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DRIVE ASSEMBLY FOR METAL WORKING MILL

Filed April 20, 1959

5 Sheets-Sheet 2

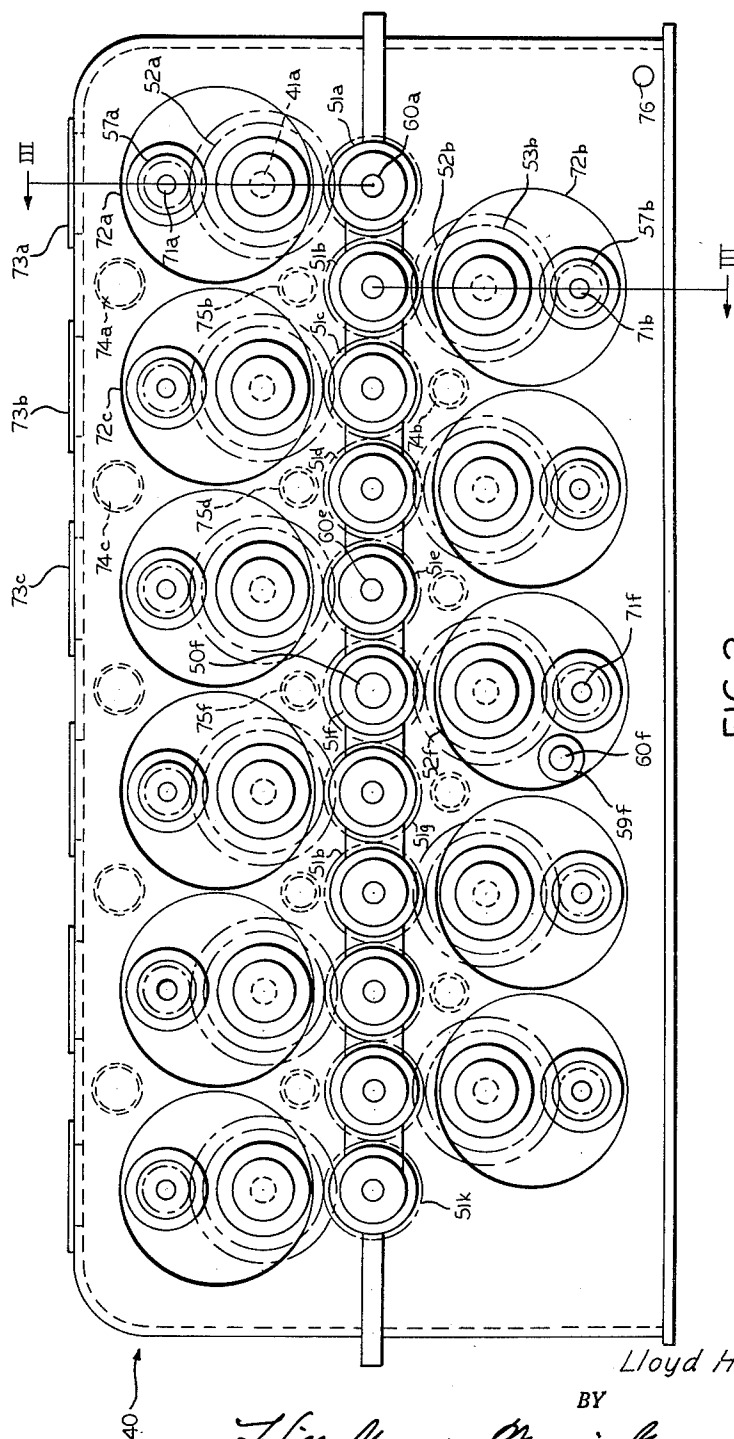


FIG. 2

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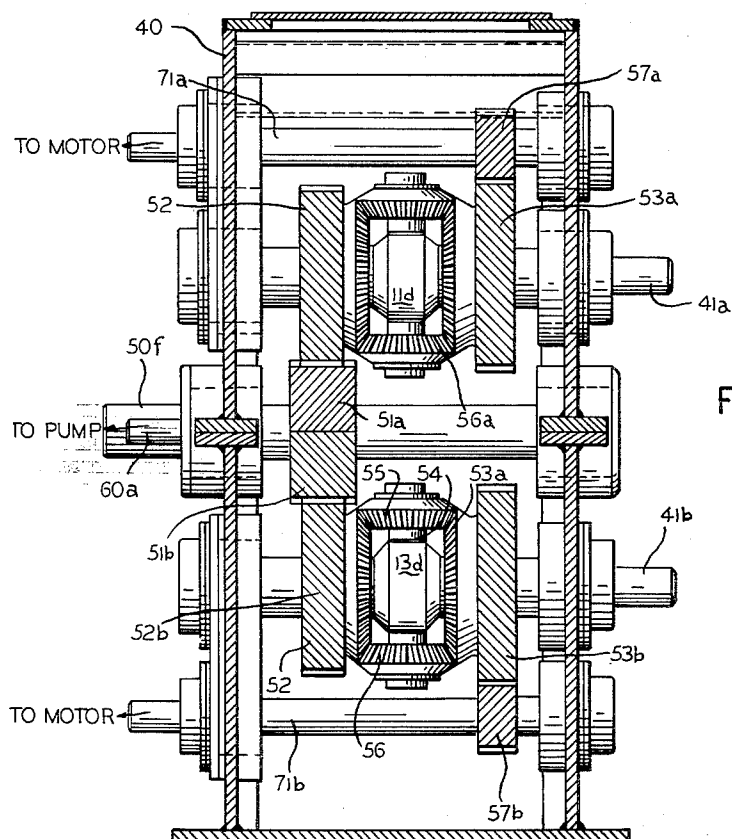


FIG. 3

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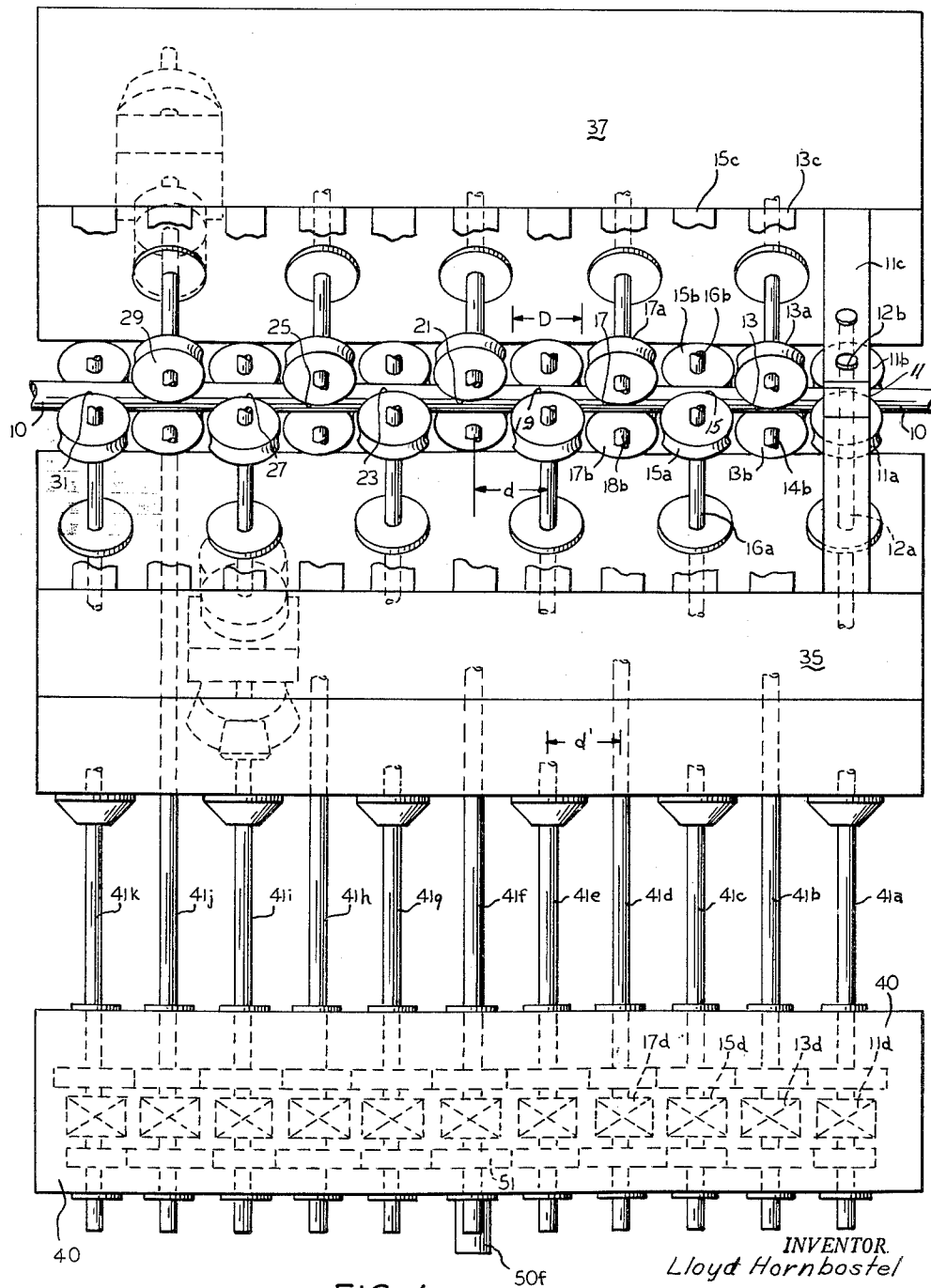
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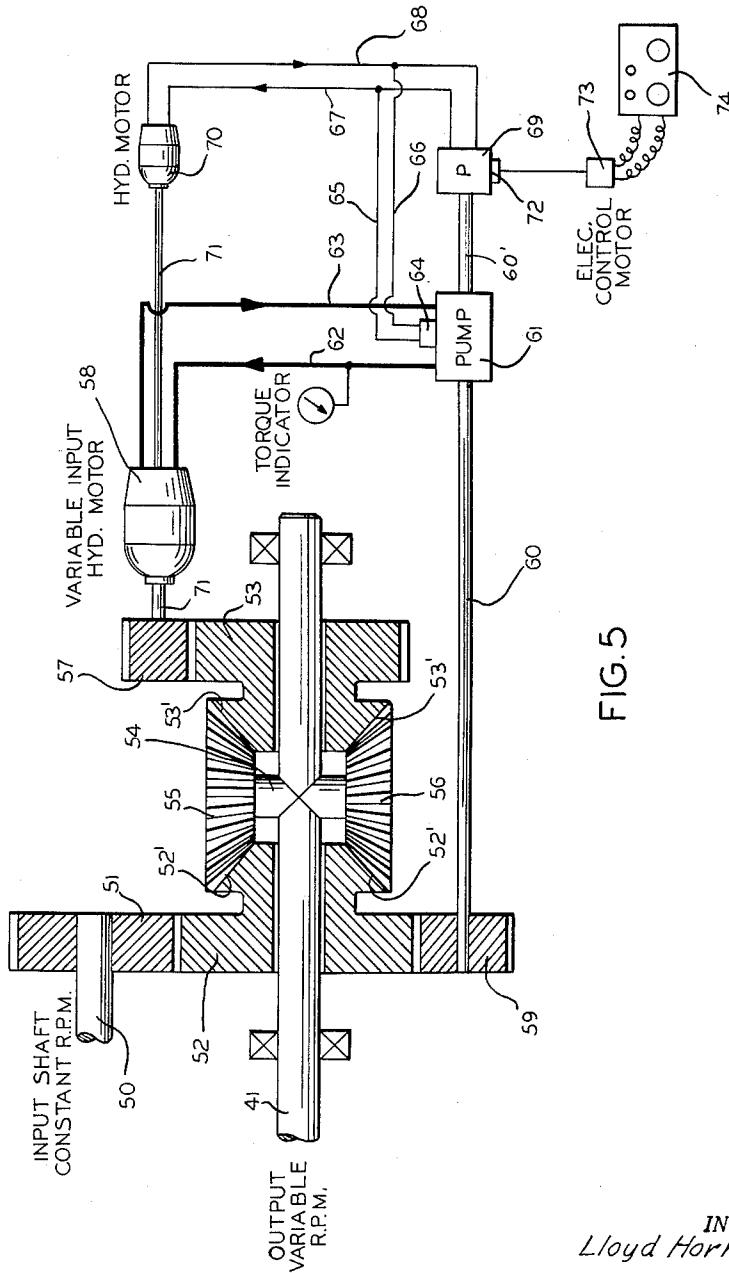
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DRIVE ASSEMBLY FOR METAL WORKING MILL

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5 Sheets-Sheet 5



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DRIVE ASSEMBLY FOR METAL WORKING MILL
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13 Claims. (Cl. 80—36)

This invention relates to a mill structure and more particularly relates to a drive assembly for continuous metal working mills of the type having a plurality of roll stands through which stock to be stretch reduced is fed.

Mills such as tube mills are used to convert pierced hot cylindrical metal billets into pipe and tubing. Such mills may receive a billet which is about five to six inches in exterior diameter, is about forty feet long, and has an interior dimension of about two to three inches. This billet is reduced to elongated piping or tubing of controlled diameter and wall thickness by being drawn through the nips of a plurality of sequentially arranged roll stands of the mill. A typical mill may, for example, have from 11 to 22 such stands. In such a mill, a billet of the type described above would produce about three hundred feet of ½ inch pipe. Of course, the size of the successive nips of the roll stand of the mill determines the outer pipe diameter whereas the relative speed ratios between successive roll stands determines the wall thickness of the pipe by determining the amount by which the original billet is stretched.

It is thus important to provide a mill wherein the drive arrangement is such that the relative speeds of the various roll stands can be accurately and easily controlled. Known electric drive units are not satisfactory because when the steel reaches its yield point, as is necessary in each nip, the driving torque is so greatly reduced that the released load on the electric driving motor will speed up the motor so as to require overcompensation for correction in speed. Since the metal must be worked in its yield area in the nip of each roll stand throughout the mill, it is obvious that the electric drive is very expensive, unduly complicated, and never sensitive enough to meet all conditions. In general, hydraulic control systems have a faster response in such a mill than an all electric drive.

Further, for either electric or hydraulic types of drive assemblies, the mechanical arrangement and layout of the drive assembly has an important relationship to possible overall mill construction and operation. Previously known mill constructions have required a substantial spacing between adjacent roll stands in order to accommodate the drive control apparatus necessary to individually control the speed of each stand. This spacing between roll stands is extremely undesirable since the greater the distance between successive nips the greater will be the crop loss in the mill and the radiated heat loss of the tubing being processed. Such heat loss and large crop losses can result in extremely inefficient operation. The larger the spacing between roll stands the more difficult also is the problem of controlling the operation of the mill particularly during intermittent operation. Since two adjacent roll stands are usually required to develop enough torque to pull the metal through the mill, the crop loss is for this reason increased as the spacing between the mill roll stands increases. Of course, the leading and trailing ends of each billet being formed will always end up as waste end plugs on the finished pipe or tube because they cannot be subjected to tension loads or draw as the tube advances through the mill. These crop losses, however, can in accordance with this invention be reduced to a minimum by minimizing the spacing between roll stands.

This is accomplished along with other objects and ad-

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vantages by providing a drive which will accommodate closer spacing together of the roll stands than has heretofore been possible. In particular, it is possible in accordance with this invention to position successive sets of rolls so that the distance between their centers can be equal to or even less than the diameter of a roll. Such close spacing has not been obtainable with previously known mill constructions of the type including a readily controllable heavy drive which can deliver any power requirement needed on any roll center spacing.

The drive unit in accordance with the present invention is encased in a single housing which extends along one side of the mill for the full length of the roll stands in the mill. This casing houses an individual differential drive assembly for each roll stand. The differential drives are each connected to be driven from a train of meshed gears which can accommodate changes in length under expansion and contraction creating conditions without resorting to slip couplings or similar devices necessary where a line shaft is used. Further, the back lash on such a gear train can be adjusted to prevent "wind-up" variations such as commonly occur in a line shaft.

The individual differential drive assemblies in the common casing of course afford the means for controlling the speed of the associated roll stand. These individual drive assemblies can be easily maintained, replaced and repaired by pulling out any unit without disassembly of the other units. For this purpose the casing is provided with a removable part adjacent each differential unit. The single casing for all of the differential units and the manner in which the units are arranged in staggered relationship within the casing make possible a more compact assembly permitting closer roll stand spacing than has heretofore been possible in known assemblies.

It is accordingly an object of this invention to provide a continuous mill structure having the foregoing features and advantages.

It is a further object of this invention to provide a drive assembly for a continuous mill which is arranged to permit extremely close spacing of the roll stands of the mill while still affording positive flexible driving power.

It is a further object of this invention to provide a continuous reducing mill wherein a differential drive assembly is provided to control the speed of each roll stand and wherein the drive assemblies are so inter-related that successive roll stands can be positioned a distance apart which may be less than the diameter of a roll of the stand.

It is a further object of this invention to provide a continuous mill structure affording a more compact arrangement and more efficient operation than has hitherto been known.

Other objects, features and advantages of the present invention will be more fully apparent to those skilled in the art from the following detailed description taken in connection with the accompanying drawings in which like reference characters refer to like parts throughout and wherein:

FIGURE 1 is an end elevational view partially broken away of a drive assembly for a continuous mill in accordance with the present invention.

FIGURE 2 is an elevational view taken on the line II—II of FIGURE 1.

FIGURE 3 is a sectional view taken on the line III—III of FIGURE 2.

FIGURE 4 is a top plan view of the apparatus shown in end elevation in FIGURE 1.

FIGURE 5 is a schematic or diagrammatic illustration of the type of differential drive assembly associated with each individual roll stand.

Turning now to the drawings and in particular to FIGURES 1 and 4, it will be seen that the pipe stock 10

which is to be drawn or reduced in the mill is fed sequentially through the nips of a plurality of roll stands. Thus, in FIGURE 1, the two adjacently positioned pulley shaped rollers 11a and 11b define between them the nip of the last roll stand through which pipe 10 is drawn as it leaves the mill. It will be noted that rollers 11a and 11b are respectively mounted on shafts 12a and 12b which lie in the same transverse plane with respect to the axis of the pipe stock 10 and which make an angle of 45° with the horizontal in that plane. Of course, rollers 11a and 11b respectively rotate in opposite directions about the axes of the shafts 12a and 12b so that each roller urges the pipe stock 10 in the same direction forwardly out of the plane of the paper as seen in FIGURE 1.

Immediately in back of the roll stand defined by rollers 11a and 11b is another roll stand the nip of which is defined between similar pulley shaped rollers 13a and 13b. Rollers 13a and 13b are respectively mounted on shafts 14a and 14b as may be seen in FIGURE 1. It will be noted that the shafts 14a and 14b also lie in the same plane which is also transverse to axis of the pipe stock 10 and in back of the plane of the shafts 12a and 12b. The shafts 14a and 14b also make an angle of 45° with the horizontal and these shafts further make an angle of 90° with the shafts 12a and 12b supporting the rollers of the next adjacent roll stand. That is to say, the axis of rotation of each of the rolls of each roll stand is parallel to that of the other roll in the same stand and perpendicular to that of each of the rolls in each of the adjacent stands.

This general arrangement may be seen more clearly in the plan view of FIGURE 4 which shows the arrangement for an eleven roll stand mill. Of course, it will be understood that the number of roll stands in any given mill is entirely a matter of design depending upon the particular application for which the mill is intended. In FIGURE 4, working from the output end of the mill towards the input or from right to left, nips 11 and 13 are defined as described above. Rolls 15a and 15b are mounted respectively on shafts 16a and 16b to define another roll stand nip 15 the axes of the roll shafts of which are parallel with the axes of the shafts 12a and 12b. Similarly, rolls 17a and 17b mounted respectively on the shafts 18a and 18b define another roll nip 17 the shafts of which are parallel with the shafts 14a and 14b. Thus, the two rolls 15a and 15b define a nip indicated generally by the reference character 15, the rolls 17a and 17b define a nip indicated generally by the reference character 17 and similarly the other nips 19, 21, 23, 25, 27, 29, and 31 are, for example, all formed by the same type of structure arranged in a repeated pattern as shown.

In order to clarify the drawing the mill as shown in FIGURE 4 has the rolls forming the nips 11, 13, 15, 17, 19, etc., positioned so that the central plane in which the axes of the shafts of the stand lies is separated from the same central plane of the next adjacent roll stand by a distance d which is greater than the diameter of the rolls of each stand. This distance, which may conveniently be referred to as the center-to-center nip separation distance, can, however, in accordance with the present invention be easily made equal to or even less than the diameter of a roll as may be seen in FIGURE 4. Thus, in FIGURE 4, the diameter of an individual roll is indicated by the capital letter D and in practice this diameter is the same for each roll of the stand. The nip separation distance, on the other hand, is indicated by the small letter d . It will be apparent from FIGURE 4 and from the discussion below that even if the shafts of adjacent roll stands were parallel to each other rather than perpendicular, the nip separation distance could in the present arrangement be reduced to be just equal to the diameter of a roll stand so that adjacent rolls would be just barely in contact. However, by virtue of the fact that the shafts of adjacent roll stands are in fact at a

90° angle to each other so that the pulley shaped rolls of adjacent stands lie in planes which are at 90° angles to each other, it will be seen that the nip separation distance d between the centers of adjacent roll stands can be made even less than the diameter of the rolls of each stand since the rolls may overlap in interfitted relationship to each other. Furthermore, as will be seen from the discussion below, the fact that the shafts are brought out from the opposite sides of the pipe stands being worked on permits an arrangement of associated parts of the differential drive assembly for each stand which accommodates this extremely close spacing of the nips of adjacent roll stands and thereby reduces heat losses and crop losses in the operation of the mill.

Turning now again to FIGURE 1, it will be noted that the shafts 12a and 12b which support the rolls 11a and 11b respectively are themselves journaled in a cage or framework 11c, there being one such cage or framework for each roll stand. In FIGURE 4, the cage 11c associated with nip 11 is shown by way of example but the cage structures for the other nips have been broken away in order to more clearly show the nip defining relationship of the various rolls.

As may be seen in FIGURE 4, the shafts for alternate nips 11, 15, 19, etc., project from and are supported in a main housing 35 which extends the full length of the mill on one side thereof. The intermediate nips have the shafts associated therewith such as the shaft for nips 17, 21, 25, etc., projecting from and supported in a similar housing 37 on the opposite side of the mill. The housing 35 and 37 are preferably upright casings generally of the shape shown in FIGS. 1 and 4 and may conveniently rest on any fixed support members or directly upon the floor. The box-like frames or cages such as 11c, 13c, 15c, etc. which support the shafts for each of the roll stands are each rigidly attached to both of the housings 35 and 37 in spaced relationship to each other along the length of the mill as may be seen in FIGS. 1 and 4. These frameworks may be welded, bolted or attached in any convenient manner to the housings 35 and 37.

Within the housings 35 and 37, there are contained conventional reduction gearing and reversal gearing for each of the roll stands since such reversing and fixed ratio reduction gearing arrangement are well known in the art and they will not be further described herein.

Extending generally parallel to and coextensively with the housing 35 is a differential drive assembly housing 40 positioned as shown in FIGURES 1, 2 and 4. Within the housing 40 there is contained one differential drive assembly for each of the roll stands so that the speed of each roll stand may be adjusted individually through its own differential drive. Each of the differential drive assemblies is of the type shown in the sectional view of FIGURE 3 and operates in a manner best seen from a consideration of the diagrammatic view of FIGURE 5.

In FIGURE 5 power output from the differential drive is indicated as being derived through the variable r.p.m. output shaft 41. As may be seen in FIGURES 1 and 4, the shaft 41a from the differential drive 11d for the first roll stand 11 extends from the casing 40 to the reduction gearing 11e associated with that stand in the casing 35. A similar output shaft 41b extends from a second identical differential drive assembly 13d to the casing 37 on the other side of the mill where the shaft 41b is connected to drive reduction gearing 13e which ultimately drives the rolls 13a and 13b of the nip 13. Similarly, as seen in FIGURE 4, the shaft 41c is connected to drive the rolls of the nip 15, the shaft 41d is connected to drive the rolls of the nip 17, etc.

Turning again to FIG. 5 it will be noted that a constant speed power input shaft 50 drives a gear 51 which in turn either directly as shown in FIG. 5 or through a gear train (as shown in FIGS. 1-4 for all but the central nip 21) drives the first of two input gears of the differential for

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the particular stand. These two input gears are indicated in FIG. 5 as the gears 52 and 53 each of which is journaled and mounted for free rotation concentrically with and about the output shaft 41 but independently of the rotation thereof. The output shaft 41 carries a cross-shaft spider assembly 54 on which are mounted two small bevel gear pinions 55 and 56 respectively. Of course it will be understood that the driving gear 51 is meshed in engagement with the input gear 52 of the differential. The gear 52 in turn has a bevel gear portion 52' which is meshed with the bevel gears 55 and 56 respectively. Similarly, the other input gear 53 of the differential has a bevel gear portion 53' which is also meshed with the bevel gear pinions 55 and 56 and the gear 53 is also meshed with another driving gear 57 which is rigidly mounted on the shaft 71 of a variable speed hydraulic motor 58. The input gear 52 is also meshed with a gear 59 rigidly mounted on the drive shaft 60 of a constant speed variable displacement hydraulic pump 61. The output of pump 61 is applied through hydraulic line 62 to the input of the constant displacement variable speed hydraulic motor 58 and hydraulic fluid is returned from motor 58 through hydraulic line 63 to the input of pump 61. The displacement of pump 61 may be controlled by any known mechanism indicated schematically by the block 64 which is connected by pressure sensing lines 65 and 66 to the high pressure line 67 and the low pressure line 68 respectively of a slave hydraulic system comprising hydraulic pump 69 and hydraulic motor 70. Hydraulic motor 70 is a constant displacement variable speed motor. Shaft 71 integrally connects the motors 58 and 70 so that they necessarily operate at the same speed. Input line 67 and output line 68 connects the constant displacement variable speed motor 70 to the variable displacement constant speed pump 69. Pump 69 is driven by shaft 60' which is rigidly connected to be driven by the main pump shaft 60. The displacement of pump 69 is controllable by means of any conventional displacement control mechanism such as a slide block indicated generally by the reference character 72 which may in turn be mechanically connected for actuation by an electric motor 73 which may be controlled by manual switch-board controls 74 or by any other suitable manual or automatic means.

When the mill operator pushes one of the buttons on the control board 74 so as to actuate motor 73 in one or the other preselected direction so as to either increase or decrease the displacement of pump 72, a pressure unbalance is created in the system which results in a pressure difference being applied through lines 65 and 66 so that the displacement control 64 of pump 61 is adjusted to a greater or lesser volume output, and so that its adjustment follows that of the adjustment of pump 69 thereby determining the speed ratio between the pump 61 and motor 58 (hence also motor 70) and thereby eliminating the unbalanced condition in the system and returning it to equilibrium at a new speed ratio.

Considering now the overall operation of the differential unit shown in FIGURE 5, first note a hypothetical situation wherein the gear 53 is held stationary. If gear 52 is now turned, the small pinion gears 55 and 56 on the cross shaft 54 of output shaft 41 will walk on the bevel gear portion of gear 53. The net result is that the output shaft 41 will rotate at one-half the speed of rotation of the gear 52. The same rotation of the output shaft would be produced if gears 52 were held stationary and gear 53 were rotated. It can readily be shown, in other words, that the rotation of output shaft 41 has a speed which is equal to one-half the algebraic sum of the speed of rotation of gears 52 and 53. Of course, when gears 52 and 53 are rotating at the same speed, the output shaft 41 will also rotate at this speed in accordance with the above formula. In this latter condition, the hydraulic system, which acts as a variable ratio reduction coupling, has an effective coupling ratio of one to one.

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Furthermore, the power transmitted to shaft 41 from gears 52 and 53 is directly proportional to the relative rotational speeds of these gears respectively. If gear 52 turns at 1000 r.p.m. and gear 53 turns at 100 r.p.m., the power input imparted to shaft 41 from gear 52 will be ten times that from gear 53. It is thus evident that if an adjustment of speed of rotation of the output shaft 41 is necessary over a relatively small range, most of the power can be transferred through gear 52 to shaft 41 from a constant r.p.m. source and that the variation in speed necessary can be accomplished by varying the speed of rotation of gear 53. Also, the amount of variable power which must be delivered to gear 53 will be small because the variation in speed required in mills of this type is in practice small. On large drives, this means that most of the power can be transmitted from a simple, economical, highly reliable constant speed source and that the variable power necessary can be supplied from a variable speed source of much lower horsepower rating.

The accuracy of the drive is also improved by the ratio of the variable to the constant horsepower. For instance, if the variable speed drive should vary 1% and the power input from the variable speed drive was only one-tenth of the total, the speed input from the variable drive would also only be one-tenth of the total and therefore the variation or error on the main output would only be one-tenth of 1%. Because this differential drive is essentially a simple, high quality gear drive, the operation, service factors, time ratings, etc. are those of gearing.

The variable portion of the drive is shown as being provided by the system comprising the hydraulic pump and motor which are adjustable in ratio of speed. The pump is driven at a constant speed from the main input shaft. The pump has an adjustable displacement per revolution. The hydraulic motor which is connected through gear 57 to gear 53 has a constant displacement per revolution. Setting of the displacement of the pump 61 by setting the displacement of the pump 69 through the operation of motor 74 thus sets the ratio between the r.p.m. of pump 61 and motor 58, and, as a consequence, determines the ratio between the r.p.m. of the input shaft 50 and of the shaft 71. The hydraulic system of speed control is preferred since it is not subject to overheating and temperature problems associated with entirely electrical systems. It is essentially a rigid ratio drive which may be adjusted as desired, but once set, holds a definite speed ratio between the pump and motor throughout the load range.

The same reference numerals used in identifying the component parts of the differential drive diagrammatically illustrated in FIGURE 5 have been applied in FIGS. 1-4 to the mechanical components in the actual embodiment of the invention which have functions similar to those of the parts to which the reference numerals were originally applied suffix letters have been added to these numerals, the letters *a* indicating the corresponding part in stand 11, *b* in stand 13, *c* in stand 15, etc. in FIGURE 5.

Thus, from FIGURES 1, 2, 3, and 4 it will be seen that a main power input shaft 50f is provided to the differential drive assembly for roll stand 21 which is centrally disposed longitudinally of the mill. In particular, referring to FIGURES 2 and 4, it will be noted that the single main input power shaft 50f drives the input gear 51f associated therewith. Each of the differential assemblies for each roll stand has such a gear 51. It will be noted from FIGURE 2 that these differential assemblies are so positioned that the input gears 51 of adjacent differential drives are meshed with each other to form a train of gears 51a through 51k centrally disposed in the housing 40 and extending longitudinally the length of the mill. By this arrangement, power is supplied to each of the differential drives through the single centrally disposed input shaft 50f, the power being transmitted through the gear train composed of the adjacently positioned

meshed gears. As may be seen in FIGURE 2, this meshed chain of gears extends horizontally along the length of the casing 40 at approximately its mid-height. Each of the gears 51 in turn is meshed with a larger diameter gear 52 positioned either vertically above or vertically below the input drive gear 51 in alternate staggered relationship. That is to say, the drive gear 52a for the differential of the last stand 11 in the mill is placed above its gear 51a whereas the drive gear 52b for the next to the last stand 13 is placed below its gear 51b, this alternate sequence of above and below being repeated throughout the mill. This sequence of positioning is shown in FIGURE 2 and the above and below relationship of alternate differential assemblies may also be seen in the transverse sectional view of FIGURE 3. It is this compact spacing arrangement which permits the mechanism driving the roll shafts to be positioned so that the roll stand can be closer together than even a single diameter of a roll for each stand.

Turning now in particular to FIGURE 2, it will be noted that the main power input shaft 50f is connected to the drive gear 51f for the centrally disposed roll stand 21. In FIGURE 2, there is shown by way of example, an eleven-stand mill wherein power is supplied through shaft 50f to the central stand. Each of the gears 51 to the left and right of the central power input are meshed to form a gear train driving the associated differential drive for its particular roll stand. As noted above, gears 52 are meshed with their associated gears 51. In the central roll stand to which the input shaft 50f is directly connected, not only is gear 52f driven by input gear 51f but also gear 51f meshes with a pump driving gear 59f in the same fashion as is illustrated in the schematic view of FIGURE 5. Gear 59f in turn is rigidly attached to and drives shaft 60f. In all other roll stands, however, it is simpler to connect the pump shaft 60 directly to the input gear 51 so that the two are rigidly attached and hence so that pump shaft 60 is directly driven by gear 51 instead of utilizing gear 59 and 52 as a take-off from gear 51.

Thus, referring in particular to FIGURE 1, it will be noted that the pump 61a is shown being driven by the shaft 60a which is integrally attached to the gear 51a. The shaft 50f shown in FIGURE 1 is of course in back of shaft 60a and is connected to the gear 51f for the central power input as is shown in FIGURE 2. Pump 61a drives hydraulic motor 58a through lines 62a and 63a as explained above. Motor 58a in turn drives shaft 71a which is rigidly attached to and drives gear 57a which in turn drives the second input gear 53a of the differential 11d to supply the variable speed portion of its input power.

It will be noted that in FIGURE 1 the hydraulic pumps and motors are shown only diagrammatically in block form. In practice, the pumps and motors can be mounted on any convenient supporting means such as a separate shelf or table extending the length of the mill adjacent to the casing 40. Considering FIGURES 1 and 2, it will be obvious that the pumps 61 for each stage would be mounted directly opposite the gear 51 and integral shaft 60 for that stand. The motors 58 would of course be positioned in staggered relationship above and below these gears and directly on the projection of the shafts 71 such as the shafts 71a and 71b shown in FIGURE 2. The slave hydraulic system for each stage which is shown in FIGURE 5 has not been illustrated in FIGURE 1 since it is believed obvious that the rest of these hydraulic components would simply be mounted on the same shelving which support the motors 58 and 61.

It will be noted from FIGURE 2, that the staggered relationship of the gearing as shown therein not only results in a compact arrangement permitting a closer spacing of the rolls but also affords a desired relationship in the direction of rotation of the output shaft with respect to the gear train through which power is fed. Thus, assume that the main input shaft 50f is driven in a coun-

terclockwise direction. It will of course drive gear 51f in the same counterclockwise direction which in turn will drive gears 51e and 51g in the clockwise direction. These two latter gears in turn drive the gears with which they mesh in the opposite direction, e.g., gears 51h and 51d are driven in the counterclockwise direction the same as input shaft 50f. It is thus apparent that alternate gears in the power feeding train of gears will rotate in opposite directions. However, the above and below staggered relationship of the differential unit for the assemblies is such throughout the casing 40 that the differential assembly for every other roll stand is above the gear train and the alternate differential assemblies are below the gear train. Thus, the gear 52a of roll stand 11 will be driven in a counterclockwise direction by the clockwise rotation of gear 51a. Similarly, all of the gears 52 for all of the differential units above the power gear train will be driven in a counterclockwise direction. Referring to FIGURE 4, however, it will be noted that these alternate differential units 11d, 15d, etc., are the drive units for the roll stands the reduction gearing of which is positioned in the left side casing 35 of the mill. On the other hand, the intermediate gears 51b, 51d, etc., have the same counterclockwise rotation as input shaft 50f and will impart a clockwise rotation to their associated differential gears below them such as the gear 52d and all other gears of the differentials 13d, 17d, etc., e.g. to all of the differentials for roll stands whose reduction gearing is in the right hand casing 37 of the mill. It will be recalled that the reversing gears such as the gears 11r and 13r associated with nips 11 and 13 respectively, are provided to insure that the two rollers of each stand such as the rollers 11a and 11b will rotate in opposite directions from each other so as to urge the pipe 19 in the same direction on both sides thereof. It will of course also be understood that the direction in which the pipe is urged by consecutive stands must also be the same. This is easily accomplished by the above noted relationship in the driving gears. These relationships ultimately result in the fact that the shaft 41a and all shafts in the same level therewith rotate in one direction whereas the shaft 41b and all similarly positioned shafts rotate in the opposite direction. Thus, where the drive assembly comprises an arrangement wherein the casing 40 is to be used with an existing mill where the reduction and reversing gears in the two sides of the mill housing are such as to accept this opposite type of shaft rotation input, the shafts 41a and 41b can be connected directly thereto as shown in FIGURE 1. If, on the other hand, the existing mill structure to be modified is such as to require that the two shaft sets 41a and 41b have the same direction of rotation, it is a simple matter to place a reversing gear in the output connection from casing 40 for the shafts 41a or for the shafts 41b as may be required.

Accessibility to the differential inside the casing 40 is afforded by a plurality of manholes such as the openings 72a, 72b, 72c, etc., associated with the differential drive assemblies for each of the stands 11, 13, 15, respectively. These manholes are of course simply openings in the side of the casing through which the gearing of the differential assembly may be reached if necessary. Further access is provided by lids such as the lids 73a, 73b, 73c, etc., associated with the same roll stand respectively. These lids as may be seen in FIGURE 2 close openings in the top of the casing 40. Each of these openings as well as the manhole openings are so positioned as to be in direct alignment with the differential assembly of its associated stage to facilitate access if necessary.

Lubrication of the gearing may be provided by an oil sprinkler pipe entering through the sides of the casing there being an entry and pipe associated with each of the differential assemblies. These lubricating sprinkler pipes are indicated in FIGURE 2 by the inlets 74a, 74b, 74c, etc., associated with each of the differential drive assem-

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blies. Additionally, a similar lubricating pipe may be provided for alternate ones of the chain of power transmission gearing. These lubricating sprinkler pipes are indicated by 75b, 75d, 75f, etc. Oil sprayed from these pipes onto the gearing may be allowed to collect in the bottom of the casing 40 and may be withdrawn therefrom through an oil outlet or outlets such as the outlet 76.

Turning again to FIGURE 4, it will be noted that the center-to-center spacing of the roll stands indicated by the small letter d as discussed above, is in practice equal to the center-to-center spacing of the output shafts 41 from the differential drive assembly. This distance is indicated in FIGURE 4 by d' . When these two distances are equal as shown, power can be transmitted directly or in straight line fashion from the drive assembly to the roll stand with a maximum efficiency and ease of transmission. On the other hand, the close spacing between the centers of the rolls of adjacent roll stands which is desirable from the point of view of heat losses and crop losses has in the past been difficult to achieve in connection with a straight through shaft connection partly because of the structure and arrangement of the drive mechanism. Thus, the magnitude of the distance d' has in the past necessarily been greater than a roll diameter by virtue of the arrangement of the drive assembly. This in turn has required a spacing apart of the rolls by a distance greater than desirable. It is thus seen that the arrangement of the drive assembly described herein in addition to its other advantages has the particular result of facilitating the close spacing between the centers of adjacent roll stands while still permitting a straight through shaft connection to drive the rolls.

While a particular exemplary preferred embodiment of the invention has been described in detail above, it will be understood that modifications and variations therein may be effected without departing from the true spirit and scope of the novel concepts of the present invention as defined by the following claims.

I claim as my invention:

1. In a stretch reduction type metal working mill, a plurality of roll stands sequentially arranged along the axial length of said mill, each of said stands comprising a pair of rollers respectively mounted for rotation on a pair of shafts having parallel axes to define a nip therebetween, said nips being axially aligned along the axial length of said mill to receive said stock to be continuously drawn in said mill, the axes of the shafts of adjacent roll stands being alternately orthogonal to each other, a plurality of individual drive units with each one of said units connected to drive the rollers of a corresponding and aligned one of said roll stands, each of said individual drive units including a differential means and a separately adjustable hydraulic means to vary the speed of its driven roll stand independently of the others and during operation and having an axial width materially greater than the diameters of said rollers and the axial spacing of said roller pairs, common meshed gear drive train means connected to all of said drive units along the length of said mill, and said drive units being in a plurality of alternately offset rows to reduce the axial spacing therebetween whereby the distance between the nips of adjacent stands is not substantially greater than the diameters of said rollers.

2. In a continuous, stretch reduction type, metal working mill, a plurality of adjacent roll stands sequentially arranged along the axial length of said mill, each of said stands comprising a pair of rollers respectively mounted for rotation on a pair of parallel shafts to define a nip therebetween, said nips being axially aligned to receive said metal stock to be drawn continuously through said mill, the axes of the shafts of adjacent roll stands being orthogonal to each other, a plurality of speed controlling differential drive units having common meshed gear input drive means to supply their entire power ex-

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tending transversely to the axial length of said mill with each connected to drive an associated and axially aligned one of said roll stands, each said differential drive unit including an individual and always connected hydraulic speed varying means adjusted during operation thereof, said drive units having axial widths greater than the diameters of said roller and being connected to the rollers of their associated and aligned roll stands by shafts whose axes are transverse to the length of said mill, the horizontal and axial distances between the centers of said last-named shafts being equal to the center-to-center nip separation between the centers of the rollers of adjacent stands, and said drive units naturally wider than the diameters of said rollers and being alternately offset in overlapping relation reducing the axial spacing therebetween to materially less than their axial widths so that said horizontal and axial distances between the centers of said last-named shafts and the corresponding distances between the centers of the rollers of adjacent stands are substantially equal to the diameters of said rolls.

3. In a continuous, stretch reduction type, metal working mill, a plurality of adjacent roll stands sequentially arranged along the axial length of said mill, each of said roll stands comprising a pair of rollers on parallel shafts to define a nip therebetween, said pairs being axially aligned to receive metal stock to be drawn in said mill, the axes of the shafts of adjacent roll stands being substantially perpendicular to each other, individual differential drive units connected one to each of said roll stands, each of said drive units including individually adjustable and always connected hydraulic pump and motor means to vary the speed of each said roll stand independently during operation thereof, all of said drive units being encased in elongated common housing means extending alongside said mill throughout its axial length, said drive units having axial widths materially greater than the diameters of said rollers and being alternately offset in axially overlapping relation to reduce the axial spacing therebetween in said common housing so that the center-to-center nip separation distance between the centers of the rolls of adjacent stands is substantially equal to the diameters of the rollers of said stand.

4. In a continuous, stretch reduction type, metal working mill, a plurality of adjacent roll stands sequentially arranged along the axial length of said mill, each of said roll stands comprising nip defining pairs of rollers, said rollers, the nips of said roll stands being aligned axially to receive metal stock to be drawn in a straight line through said mill, individual differential drive units, each always connected to an aligned one of said roll stands, each of said drive units including always connected hydraulic pump and motor means to vary the speed of its associated roll stand independently of the other roll stands, each said drive unit having an axial width materially greater than the diameters of said rollers, a train of intermeshed spur gears extending horizontally along the axial length of said mill, alternate rows of said differential drive units being positioned above and below said gear train respectively and in meshed relation therewith to be driven thereby, a common constant speed source connected to said gear train, and said drive units being alternately and vertically offset and overlapped to reduce the axial distances therebetween and with their aligned roll stands positioned so that the center-to-center nip separation distances between the centers of the rolls of adjacent stands is not substantially greater than the diameters of said rollers.

5. In a continuous, stretch reduction type, metal working mill, a plurality of adjacent roll stands sequentially arranged along the axial length of said mill, each of said stands comprising a pair of rollers having parallel shafts to define a nip therebetween, said nips being aligned axially to receive said metal stock to be drawn through said mill, the axes of the shafts of adjacent roll stands being perpendicular to each other, said pair of shafts of each of said roll stands both being driven from common reduction

gearing sets, said reduction gearing sets for alternate adjacent roll stands being on opposite sides of said rollers and being enclosed in two common housings extending substantially throughout the length of said mill on each side of said rollers and each supporting said roll stands, individual differential drive units with one directly connected to its corresponding said reduction gearing set for each of said roll stands, each of said drive units including hydraulic means to vary the speed of each of said roll stands independently of the other roll stands during operation thereof, said drive units having axially extending widths materially greater than the diameters of said rollers, a train of meshed gears extending horizontally along the length of said mill, a common constant speed source connected to drive the meshed gears of said train to supply power to all of said differential drive units, alternate adjacent ones of said differential drive units being positioned above and below said gear train respectively and in meshed relation therewith, said gear train and all of said differential drive units being encased in a third common housing extending substantially throughout the length of, and along the side of, said mill and parallel to said first two housings, and said differential drive units being alternately and vertically offset and in overlapping relation in said third housing to reduce the axial spacing therebetween with their aligned roll stands positioned so that the center-to-center nip separation distance between the centers of the rolls of adjacent stands closely space down to the diameters of the rolls of said stands.

6. For use with a continuous, stretch reduction, metal working mill of the type comprising a plurality of adjacent roll stands sequentially and axially arranged and defining aligned nips through which said metal is drawn; a drive assembly comprising, a plurality of adjacent, individual, speed controlling differential drive units each to be connected to an aligned one of said roll stands and including shafts extending transverse to the axial length of said mill, a train of intermeshed gears extending in a generally horizontal direction throughout the length of said mill, means to supply power from a common constant speed source connected to said gear train to supply power to all of said differential drive units, said differential drive units having axial widths greater than the maximum diameters of the mill to be driven thereby, alternate ones of said differential drive units being offset in overlapping relation to reduce the axial spacing therebetween and positioned alternately above and below said gear train and in meshed relation therewith, each of said drive units having an output drive shaft extending transversely to the length of said mill and adapted to be connected to drive an aligned roll stand of a mill, axes of all of said drive shafts being substantially parallel to each other, the horizontal axial distances between the centers of said shafts being substantially not greater than the maximum diameters of the rolls of a said mill to be driven thereby, and said meshed gear train and all of said differential drive units being enclosed in a common and longitudinally extending housing adapted to be positioned along the side of a said mill with said drive shafts projecting transversely therefrom.

7. For use in a continuous, stretch reduction, metal working mill of the type comprising a plurality of adjacent roll stands sequentially and axially arranged and defining axially aligned nips through which said metal is drawn and in which each roll stand has an individual drive unit whose axial width limits the minimum axial spacing between said roll stands; a drive assembly comprising a common housing adapted to be positioned on one side of said mill and extending axially throughout the length thereof, a plurality of drive shafts extending from one side of said housing substantially horizontally and transverse to its length, each of said drive shafts being adapted to be connected to an individual roll stand of said mill, alternate ones of said drive shafts being arranged in an upper row and a lower row with the shafts of two rows

being sequentially positioned in alternate staggered relationship to each other, adjacent shafts in said upper row being adapted to be connected to alternate roll stands of said mill on adjacent stands and said lower row being adapted to be connected to roll stands intermediate to those to which said upper row shafts are connected, the axes of all of said drive shafts being substantially parallel to each other, a plurality of individual drive units substantially entirely in said common housing with adjacent alternate drive units being arranged in an upper row and a lower row in alternate staggered relationship to reduce the axial spacing therebetween to substantially one-half of their axial widths, said drive units being axially aligned with, and connected to, said upper and lower rows of shafts, each drive unit including a differential gear set having variable speed drive means connected to one input side thereof at all times to independently vary its speed during operation thereof, and each drive means having the other input of its differential gear set always connected to a substantially constant speed common drive comprising an axially extending train of meshed gears in said common housing.

8. For use in a multi-roll stand continuous, stretch reduction tube mill of the type having individual roll stand drive units which are the axially widest parts of said mill, a drive comprising an elongated housing, adapted to be mounted on one side of such a mill and extending along its length, superimposed rows of drive units in said common housing, each drive unit having an output shaft extending from one side of said housing substantially horizontally and transverse to its length for connection to a transversely aligned roll stand of such a mill, a common main drive input means in said housing comprising a train of meshed gears, each drive unit including a differential gear set having an input thereof operatively connected with said common main drive means and a second input thereof operatively connected with a variable speed drive means individual to each drive unit, all of said variable speed means being operatively to be driven by said common main drive means, and said drive units being in alternately offset and overlapping relation in said superimposed rows to reduce the axial spacing therebetween to approximately one-half of the axial width of each said drive unit to thereby provide for a minimum spacing between the input shafts and the corresponding roll stands of said mill to be driven.

9. For use in a continuous, stretch reduction, multi-roll stand tube mill to permit any desired minimum spacing of its roll stands limited only by their roll diameters to thereby minimize mill length, crop loss and temperature losses of tube metal between the stands of said mill, a drive comprising an axially elongated, common housing means adapted to be mounted along one side of the mill and extending throughout its length, a plurality of rows of differential drive units in, and extending horizontally and transversely across the width of, said housing means, each drive unit having a main driving gear at one end thereof, a variable speed input gear in opposed relationship therewith and at the other end thereof, pinion gears between said opposed main and variable speed gears in meshed relation therewith, a spider rotatably mounting said pinion gears and an output shaft driven by said spider, a common main, gear drive, input means coupled to the main driving gear drive unit, a separate variable speed input means coupled to the variable speed gear of each drive unit, each variable speed means being operatively and directly connected to be individually driven by said common drive means, said main drive input means and said variable speed input means cooperating for controlling the relative rates of rotation of the output shafts of said drive units, and the said drive units of one row in offset and overlapping positions relative to the said drive units of the other row for aligning the output shafts with roll stands of a mill to be driven thereby and to reduce the axial spacing between the said output shafts

and the correspondingly aligned and driven roll stands of said mill.

10. For use in a multi-roll stand, continuous, stretch reduction tube mill to permit close spacing between the roll stands thereof to thereby minimize mill length, crop loss and temperature losses of tube metal between said stands; a drive comprising a single and common axially elongated housing adapted to be mounted on side of, and to extend along the length of, the mill, a superimposed row of differential drive units in said housing extending horizontally and transverse to its length, each said drive unit having an output shaft for coupling with the aligned roll stand of the tube mill to drive the rolls thereof, a common main drive input means of the meshed gear type coupled to each drive unit, an individual variable speed input means for each unit connected to be driven by said common drive means and coupled to each unit to cooperate with the main drive means for controlling the relative rates of rotation of the output shafts, the units of one row being staggered and partially overlapped with the units of the other row in axially offset relation for aligning said output shafts with their corresponding roll stands and with the degree of overlapping of the staggered units reducing the axial spacing between said units and their corresponding aligned roll stands to any desired close spacing of the roll stands down to approximately one-half of the axial width of said units.

11. A differential drive for tube mills of the continuous, stretch reduction type, said drive comprising a single axially elongated, common housing adapted to be mounted on one side of a tube mill and to extend throughout its length, a plurality of drive units each including a differential gear set mounted in said housing and extending generally horizontally and transverse to its length, each of said units and said sets having an output shaft extending from one side of said common housing for coupling with an adjacent and aligned driving shaft of said mill, each of said units including a variable and slower speed, relatively adjustable, hydraulic pump and motor drive means always connected to one side of said differential gearing set, a single and common main drive input of the meshed gear type coupled with the other sides of each of said differential sets and with the pumps of said variable speed drive means, and said drive units having axial widths materially greater than the rolls or the other portions of each roll stand, said drive units being arranged in alternately superimposed upper and lower rows with the units of one row staggered and overlapping relative to the units of the other row to reduce the axial spacing between the output shafts thereof and to thereby permit a desired close spacing of the roll stands of said mill limited only by the roll diameters thereof.

12. A continuous, stretch reduction, metal working mill comprising a plurality of roll stands sequentially arranged along the axial length of said mill and each including nip defining rollers on alternately inclined and substantially orthogonal pairs of shafts, floor supported common housing means supporting said alternately inclined shafts and comprising at least two elongated housing portions adjacent to, and on opposite sides of said rollers along the axial length of said mill, at least one row of a plurality of individual drive units with each one of said units directly connected

to drive the rollers of a corresponding and transversely aligned roll stand, each of said plurality of drive units including an individual differential gear set and an individual reduction gear set, said differential gear sets being located entirely within said common housing means, said reduction gear sets being located entirely within each of said two roller shaft supporting elongated housing portions on opposite sides of said rollers, said differential gear sets being substantially wider axially than the diameters of said rollers and being in axially overlapping relation with said common housing means to reduce the axial spacing therebetween and permit a closing spacing of said roller pairs, a common drive means comprising at least one train of meshed gears extending substantially throughout the axial length of said mill interconnecting said drive units and one of the inputs of their differential gear sets and being entirely enclosed within said common housing means adjacent to the corresponding driven drive units, each said enclosed drive unit having an output shaft projecting laterally out through a side of said common housing and driven by said common drive means therein, each of said enclosed drive units having an adjacent input shaft projecting laterally out through said same side of said common housing means and connected to drive the other input of its differential gear set, and externally mounted and accessible, always connected, and individually adjustable hydraulic speed varying units each including an hydraulic pump on said output shaft and supplying an hydraulic motor on said input shaft.

13. A continuous, stretch reduction, metal working mill comprising a plurality of pairs of nip defining rollers on parallel shafts sequentially arranged along the axial length of said mill, said pairs of rollers being alternately oppositely inclined and substantially relatively orthogonal, each pair of parallel roller shafts having a bearing and support on opposite sides of its roller in an individual open frame, elongated common housing means extending along the axial length of said mill and including at least two upright floor supported, common housing portions closely adjacent on opposite sides of said rollers; supporting said parallel shaft pairs, and connected to support their said individual frames, a common drive comprising at least one axially extending train of meshed gears and a plurality of individual differential drive units each connected to be driven by said common drive with both enclosed in said common housing means, said differential drive units each including connected hydraulic means to vary its speed during operation and all said units being axially overlapping to reduce the effective axial spacing therebetween, and a plurality of reduction gear sets enclosed in said two common housing portions and each directly connected between each differential drive unit and its corresponding pair of roller shafts.

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