bodies of the rolls irregularly and thus affects the shape of the pass. The amount of variation to the pass due to such causes cannot be accurately predicted in advance.

It is one of the objects of my invention to provide a backing means for the working roll of a rolling mill which is so shaped and adjustable to control the shape of the pass between the working rolls.

Another object of my invention is the provision of a novel means for supporting the upper roll of a rolling mill adapted to maintain the working rolls in spaced relation.

In its broader aspect my invention comprises working rolls, a backing roll which has its exterior surface curved longitudinally for supporting the working roll, and means to adjust the axis of the backing roll obliquely to the axis of the working roll in the direction of the path of the work.

The novel features of my invention will be more fully understood from the following description and claims taken with the drawings in which;

Fig. 1 is a side elevation of a four high mill embodying one form of my invention;

Fig. 2 is a cross section taken on the line 2—2 in Fig. 1, showing the rolls in elevation;

Fig. 3 is a cross section taken on the line 3—3 in Fig. 1, showing the backing rolls in elevation and disposed in its middle supporting position;

Fig. 4 is a partial cross section taken on the line 4—4 in Fig. 1, showing the working roll in elevation;

Fig. 5 is a plan of the working roll superposed on the backing roll illustrating various positions to which the latter may be adjusted relatively to the axis of the working roll;

Fig. 6 is an end view of the rolls of a three high mill illustrating a further embodiment of my invention;

Fig. 7 is a conventional front view of the

rolls of a four high mill embodying my invention illustrating the backing rolls in its end support position, that is, they support the working rolls at their ends;

Fig. 8 is a conventional end view of the rolls shown in Fig. 7;

Fig. 9 is a similar view to Fig. 7, except that the backing rolls are shown adjusted to their full support position, that is, they support the working rolls throughout their length;

Fig. 10 is a cross section taken on the line 10—10 in Fig. 9;

Fig. 11 is a cross section taken on the line 11—11 in Fig. 10;

Fig. 12 is a similar view to Fig. 7, except that the backing rolls are adjusted to their center support position, that is, they support the working rolls at the midpoint of their length;

Fig. 13 is a cross section taken on the line 13—13 in Fig. 12;

Fig. 14 is a cross section taken on the line 14—14 in Fig. 12;

Fig. 15 shows the contour of a sheet rolled between the working rolls when the backing rolls are positioned as shown in Fig. 7;

Fig. 16 shows a sheet of uniform thickness as rolled between the working rolls when the backing rolls are positioned as shown in Fig. 9; and

Fig. 17 shows the contour of a sheet rolled between the working rolls when the backing rolls are positioned as shown in Fig. 12.

Referring to the drawings: 20 and 21 designate, respectively, a pair of spaced housings rigidly connected together by the bridge member 22.

Mounted in suitable bearings within the windows 23 of the housings and extending therebetween is a pair of working rolls 24 and 25, respectively. Also mounted in suitable bearings within the windows of the housings is a pair of backing rolls 26 and 27, respectively, which have their surface concaved longitudinally and are adapted to support the working rolls 24 and 25, respectively, in a manner hereinafter set forth.

I preferably positively drive the working rolls 24 and 25 through the medium of the spindles 28 and 29, respectively, in a manner well known in the art and allow the backing rolls 26 and 27 to revolve by frictional contact with the working rolls. It is of course understood that I may positively drive the backing rolls and cause the working rolls by frictional contact to operate on the work without departing from the spirit of my invention.

The bearings which engage each of the necks of the backing rolls 26 and 27 are preferably of the anti-friction type and are designated generally by the numerals 30 and 31, respectively. Each of the bearings 30 and 31 are similar and the manner of mounting each of them in the housing is the same, so a description of one bearing and the means of securing it in the housing will suffice as descriptive of each of the bearings 30 and 31.

The bearing 30 comprises a casing 32 containing an inner race member 33 closely fitting the roll necks, an outer race member 34 closely fitting the casing, and rollers 35 intermediate said race members, a construction well-known in the art.

Extending vertically up each side of the casing 32 is a convex rib member 36, which is curved transversely and each engage the concave face of a shoe member 37 which is rotatably secured at the inner end of a transverse adjusting screw 38, which is threaded to a nut secured in the housing in a well-known manner.

The arrangement is such that the necks of the backing rolls 26 and 27 may be adjusted a desirable amount in a plane parallel to the path of the work by rotating the adjusting screws 38. The casing 32 is rigidly held by the latter in the direction of its adjustment, but, nevertheless is free to move in the direction at right lines to the direction of adjustment, for the purpose hereinafter set forth.

The adjusting screws 38 have threaded engagement with the housings so that when they are rotated in the desired direction by means of a wrench or other suitable means, they are caused to move axially and the casing 32 may thus be adjusted in a plane parallel to the path of the work passing through the mill.

After the casing 32 is adjusted to the desired position each of the screws 38 are locked in position by means of a nut 39. Each neck of the working rolls is journaled in boxes 40 and 40′ for the upper and lower working rolls respectively of the ordinary type, which is slidably mounted in the housing.

The boxes 40 are retained in the housings by means of the adjustable clamp members 41, carried by studs 42, which are adjustable by the nuts 43 threaded on said studs to take up end play in the working rolls. Similar clamps and fastening means are provided for the casings 32, as at 44, to take up end play in the backing rolls 26 and 27.

The casings 32 supporting the lower backing roll 27 at each end are supported on the housings at the bottom of the windows. The lower working roll 25 is supported on the lower backing roll 27 and is not ordinarily adjusted vertically to form the different passes of the mill.

The upper working roll 24 and its backing roll 26 are adjustable to permit the rolling of sheets of different thicknesses. This adjustment is effected by a pair of adjusting screws 45 and 46 which are in threaded engagement with the housing and are operated

by the screw-down mechanism 47 in a manner well known to the art. Intermediate the end of each of the adjusting screws 45 and 46 and the bearings 30 at the ends of the upper backing roll 26 is a bearing block 48 and the upper rolls are constrained to their upper position against said adjusting screws by means of the lift mechanism indicated generally by the numeral 49.

The lift mechanism comprises a cylinder 50 mounted in the bridge member 22. A ram 51 is operatively mounted in said cylinder and is provided at its upper end with a cross member 52. Depending at each end of the latter is a link 53 to support the beam members 54 and 55, respectively, which extend through the windows of the housings and at the sides of the adjusting screws 45 and 46.

A chain 56 is fastened at each end of the beam members 54 and 55 beyond the housings, and each chain, at its lower end, is linked to a lever member 57, which is interposed between the superposed boxes 40 and 40′ at the ends of the working rolls. The lower surface of each box 40 has formed thereon a pair of spaced parallel ribs 58 rounded at their extended edges and having therebetween a groove 59 which is concaved transversely and of substantially semi-cylindrical formation. The lever member 57 has formed on its upper face, at a distance from its inner end, a pair of spaced parallel grooves 60 receptive of the ribs 58, and intermediate said grooves is a convex ridge 61 which pivotally fits the groove 59. The lower edge at the inner end of the lever member 57 is radiused, as at 62.

It will be easily seen that a constant fluid pressure admitted to the cylinder 50 exerts a pressure on the ram 51 to cause the chains to exert an upward pull at the outer end of each of the lever members 57. The inner end of the latter acts as fulcrum against the upper face of the box 40′ at each end of the lower working roll and applies a pressure on the underside of the box 40 at each end of the upper working roll at the point where the ridge 61 engages the groove 59. Any tendency of the lever 57 to slip is prevented by virtue of the interlocking engagement of the ribs 58 with the grooves 60.

In this manner the upper working roll is constrained against the upper backing roll which in turn is constrained against the adjusting screws 45 and 46, and the lower working roll is forced against its respective backing roll; by rotating the adjusting screws 45 and 46 the opening between the working rolls, which constitutes the pass of the mill, may be increased or decreased depending upon the direction of rotation of said screws.

As stated above, due to certain factors being present during the operation of the mill, the rolls expand irregularly which tends to change the contour of the pass and it is necessary to provide means to counteract this tendency so that the contour of the work will not be adversely affected. To this end, I concave the surface of the backing rolls 26 and 27 longitudinally, that is, the rolls gradually increase in diameter from the midpoint of their length in opposite directions toward their ends, so that when the axes of said rolls and the axes of the working rolls 24 and 25 are in a common plane, as shown in full lines in Fig. 5 and in Figs. 7 and 8, the working pressure on the sheet passing through the mill will deflect the latter rolls at the midpoint of their length against their respective backing rolls and thus produce a sheet which is convexed laterally on both faces. Under normal conditions the amount of such convexity depends upon the amount of longitudinal curvature of the surface of the backing rolls and the spring of the working roll is maintained during the entire passage of the sheet through the mill. For convenience this position of the backing roll with respect to the working will hereinafter be referred to as the end support position.

The backing rolls may be adjusted in a horizontal plane obliquely to the axes of the working rolls to support and maintain the latter rolls throughout their length in a horizontal plane when the sheet is being reduced in the mill. The backing rolls are swung obliquely to the axis of their respective working roll by advancing one or the other of the adjusting screws 38 and retracting the oppositely disposed adjusting screws 38 the same amount at each end of the rolls and in either direction as indicated by broken lines in Fig. 5, whereby the vertical planes passing through the axes of the working rolls and the backing rolls intersect at about the midpoint of the rolls. The degree of adjustment to the backing rolls required to afford support to the working rolls throughout their length more or less depends upon the longitudinal curvature of the backing rolls. The amount of longitudinal curvature given to the surface of the backing rolls is determined more or less by size of the mill and the kind of work rolled, and is based more or less on the experience of the operators.

In order to support the working roll throughout substantially its entire length the backing roll is swung about a transverse axis, in the horizontal plane, obliquely to the axis of the working roll until at any distance along the rolls a line joining their axes and normal thereto will intersect the surfaces of both rolls at a common point of tangency, as shown in Figs. 9, 10 and 11. By way of illustration, Fig. 11 is a conventional cross section taken at any distance along the working roll when the backing roll has been adjusted to support the former throughout its length; a

radial line X joins the axes of the rolls and a line Y drawn at right lines to the line X will be approximately tangential to the surface of both rolls. To avoid prolixity this position of the rolls will be hereinafter referred to as the full support position.

In order to provide a wide range of adjustments to control the pass of the mill, the backing roll may be swung obliquely to the working roll past the full support position, so that the working roll is normally supported solely at the midpoint of the length of the backing roll, as illustrated in Figs. 12, 13 and 14; the latter position will be for convenience, hereinafter referred to as the center support position. When the backing roll is at its center support position the working pressure on the sheet passing through the mill will deflect the ends of the working rolls against their respective backing rolls and produce a sheet which is concavo-concave in cross section.

Assuming that the backing rolls are adjusted in the end support position, as illustrated conventionally in full lines in Fig. 5 and in Figs. 7 and 8, the working pressure on the work will cause the working rolls to bow against the backing rolls an amount approximately corresponding to the longitudinal curvature of the surface of the latter rolls, and the work emitted from the pass between the working rolls will be convexed transversely on both faces, as illustrated in Fig. 15. The amount of spring in the roll and the resulting convexity to the work may be controlled by adjusting the backing rolls to or beyond their full support position. When the backing rolls are in their full support position, as illustrated conventionally in Figs. 9, 10 and 11, the work emitted from the pass will be substantially of uniform thickness throughout. Theoretically when the backing rolls are set in their full support position, the work would be reduced uniformly; however, due to the springing of the rolls under the working pressure, the irregular expansion of the rolls and other causes, the work may be reduced a greater amount at one point than at another, and thus increase the length more along one line than another. In a long sheet, such as, a strip, the result of increasing the length more along one line than another tends particularly at the finishing passes, to twist or buckle the piece. If the reduction is greater at the middle than at the edges, the surface of the strip will be concave transversely and elongated more at the center than at the sides, which will result, in most cases, particularly when the strip is thin, in buckling the work. Heretofore it has been impossible to remedy this during the rolling operation, but with a rolling mill, embodying the principle of my invention, the backing rolls may be adjusted by the operator toward the end support position a sufficient amount to allow the working rolls to spring at their midpoint against the backing rolls a determined amount under the working pressure whereby the reduction is uniform throughout the width of the strip.

Then again, supposing that the strip or sheet is being reduced a greater amount at the edges than at the middle, the surface of the strip will be convexed transversely and it will be elongated to a greater extent in the line along the edges than the line along the middle, which will result in the piece being distorted. With my rolling mill the deleterious effect may be easily eliminated by adjusting the backing rolls toward the center support position a sufficient amount to allow the working rolls to spring at their ends from the middle a determined amount under the working pressure whereby the reduction is uniform throughout the width of the strip.

In a mill, provided with means embodying my invention for controlling the working pass of the mill, the working rolls may be shaped before they are mounted in the mill to anticipate irregular expansion which may occur to them when they become heated.

My invention is useful in the mills practicing the so-called continuous process. In this practice several stands of mills are placed in series, and the contour of the pass of each mill is varied so that the transverse shape of the strip or sheet changes gradually as the work proceeds through the rolling process and it is important that in any stand the sheet must be formed to the proper shape for the succeeding stand. This variation in the shape of the several passes of the series may be easily effected in mills embodying the principle of my invention by adjusting the backing rolls of each of the stands so as to provide the correct contour to the work as it is rolled progressively through the series of stands.

While I have described my invention with relation to a four high mill, the principle thereof may be applied to mills having more than two backing rolls, or a mill with only one backing roll. In Fig. 6, I illustrate an embodiment of my invention applied to a mill having an upper working roll of large diameter and a lower working roll of comparatively small diameter supported by a backing roll. The latter has its exterior surface curved longitudinally and is supported and adjusted in the same manner as the backing rolls of my four high mill hereinbefore described. In this mill the work is rolled between the large and the small working rolls and the contour of the pass is controlled by permitting the small working roll to flex under the working pressure an amount and in the manner governed by the position and shape of the backing roll which affords the support.

It will be seen from the foregoing descrip-

tion that I have devised a novel sheet rolling mill which is easily adjusted to control the contour of the work.

While I have shown my invention in two forms, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various other changes and modifications without departing from the spirit thereof, and I desire, therefore, that only such limitations shall be placed thereupon as are imposed by the prior art or as are specifically set forth in the appended claims.

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

1. In a rolling mill, a working roll, and a roll having its surface curved longitudinally for supporting said working roll, said curved surface throughout substantially its length engaging the working roll during the passage of the work through the mill.

2. In a rolling mill, a housing, a lower working roll, an upper working roll, a backing roll having its surface curved longitudinally for supporting the lower working roll, a backing roll having its surface curved longitudinally for supporting the upper working roll, journal bearings mounted in said housing for engaging said working rolls, anti-friction bearing members mounted in said housing for engaging said backing rolls, each of said bearing members comprising a casing having transversely curved ribs at each side thereof, shoe members having curved faces adapted to engage said ribs, and adjusting screws mounted in said housing for backing up said shoe members.

3. In a rolling mill, a housing, a lower working roll, an upper working roll, a backing roll having its surface curved longitudinally for supporting the lower working roll in a vertical direction, said curved surface substantially throughout its length engaging the roll during the passage of the work through the mill, a journal member engaging said backing roll, and means mounted in said housing for adjustably securing said journal member from movement in a horizontal direction.

4. In a rolling mill, a housing, a working roll, a backing roll having its surface concavely curved longitudinally for supporting said working roll, and means supporting said backing roll in a position to support said working roll at substantially the midpoint of its length when the work is not passing through the mill.

5. In a rolling mill, a housing, a working roll, a backing roll having its surface curved longitudinally for supporting said working roll and adapted throughout substantially its length to engage the working roll during the passage of the work through the mill, and means to support said backing roll in a position to support said working roll at its ends when the work is not passing through the mill.

6. In a rolling mill, a housing, a working roll, a backing roll having its surface curved longitudinally for supporting said working roll, a journal member at each end of the working roll mounted in said housing, a bearing member at each end of the backing roll, and means adjustably mounted in said housing pivotally engaging said bearings for adjusting said backing roll in a direction transversely to the radial direction of the working roll.

7. In a rolling mill, a working roll, a backing roll having its surface curved longitudinally for supporting said working roll in a vertical direction, and means to adjust said backing roll obliquely to said working roll in a horizontal direction.

8. In a rolling mill, a working roll, a backing roll having its surface curved longitudinally for supporting said working roll transversely to the direction of rolling, and means to adjust the backing roll in the direction of rolling.

9. In a rolling mill, a housing, a pair of superposed working rolls mounted in said housing, a backing roll having its surface curved longitudinally supporting each backing roll in a vertical direction, a journal member at each end of said working rolls, the journal members on the upper working roll slidingly engaging said housing, a bearing member at each end of each backing roll, oppositely disposed horizontal adjusting screws mounted in said housing pivotally engaging the sides of each of the bearing members at the end of the lower backing roll, a pair of oppositely disposed horizontal adjusting screws mounted in said housing pivotally and slidingly engaging the sides of each of the bearing members at the end of the upper backing roll, vertical adjusting screws mounted in the housing and pivotally engaging the upper side of each of the bearing members at the ends of the upper backing roll, a lever member intermediate said journal members adapted to force the latter apart, a supporting means, means connecting the latter to said lever members, and a lift means supporting said supporting member.

10. In a rolling mill, a housing, a pair of superposed working rolls mounted in said housing, a backing roll having its surface curved longitudinally supporting each working roll in a vertical direction, a journal member at each end of said working rolls, the journal members on the upper working roll slidingly engaging said housing, a bearing member at each end of each backing roll, oppositely disposed horizontal adjusting screws mounted in said housing pivotally engaging the sides of each of the bearing members at the end of the lower backing roll, a pair of oppositely disposed horizontal adjusting

screws mounted in said housing pivotally and slidingly engaging the sides of each of the bearing members at the end of the upper backing roll, vertical adjusting screws mounted in the housing and pivotally engaging the upper side of each of the bearing members at the ends of the upper backing roll, and a lift means supporting the upper working roll.

11. In a rolling mill, a housing, a pair of superposed working rolls mounted in said housing, a backing roll having its surface curved longitudinally supporting each backing roll in a vertical direction, a journal member at each end of said working rolls, the journal members on the upper working roll slidingly engaging said housing, a bearing member at each end of each backing roll, a pair of oppositely disposed horizontal adjusting screws mounted in said housing pivotally engaging the sides of each of the bearing members at the end of the lower backing roll, oppositely disposed horizontal adjusting screws mounted in said housing pivotally and slidingly engaging the sides of each of the bearing members at the end of the upper backing roll, vertical adjusting screws mounted in the housing and pivotally engaging the upper side of each of the bearing members at the ends of the upper backing roll, a lever member intermediate said journal members adapted to force the latter apart, a beam member, a link connecting the beam member to the lever members, a ram supporting said beam member, and a source of constant pressure supporting said ram.

12. In a rolling mill, a housing, a pair of superposed working rolls mounted in said housing, a backing roll having its surface curved longitudinally for supporting one of said working rolls in a vertical direction, a journal member at each end of said working rolls, a bearing member at each end of the backing roll, means engaging said bearing members for adjusting said backing roll horizontally, adjusting screws for limiting the vertical movement of one of said working rolls, and means to constrain the latter roll toward the adjusting screws.

13. In a rolling mill, a housing, a pair of superposed working rolls mounted in said housing, a backing roll having its surface curved longitudinally for supporting one of said working rolls in a vertical direction, a journal member at each end of said working rolls, a bearing member at each end of the backing roll, vertical adjusting screws for limiting the vertical movement of one of said working rolls, a lever member intermediate said working rolls to force the latter apart, a lift means, and a link connecting said lift means to said lever member.

14. In a rolling mill, a pair of working rolls, a backing roll having its surface curved longitudinally for supporting one of the working rolls in a vertical direction, and means to horizontally adjust the backing roll obliquely to the working roll whereby the latter may be normally supported at its middle or at its ends or fully along its length.

15. In a rolling mill, a working roll, and a backing roll having its surface curved longitudinally and disposed obliquely to said working roll to support the latter throughout its length.

16. In a rolling mill, a working roll, a backing roll having its surface curved longitudinally for supporting said working roll in a vertical direction substantially throughout its length during the passage of the work through the mill, a bearing means at each end of said backing roll, and means engaging said bearing means to rotate said backing roll in a horizontal direction about its transverse axis.

17. In a rolling mill, a working roll, and a backing roll having its surface curved longitudinally and disposed obliquely to said working roll to support the latter at substantially the midpoint of its length.

18. In a rolling mill, a working roll, and a backing roll having its surface curved longitudinally and disposed obliquely to said working roll to support the latter at its ends.

19. In a rolling mill, a housing, a pair of working rolls, a backing roll having its surface concave in the longitudinal direction supporting one of said working rolls, journal members at each end of said working rolls adapted to slide vertically in said housing, bearing members at each end of said backing roll mounted in said housing so as to allow the backing roll to swing obliquely to the working roll in the horizontal direction and means to adjustably secure said backing roll against horizontal movement.

20. In a rolling mill, a working roll, a backing roll increasing in diameter from the midpoint of its length outwardly for supporting said working roll in a vertical direction, and means to adjust said backing roll obliquely to said working roll in a horizontal direction.

21. In a rolling mill, a working roll, a roll varying in diameter along at least a portion of its length for supporting said working roll, and means to adjust and secure said rolls in oblique relation to each other.

22. In a rolling mill, a working roll, a backing roll therefor, one of said rolls having its surface curved longitudinally, and means for varying the angular relationship of the axes of the rolls.

23. In a process of rolling sheet material, the steps of rolling a blank between formative rolls, applying backing pressure to at least one of said rolls, and varying the position of application of such backing pressure to vary the shape of the pass.

24. In a process for rolling metal, the steps of passing the metal between formative rolls, at least one of which rolls is backed by a supporting roll, and varying the horizontal angular relationship of the axes of said supporting roll and the formative roll supported thereby, to control the shape of the pass between the formative rolls.

25. In a process for rolling metal, the steps of passing metal between formative rolls, at least one of which rolls is backed by a supporting roll with a surface curved longitudinally thereof, and varying the angular relationship of the axes of said backing roll and the formative roll supported thereby, to control the shape of the pass between the formative rolls.

In testimony whereof I hereunto affix my signature.

ALBERT T. KELLER.