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(54) **Rolling mill apparatus.**

(57) Rolling mill apparatus including a pair of roll assemblies (10,12) each constituted by a rotatably mounted support roll (14,16) and a plurality of work rolls (18,20) spaced around said support roll. So that the mill will be capable of relatively high reductions and will require only a relatively low power input, the work rolls are backed by respective cradle elements (22,24) and means are provided whereby each work roll (18,20) and its respective cradle elements (22,24) are initially positioned in readiness for a bite by the work roll into a workpiece being fed between the roll assemblies, said work roll and cradle element roll together through an arc of movement in which a bite into the workpiece is taken, and said work roll and cradle element are then caused to precess around the support roll (14,16) to their initial positions relative to said support rolls.

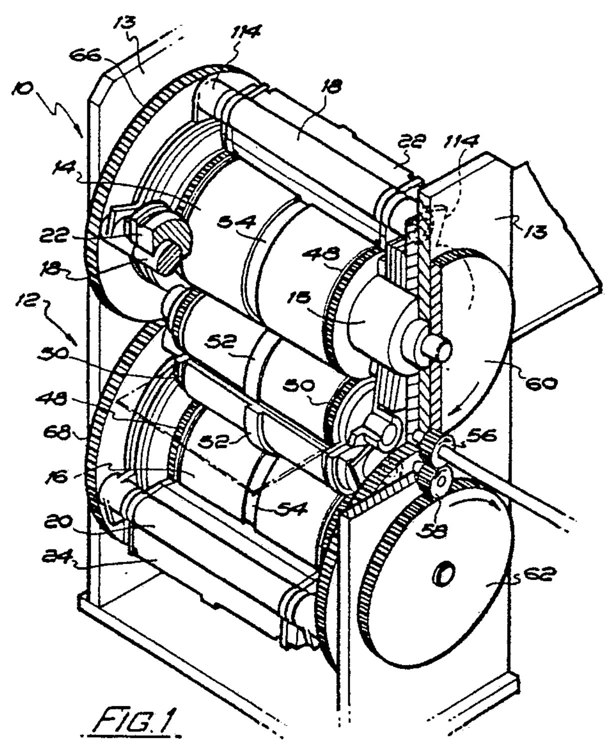

FIG.1

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Rolling mill apparatus.

The invention relates to rolling mill apparatus and in particular to such apparatus capable of relatively high reductions.

The design of a rolling mill stand is dictated by various basic considerations. For example, the rolling loads are proportional to the width of the rolled product. Consequently, in the case of wide flat products, very high loads are transmitted through the rolls.

A conflicting design consideration is that for the most efficient reduction of the rolled product the minimum work roll diameters must be used, and even if the work rolls are supported by back-up rolls the intensity of pressure between the work rolls and back-up rolls acting through virtually line contact, can be very high indeed and can cause spalling at the interfaces. This can to some extent be countered by employing hard roll materials and smooth roll surfaces but the use of very hard roll materials introduces the further complication that such materials are highly susceptible to rapid surface deterioration due to thermal shock.

In the result, the design of a rolling mill stand has invariably been a compromise between using the smallest possible diameter work rolls in the interests of achieving the most efficient rolling, and the need to increase work roll diameters in order to satisfy entry and strength requirements. This compromise has often resulted in undesirably high rolling loads and driving torques, necessitating very large and consequently expensive equipment.

Various attempts have been made to produce rolling mill apparatus capable of relatively high reductions and requiring only a relatively low power input whilst also being capable of operating at relatively low speeds without incurring critical thermal stresses in the rolls. Amongst these are so-called planetary mills in which a plurality of relatively small work rolls follow each other in succession in planetary fashion around respective back-up rolls, the upper and lower sets of work rolls moving in synchronism with each other, the arrangement being such that as a workpiece progresses through the mill, the plurality of relatively small work rolls reduce the workpiece by very small increments per bite. This type of mill runs very fast and the rolling load is relatively small because of the fact that the rolls reduce the workpiece by very small increments per bite. However, such light working loads and high speeds cause excessive noise and vibration and have been found to result in serious maintenance problems. In addition, the quality of the rolled product has been low. For example, because the rolls reduce the workpiece by very small increments per bite, the top surface of the workpiece is worked in a way which causes the edges to become concave. In order to combat this tendency the edges of slabs have needed to be severely rounded before rolling and this has been a nuisance.

The use of relatively small diameter rolls at relatively high speeds (that is to say in the region of 3,000 r.p.m.) causes critical conditions. For example, the presence of scale between the work rolls and back up rolls causes great difficulty and when the scale becomes rolled into the surfaces of the workpiece the surfaces can become so badly affected as to result in the workpiece having to be rejected.

The invention as claimed is intended to provide a remedy. It solves the problem of how to design a rolling mill capable of relatively high reductions.

The main advantage offered by the invention is that it provides a rolling mill apparatus capable of relatively high reductions but requiring only a relatively low power input. A further advantage is that the apparatus is capable of operating at relatively low speeds in order to at least alleviate the problems of excessive noise and vibration referred to above.

One way of carrying out the invention is described in detail below with reference to drawings which illustrate, by way of example only, specific embodiments, of which:-

Figure 1 is a schematic partly broken away perspective view of rolling mill apparatus embodying the invention,

Figure 2 is a diagrammatic end view thereof,

Figure 3 is a sectional view on the line 3-3 in Figure 2,

Figure 4 is a sectional view on the line 4-4 in Figure 3,

Figure 5 is an exploded view which will be referred to,

Figure 6 is a semi-diagrammatic sectional view on the line 6-6 in Figure 3 which illustrates a spring return mechanism forming a part of the apparatus, and

Figures 7 to 12 are views which will presently be referred to when describing possible modifications.

Referring now to Figures I to 6 of the drawings, the rolling mill apparatus there illustrated includes a pair of roll assemblies, generally indicated 10 and 12, mounted for rotation in the directions indicated by the arrows in Figure 2, in a roll stand the upstanding side frame members of which are designated 13,13. The roll assemblies are constituted by respective rotatably mounted support rolls 14 and 16 and a plurality of work rolls 18 and 20, the work rolls being backed by respective cradle elements 22 and 24 of segmental shape and bearing against the respective support rolls. The arrangement is such that as the roll assemblies rotate, the work rolls are brought in turn, in oppositely disposed pairs, into engagement with the workpiece, only the exposed portions of the work rolls being in use at any time and thus subjected to wear. As shown in Figure 5 the plurality of work rolls are capable of adjustment relative to their respective cradle elements so that, after a period of use of the apparatus, previously unused segments of the rolls can be brought into use. This is possible by virtue of the fact that face keys 28 are permanently located in respective cradle extensions 26, so that the work rolls can be rotatably adjusted to bring different diametrical end slots 30 formed across the end faces of the rolls into alignment with said keys. However, it should perhaps be pointed out that the work rolls are rotatably driven, as they engage the workpiece, by frictional contact between their hidden surfaces and the internal surfaces of their associated cradle elements. The keys and end slots 28,30 act merely as locators.

In the illustrated example, four work rolls are spaced apart around each support roll, cradle elements associated with the work rolls being located in contact with their respective support rolls by respective pairs of carrier links 32,32, 34,34, 36,36, 38,38 and 40,40 42,42, 44,44, and 46,46. The cradle extensions are formed with stub shaft portions 112 which are located in respective journal portions 14 carried by the pairs of links. The pairs of links are mounted for limited rotation, as will presently be described, on the cylindrical surfaces of respective shaft extensions 15,15 carried by the support rolls 14 and 16. The cradle elements are maintained in non-slip engagement with their support rolls by means of respective gear and gear segments 48,50 (see Figure 1 and 3). The work rolls and their respective cradle elements are longitudinally located relative to the support rolls by means of respective peripheral enlargements 52 which are formed on said cradle elements, the enlargements engaging complementary grooves 54 in the surfaces of the support rolls.

The roll assemblies, each of which comprises a support roll, four work rolls and their associated cradle elements, are driven bodily by means of a pair of input pinions 56 and 58 which engage respective driven gears 60 and 62, said driven gears being keyed to the shaft extensions 15,15 of the support rolls 14 and 16.

Means are provided whereby each work roll and cradle combination rotates relative to the respective support roll during the bite sequence, in other words to ensure that, as the roll assemblies rotate, each work roll and its respective cradle element are initially positioned in readiness for a bite by the work roll into a workpiece being fed between the roll assemblies, said work roll and cradle element roll together through an arc of movement in which a bite into the workpiece is taken, and said work roll and cradle element are then returned to their initial positions relative to their support rolls, (hence the requirement for limited rotational movement of the pairs of links relative to the support rolls). These means are constituted by the gear and gear segment drives 48 and 50 between the support rolls and their respective cradle elements and by spring return mechanisms, generally indicated 64 in Figure 2, whereby the work rolls and cradle elements are returned to their initial positions relative to the support rolls. The spring return mechanism 64 is shown in rather more detail in Figure 6 where it can be seen that the pairs of links which carry the cradle elements are rotatably mounted on the shaft extensions by means of respective sets of rollers 90. The portions of the links which surround the shaft extensions concerned are provided with respective part-circular apertures 92 and 94 which accommodate respective tension springs 96 and a common stop member 98 which extends longitudinally of the shaft extension. Each tension spring 96 extends as shown, along the aperture 92 concerned, from a common anchorage member 100, upstanding from the shaft extension, to a pivot pin 102 connected to the respective link. The stop member 98 carries a resilient cushion element 104 on one side face, as shown.

The arrangement is such that the pairs of links are capable of limited rotation on the respective shaft extensions of the support rolls as their respective work rolls pass through the roll bite zone. As drawn in Figure 6, the operative pair of work rolls are just entering the roll bite zone. The respective springs 96 are thus at their shortest length and the respective links are in their initial positions relative to their support rolls, abutment surfaces 106 of the links being shown in abutment with the cushion elements 104 of the stop members 98. It will be understood that as the operative pair of work rolls have passed through the relatively small angular distance in which they are shown to have been rotated whilst passing through the roll bite zone, the support rolls will have been rotated through a relatively greater angular distance so that the springs 96 will have been fully extended as shown in chain-dotted lines.

In addition, means are provided for reducing the orbiting movement of each oppositely disposed pair of work rolls as they enter the roll bite zone so that the continued rotation of the support roll causes the work rolls and cradle elements to be rotated in such a way that the workpiece is drawn between the roll assemblies. These means are constituted by stop mechanism for latching the movement of the respective work rolls, in turn, to slower moving parts as said work rolls pass through the roll bite zone. The zones in which the stop mechanism is engaged and disengaged are indicated in Figure 2. The stop mechanism referred to is illustrated in Figures 3 and 4 and includes pairs of reaction members 66,66 and 68,68 (constituted by further gear pairs) which flank the roll assemblies, as shown, but which are driven (by gearing not shown) at a somewhat slower speed than the roll assemblies. The reaction members each carry a plurality of spring loaded stop members 70 formed integrally with respective plungers 72 each of which normally projects laterally from a side surface of the respective reaction member. At the commencement of their passage through the roll bite zone, the pairs of plungers at the opposite ends of the roll assemblies contact tapered ramps 74 which force the respective stop members outwards of the reaction members, as shown in Figure 4, against the force of the respective springs 76, and into the path of movement of the journal portions of the pairs of carrier links carrying respective work rolls between them, that is to say a pair of synchronised and oppositely rotating work rolls which are about to enter the roll bite zone. Throughout their movement through the roll bite zone, the pair of work rolls are thus constrained to move at the speed of movement of the respective pair of reaction members. It will be seen from Figure 2, however, that the unimpeded forward movement of the support rolls 14 and 16 thereby impart a positive rotation to the respective work rolls through the arcs of movement subtended by the respective cradle elements. In Figure 2 there is shown in full lines a pair of oppositely disposed work rolls just entering the roll bite zone and about to be latched to the reaction members by the engagement of the stop mechanism. The subsequent positions in which the pair of work rolls are shown in chain-dotted lines during their passage through the roll bite zone clearly indicate the manner in which their associated cradle elements are rotated by the respective support rolls through the arcs of movement subtended by the respective cradle elements. This has the result, as previously stated, that during the intermittent action of the pairs of work rolls the workpiece is drawn between the roll assemblies, with the advantage that little or no direct force is required to feed the workpiece between the roll assemblies. At the end of their movement through the roll bite zone, the work rolls are once again unlatched from the reaction members when the respective plungers 72 run off the ends of the ramps 74 so that the stop members are retracted by their respective springs 76. (In Figure 2 it will be seen that the oppositely disposed pair of work rolls and cradle elements just referrred to appear to have returned to their initial positions relative to the support rolls in less than one quarter of a revolution of each roll assembly. However, it will be understood that this may not be the case and that the angular extent of the 'return movement' zone is not at all critical. The only essential requirement is that each pair of work rolls be returned to their initial positions before they next enter the roll bite zone). The much greater angular movement $\underline{A}$ of the remaining pairs of work rolls during the passage of an operative pair of work rolls through the roll bite zone is also shown in chain-dotted lines in Figure 2.

Thus there is provided rolling mill apparatus capable of relatively high reductions whilst requiring only a relatively low power input. For example, it is thought that a rolling mill embodying the invention will be capable of reducing a slab of steel in one continuous pass to one tenth of its ingoing thickness and possibly less, whereas in a conventional mill the maximum reduction per pass is usually in the region of 30% to 50%. It follows that a rolling mill embodying the invention can do the work of five conventional stands operating in line and the power requirement will clearly be far less. The apparatus is also capable of operating at relatively low speeds and because the work rolls are exposed to the product for relatively short periods of time there is no risk of critical thermal stresses in the rolls. This makes the apparatus particularly advantageous when used in line with a thin continuous slab caster. Although the work rolls are of relatively small diameter they are very strong by virtue of the fact that they are backed by the respective cradle elements along their entire length. The load which is transmitted from the work rolls to the support rolls is by line contact between the respective cradle elements and the support rolls but in this arrangement relatively large diameters are in contact (the rolling support radius of the cradle elements being at least twice the work roll radius) and this has the effect of reducing the intensity of pressure at the interfaces. Furthermore, these surfaces through which the rolling load is transmitted never come in contact with the workpiece or with any other surface which has been in contact with the workpiece. Consequently, these surfaces will remain free of scale and can be expected to be preserved in good condition for an extended period of time, especially since they are not subject to thermal shock. The only surfaces which can be expected to wear to any significant extent are the surfaces of the work rolls for the time being in use, and as previously explained the work rolls can be re-adjusted relative to their respective cradle elements and cradle extensions from time to time to bring previously un-used segments into use. If the work rolls are re-ground before being re-fitted in their cradle elements, they can be re-fitted with the use of shims or pressed shell elements so that the roll gap is unchanged.

It will be understood that since the work rolls are fully supported along their entire length and not likely to suffer any significant thermal shock or surface wear they need not be made particularly strong when unsupported. Because of this the possibility exists that they could be made of a ceramic material. Furthermore, because the support rolls and cradle elements do not contact the product and therefore are not subject to thermal shock, higher strength materials without high resistance to thermal shock can by used for these components. Because the support rolls and cradle elements abut together at relatively large radii, and the intensity of pressure between them is thus relatively low, it is possible to achieve higher reductions with relatively small diameter work rolls, this in turn resulting in lower power requirements.

Various modifications may be made. For example, the means provided for reducing the rate of orbiting movement of each work roll as it reaches the roll bite zone may be very different from that already described by way of example and need not necessarily include the spring loaded stop members moveable laterally from the reaction members. Other latching means may be devised. For example, in Figures 7 to 12 there is illustrated a modified arrangement in which each work roll assembly is carried between a pair of substantial carrier plates 78,78 for intermittent motion about the respective support rolls. As best seen in Figure 7, which is similar to Figure 1, in this modified arrangement each roll assembly has a support roll and a plurality of work rolls backed by respective cradle elements as in the original arrangement. However, in this case, although the support rolls are again driven at constant speed by means of the pair of input pinions 56 and 58 which engage the respective driven gears 60 and 62, the input pinions are co-axial with further pinions 80 and 82 in constant mesh with further driven gears 84 and 86 which are connected to adjacent carrier plates 78. As shown, the pinions 80 and 82 are somewhat smaller than the pinions 56 and 58. The further pair of pinions 80 and 82 are capable of being drivably connected to the pair of input pinions 56 and 58 by respective clutches 88,88 which can be engaged and disengaged simultaneously. As illustrated schematically in Figure 8, each clutch 88 is a hydraulically actuated clutch capable of fixedly connecting the associated pinion on the shaft on which the respective input pinion is keyed. When said clutches are disengaged, the pinions 80 and 82 can rotate freely on the shafts on which they are located.

This modified arrangement is such that, in operation of the mill, as the support rolls are driven at constant speed by the pair of input pinions 56 and 58, the work rolls move intermittently but simultaneously around them. The spring return mechanisms 64, as illustrated in Figure 6 but in this case comprising only one such mechanism in each roll assembly, bring them to positions such that, as shown in Figure 9, an opposed pair of work rolls are about to enter the roll bite zone. At this point the clutches are engaged and this causes the gears 60 and 62 and with them the carrier plates 78,78 to be retarded. This reduces the orbiting movement of the work rolls (all of them together in this modified arrangement) so that the continued rotation of the support rolls causes the work rolls and cradle elements to be rotated. As in the previously described embodiment, the workpiece is thereby drawn between the roll assemblies by the operative pair of work rolls. When said operative pair of work rolls emerge from the roll bite zone, the clutches 88,88 will be disengaged so that the gears 84 and 86 are no longer restrained and the spring return mechanism 64 can once again bring the work rolls to their initial starting positions relative to the support rolls, that is to say to positions in which the next opposed pair of work rolls are about to enter the roll bite zone.

It will be understood that although little or no force is required to feed the workpiece between the roll assemblies during a roll bite (and in fact if the gearing is such that the peripheral speed of rotation of each work roll is slightly in excess of the peripheral speed corresponding to the movement of its axis through the roll bite zone the workpiece will actually be drawn into the roll gap) feed rolls, which for the sake of clarity have not been shown in the drawings, are required to maintain the forward motion of the workpiece between the intermittent bites by the work rolls. It will also be understood that, although the work rolls may appear to be relatively widely spaced around the support rolls, the fact that the work rolls move more slowly through the roll bite zone than through the remainder of their orbiting motion around their respective support rolls results in the next following pair of work rolls being brought into contact with the workpiece within a very short space of time following each pair of work rolls having completed a rolling operation. This will be readily understood if reference is made to Figure 2. Nevertheless, if desired, idler rolls could be incorporated in the apparatus to keep the mill under pressure for the instants of time between roll bites by the work rolls. Such idler rolls are shown in chain-dotted lines and indicated

108 in Figure 6.

Various other modifications may be made. For example, the cradle elements need not necessarily have separable extensions as in the embodiment illustrated in Figures 1 to 6. As illustrated in Figures 10 to 12, the cradle elements and their extensions could be fabricated integrally together, the work rolls then being inserted into their nested positions and held in place during rolling by means of removable keeper plates 110. In this way, since the work rolls can be extracted laterally from the cradle elements as shown in chain-dotted lines in Figure 11, the work rolls can very easily be compensated for wear by shimming their seatings within said cradle elements without any major dismantling of the remainder of the apparatus.

Claims

1. Rolling mill apparatus including a pair of roll assemblies (10,12) each constituted by a rotatably mounted support roll (14,16) and a plurality of work rolls (18,20) spaced around said support roll, characterised in that the work rolls are backed by respective cradle elements (22,24), means being provided whereby, as the roll assemblies rotate so that the work rolls and cradle elements orbit the respective axes of the support rolls, each work roll (18,20) and its respective cradle element (22,24) are initially positioned in readiness for a bite by the work roll into a workpiece being fed between the roll assemblies, said work roll and cradle element roll together through an arc of movement in which a bite into the workpiece is taken, and said work roll and cradle element are then caused to precess around the support roll (14,16) to their initial positions relative to said support rolls.

2. Rolling mill apparatus according to claim 1, further characterised in that the means whereby each work roll (18,20) and its respective cradle element (22,24) are initially positioned in readiness for a bite by the work roll into a workpiece being fed between the roll assemblies (10,12), said work roll and cradle element roll together through an arc of movement in which a bite into the workpiece is taken, and said work roll and cradle element are then caused to precess around the support roll (14,16) to their initial positions relative to said support rolls, are constituted by gear and gear segment drives (48,50) between the support rolls (14,16) and the respective cradle elements (22,24), and by spring return mechanisms (64) whereby the work rolls (18,20) and cradle elements (22,24) are returned to their initial positions relative to their respective support rolls (14,16).

3. Rolling mill apparatus according to either one of the preceding claims, further characterised in that means are also provided for reducing the rate of orbiting movement of each work roll (18,20) as it reaches the roll bite zone whereby the continued rotation of the respective support roll (14,16) causes the work roll (18,20) and cradle element (22,24) to be rotated in such a way that the workpiece is drawn between the roll assemblies (10,12) and no direct force is required to feed the workpiece between the roll assemblies.

4. Rolling mill apparatus according to claim 3, further characterised in that the means for reducing the rate of orbiting movement of each work roll (18,20) as it reaches the roll bite zone are constituted by stop mechanism for latching the movement of the respective work rolls (18,20), in turn, to slower moving parts as said work rolls pass through the roll bite zone.

5. Rolling mill apparatus according to claim 4, further characterised in that the stop mechanism includes pairs of reaction members constituted by further gear pairs (66,66 and 68,68) which flank the roll assemblies (10,12) but which are driven at a somewhat slower speed than said roll assemblies, the reaction members each carrying a plurality of spring loaded stop members (70) associated with respective plungers (72) each of which normally projects laterally from a side surface of the respective reaction member, the pairs of plungers (72,72) at the opposite ends of the roll assemblies (10,12) contacting respective ramps (74) at the commencement of their passage through the roll bite zone which force the respective stop members (70) outwards of the reaction members against the force of their respective springs (76) and into the path of movement of portions of carrier links carrying respective work rolls (18,20) between them, that is to say a pair of synchronised and oppositely rotating work rolls which are about to enter the roll bite zone, the pair of work rolls thus being constrained to move at the speed of movement of the respective pair of reaction members through said roll bit zone.

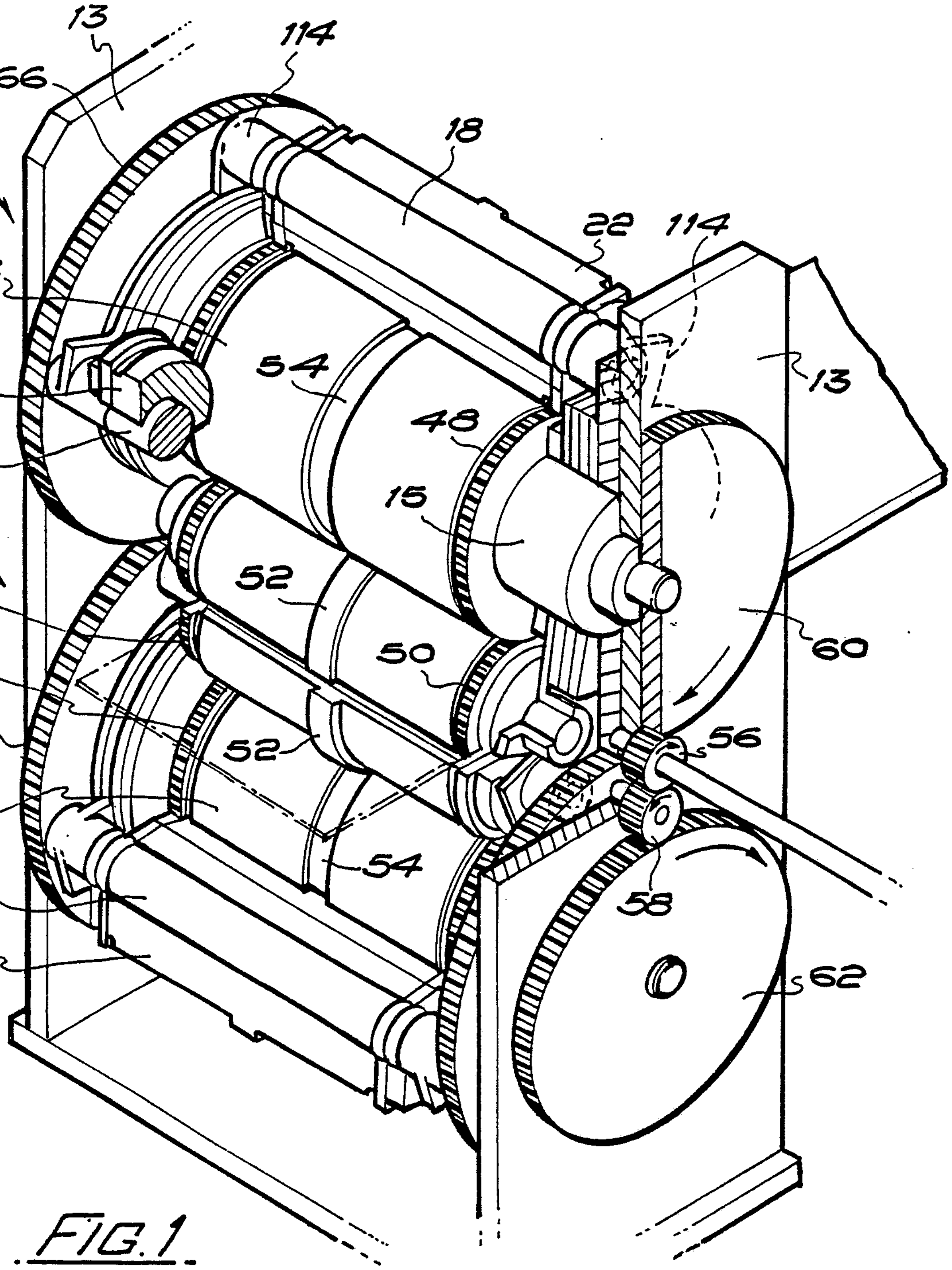
6. Rolling mill apparatus according to any one of the preceding claims, further characterised in that the plurality of work rolls (18,20) are capable of adjustment relative to their respective cradle elements (22,24) so that, after a period of use of the apparatus, previously unused segments of the rolls (18,20) can be brought into use.

7. Rolling mill apparatus according to claim 6, further characterised in that face keys (28) are located in respective cradle extensions (26) so that the work rolls (18,20) can be rotatably adjusted to bring different diametrical end slots (30) formed across the end faces of said rolls into alignment with said keys.

8. Rolling mill apparatus according to any one of the preceding claims, further characterised in that the cradle elements (22,24) associated with the work rolls (18,20) are located in contact with their respective support rolls (14,16) by respective pairs of carrier links (32,32 - 46,46) which are mounted for limited rotation on cylindrical surfaces of respective shaft extensions (15,15) of the support rolls (14,16).

9. Rolling mill apparatus according to any one of the preceding claims, further characterised in that the work rolls (18,20) and their respective cradle elements (22,24) are longitudinally located relative to the support rolls (14,16) by means of respective peripheral enlargements (52) which are formed on said cradle elements, the enlargements engaging complementary grooves (54) in the surfaces of the support rolls (14,16).

10. Rolling mill apparatus according to any one of the preceding claims, further characterised in that idler rolls (108,108) are included to keep the mill under pressure for the instants of time between roll bites by the work rolls (18,20).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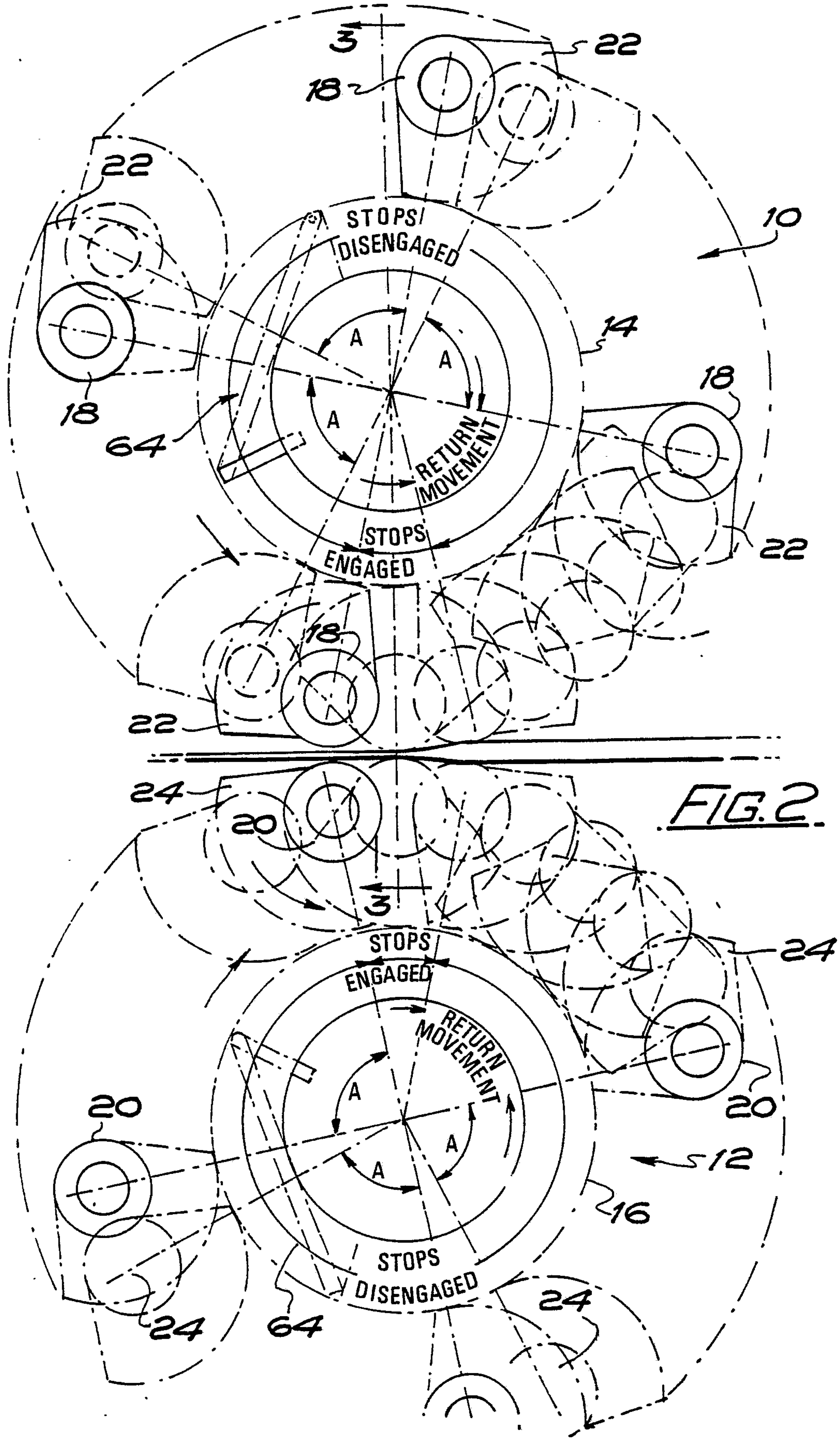
114

FIG.1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22
24
20
3
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FIG. 2

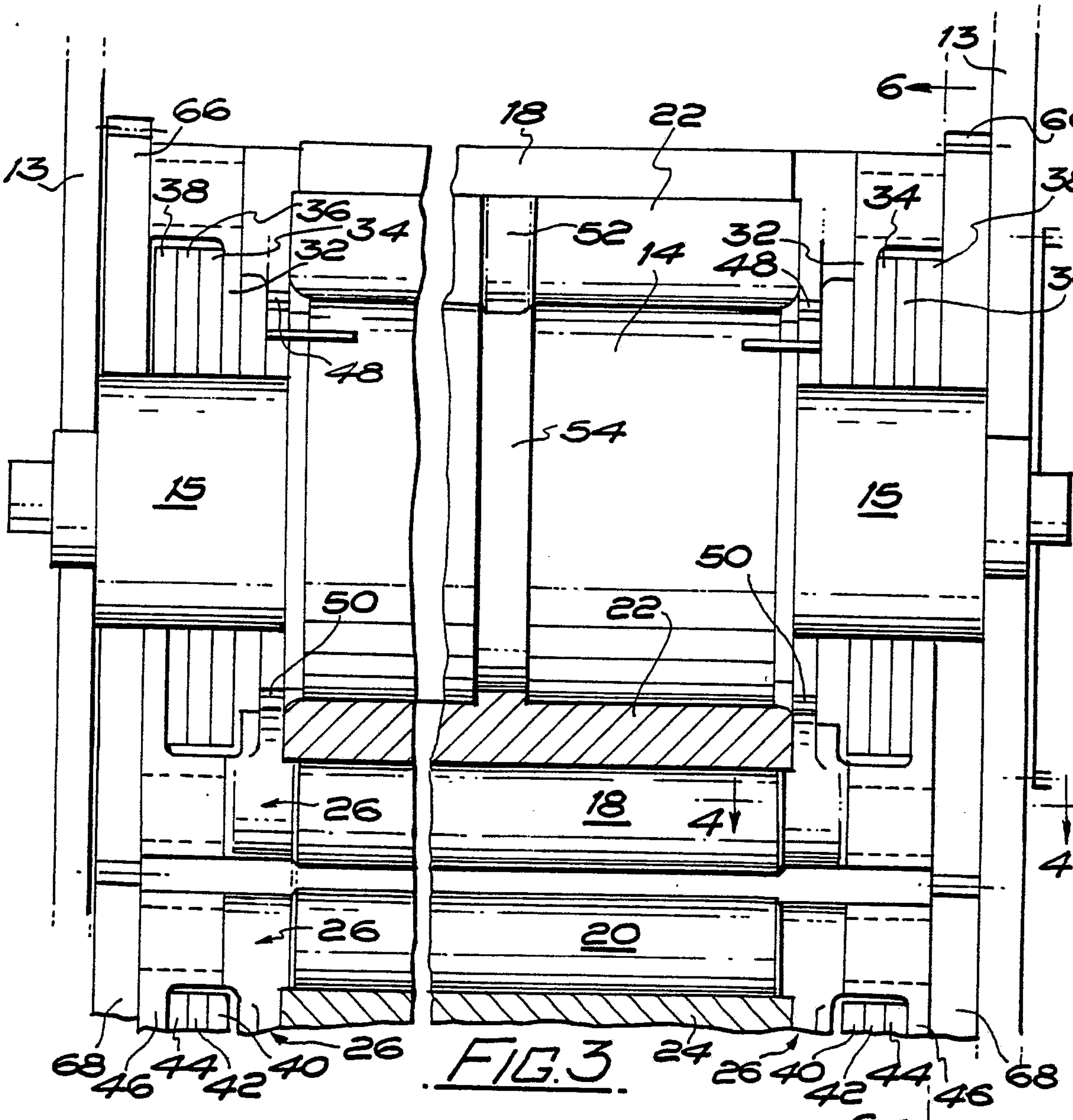
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FIG.3

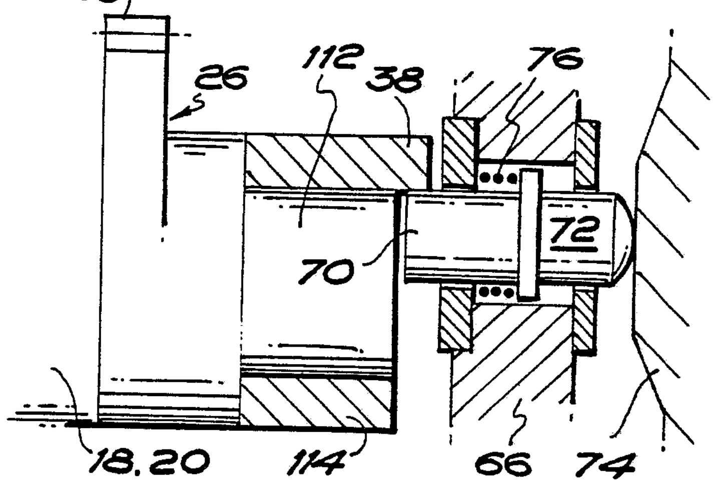
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FIG.4

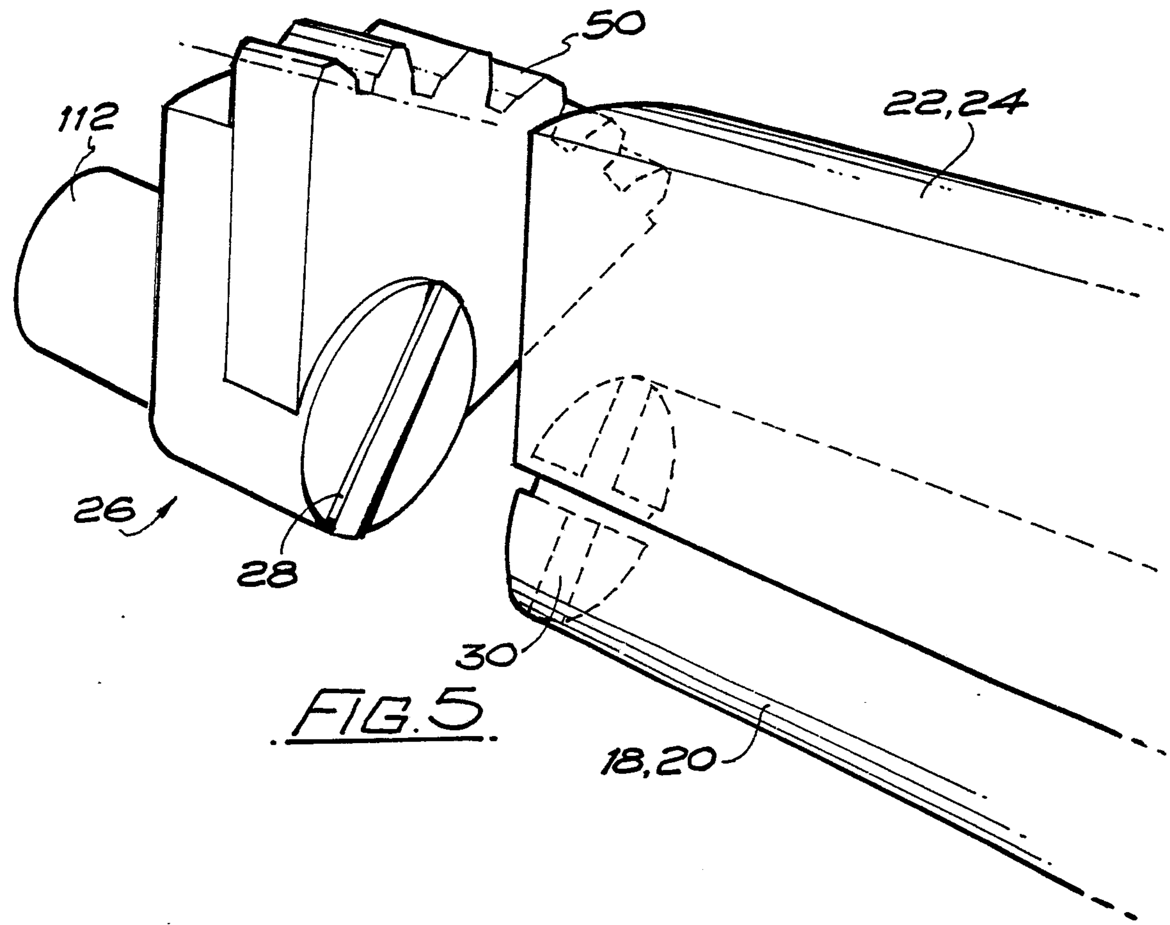

FIG.5

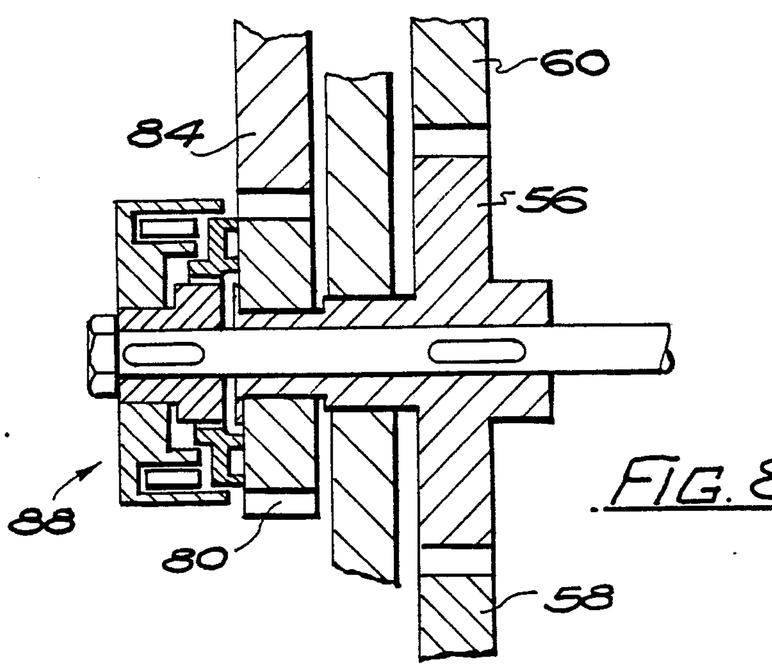

FIG. 8

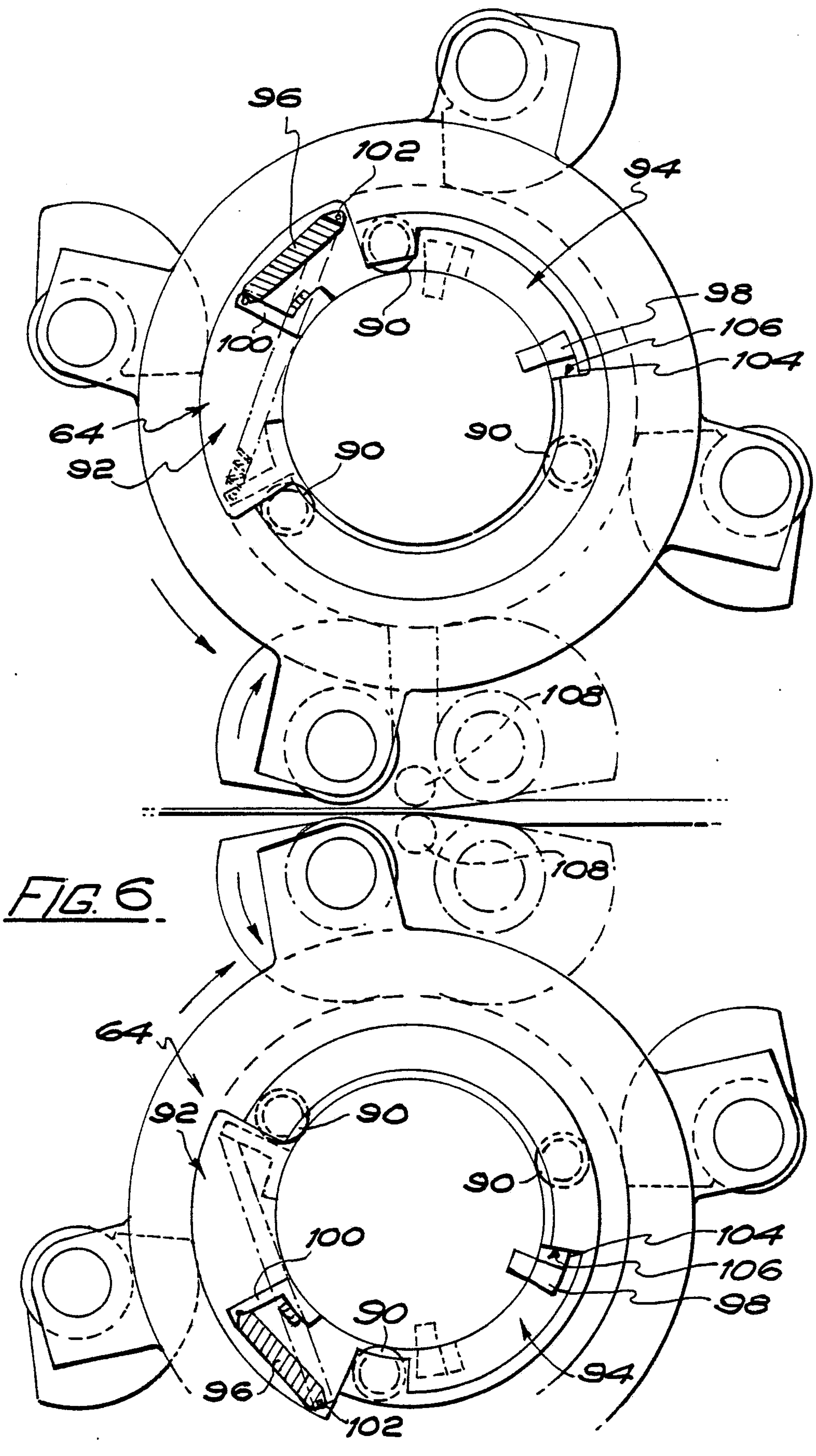
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FIG. 6

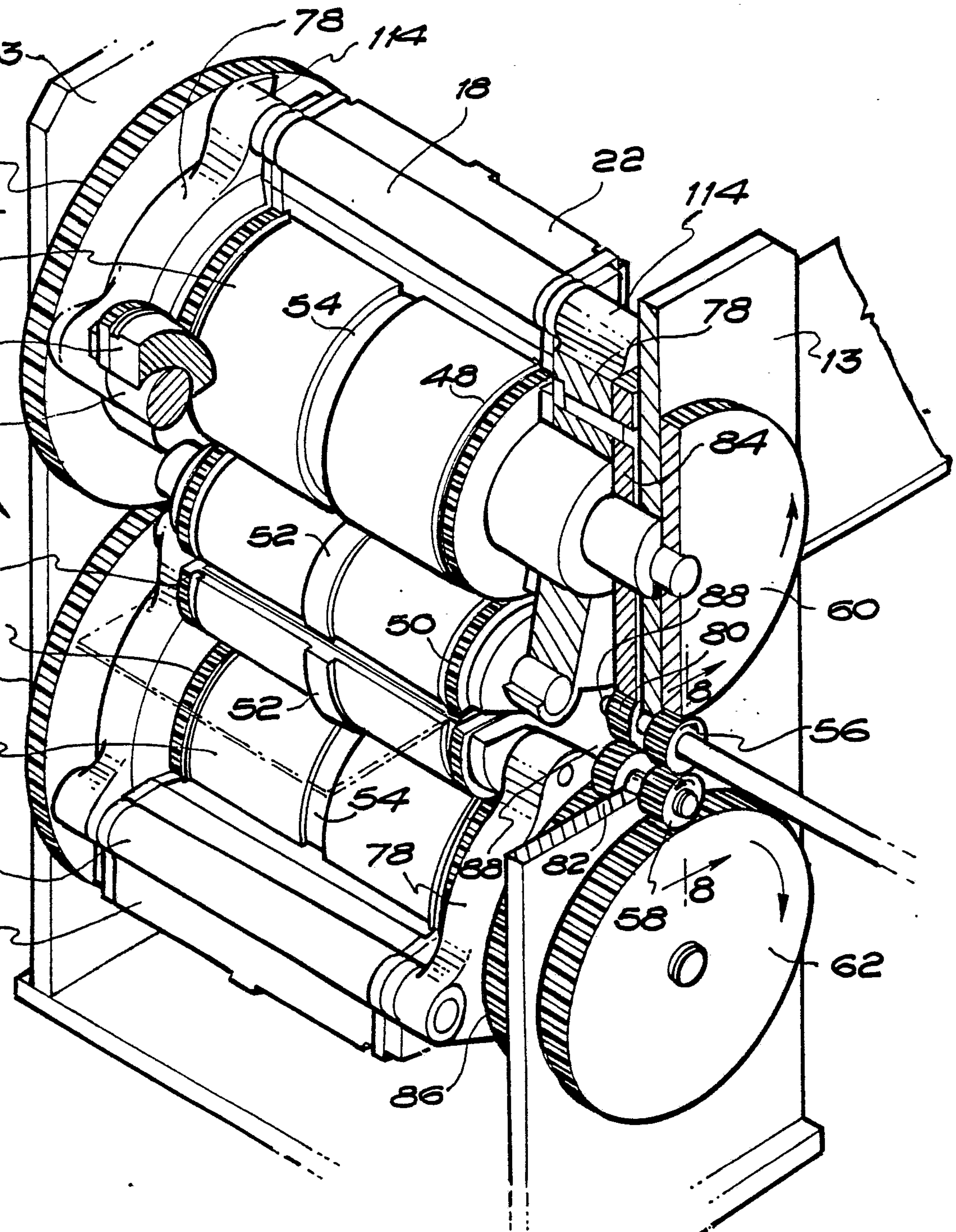
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FIG.7

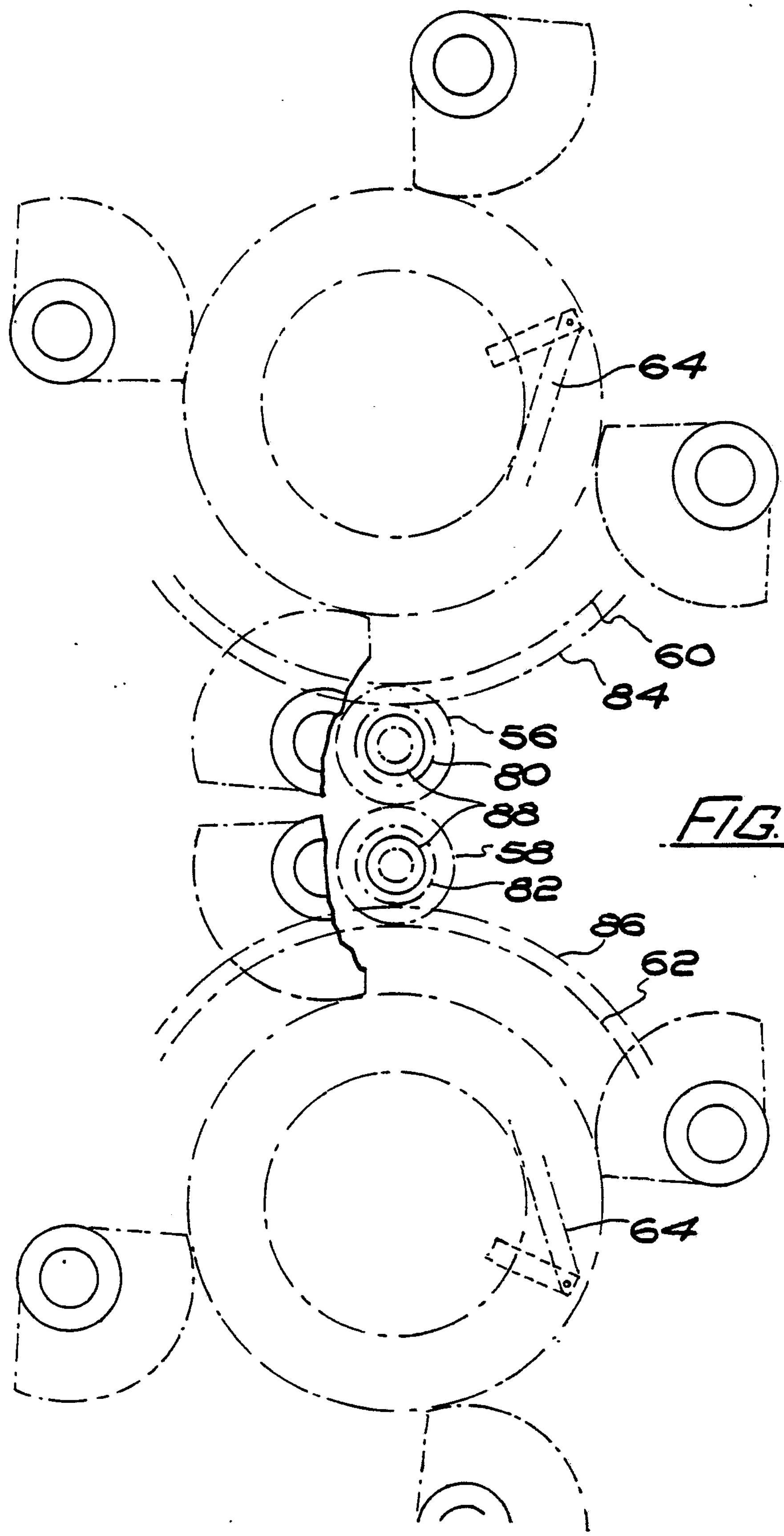

FIG. 9

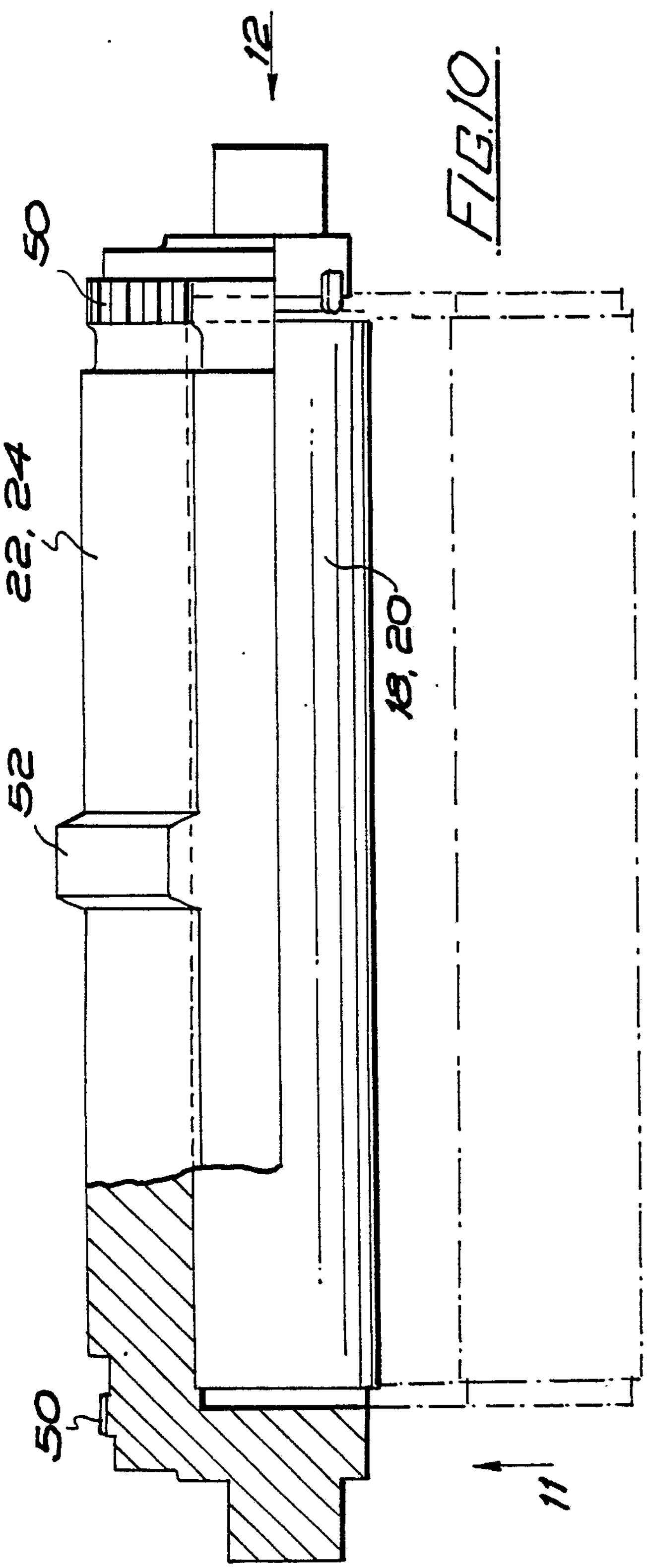

FIG.10

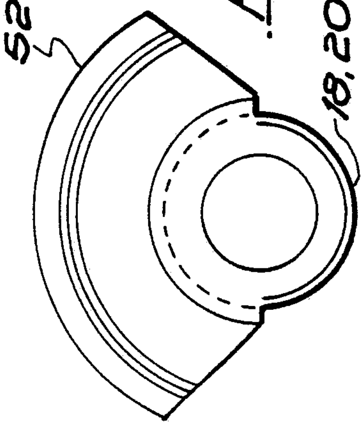

FIG.12

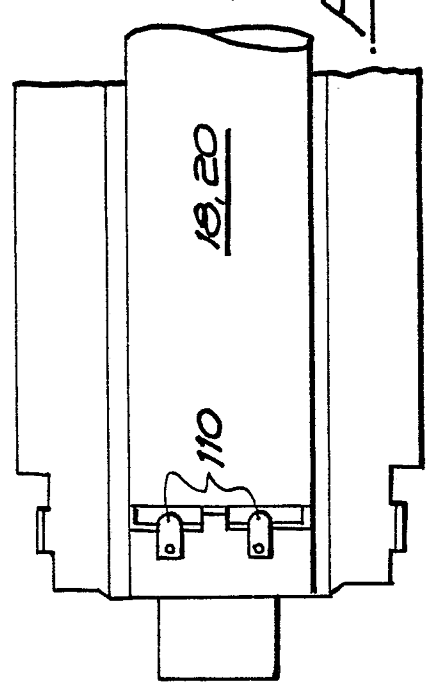

FIG.11