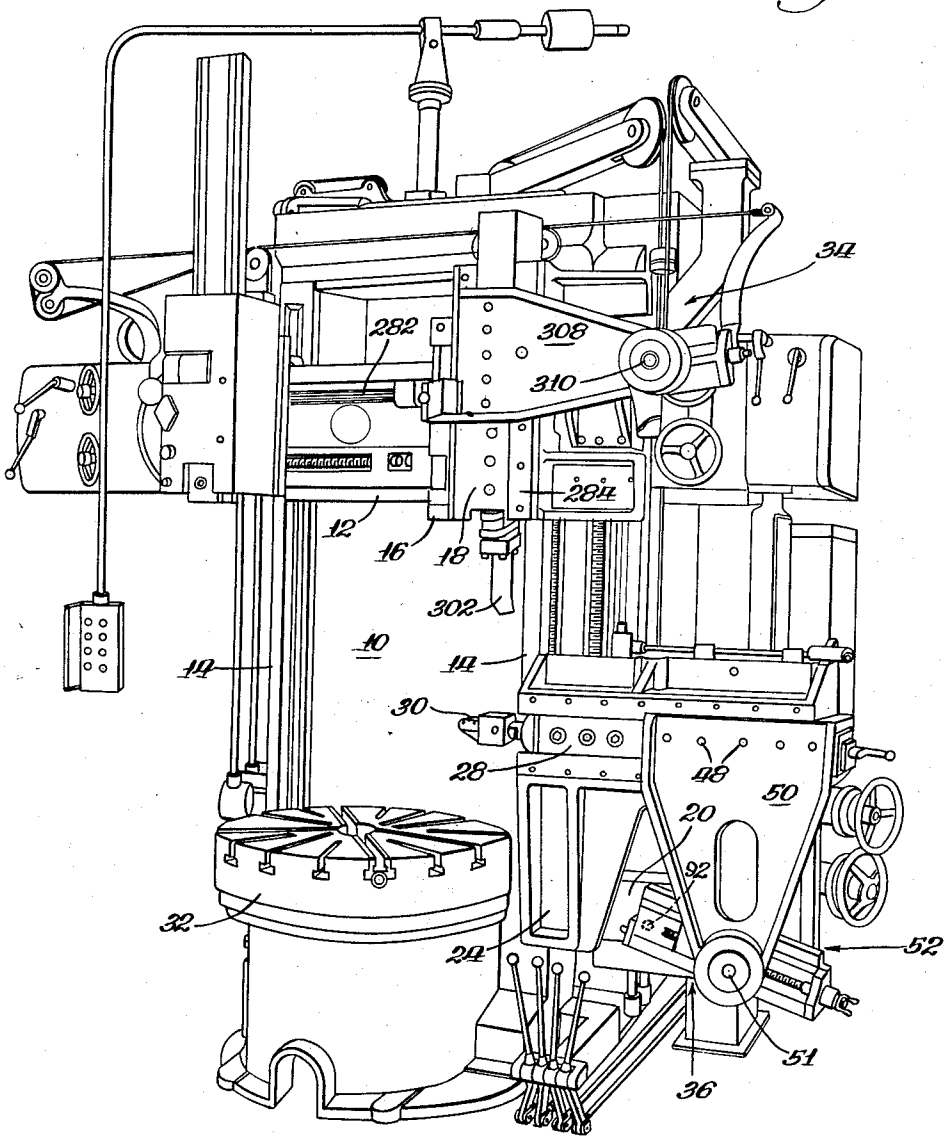
June 28, 1960 T. FOSTER 2,942,509

SPHERICAL TURNING DEVICE

Filed April 24, 1956 6 Sheets-Sheet 1

Fig. 1.



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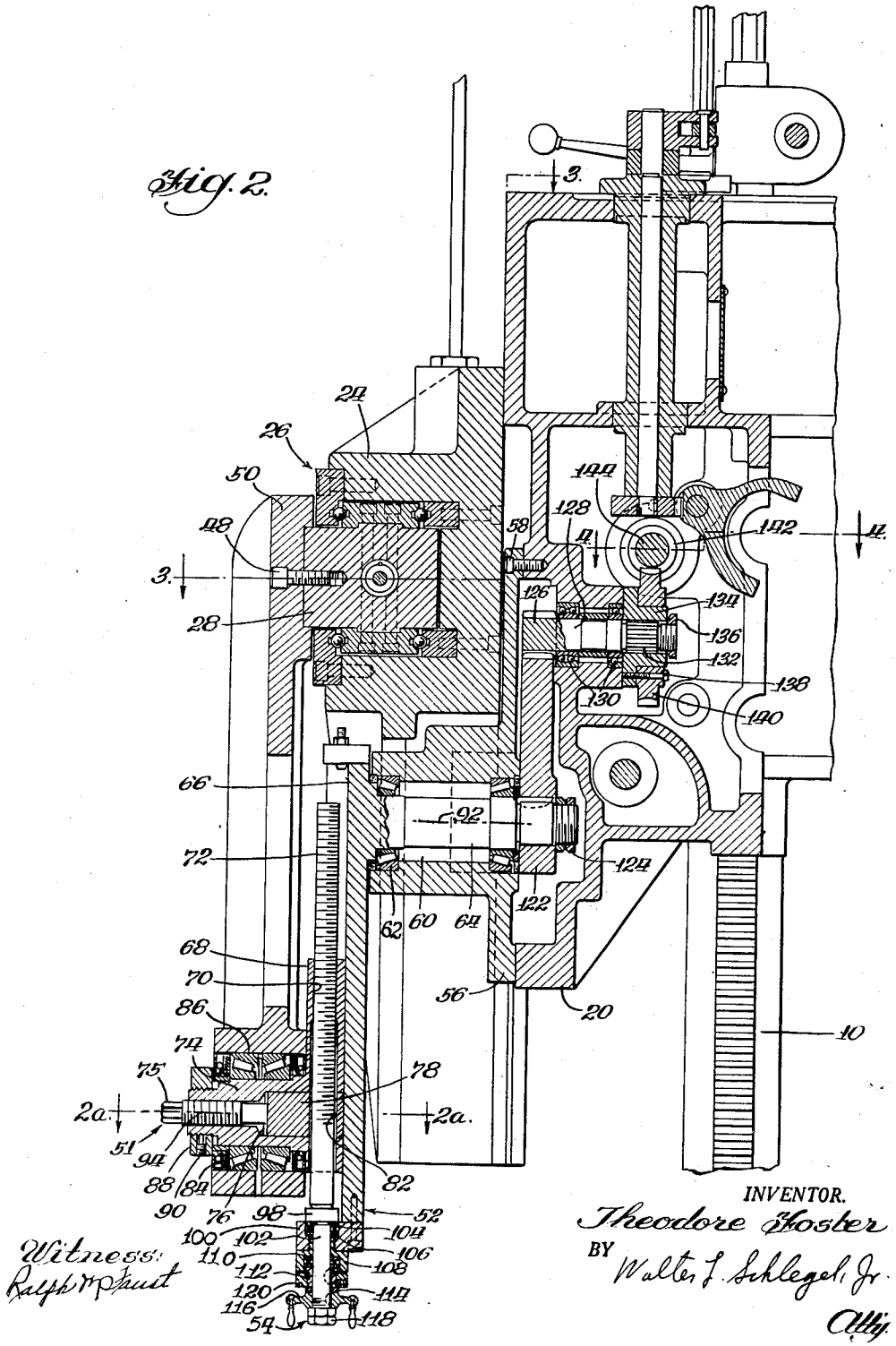
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SPHERICAL TURNING DEVICE

Filed April 24, 1956 6 Sheets-Sheet 2

Fig. 2.



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SPHERICAL TURNING DEVICE

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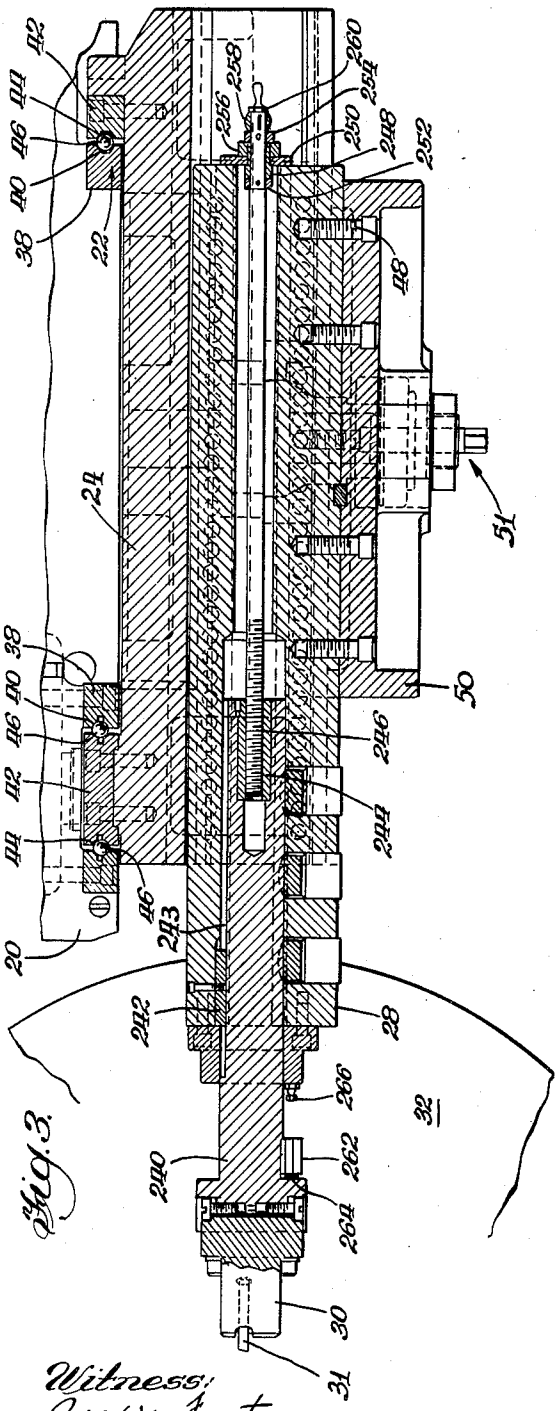


Fig. 3.

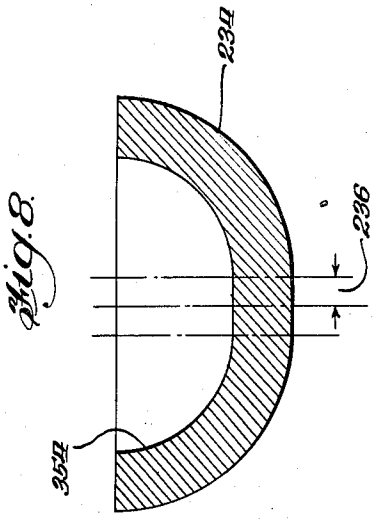


Fig. 8.

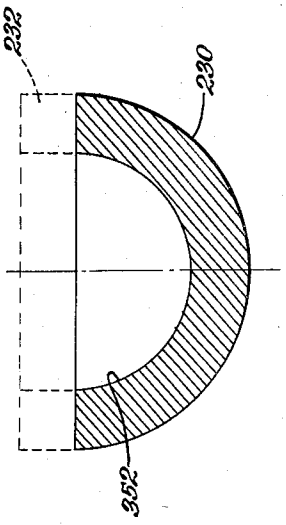


Fig. 7.

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June 28, 1960 T. FOSTER 2,942,509

SPHERICAL TURNING DEVICE

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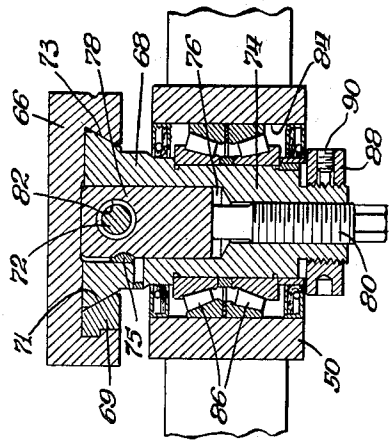


Fig. 2a.

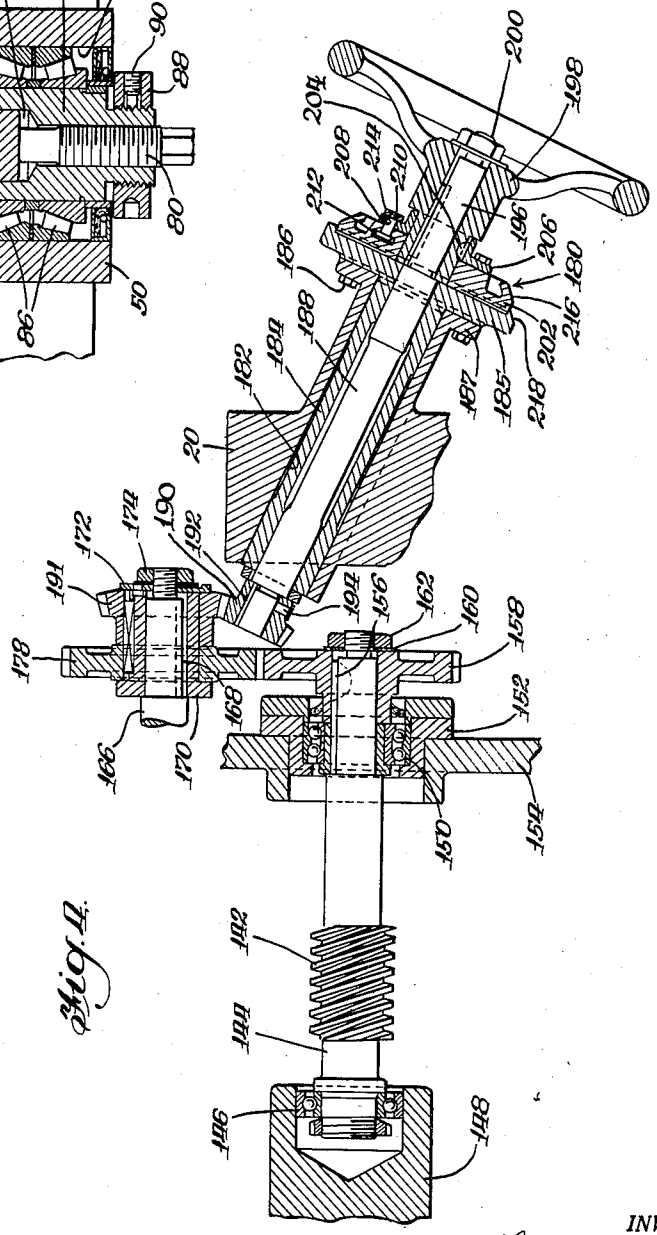


Fig. 2.

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SPHERICAL TURNING DEVICE

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Fig. 5.

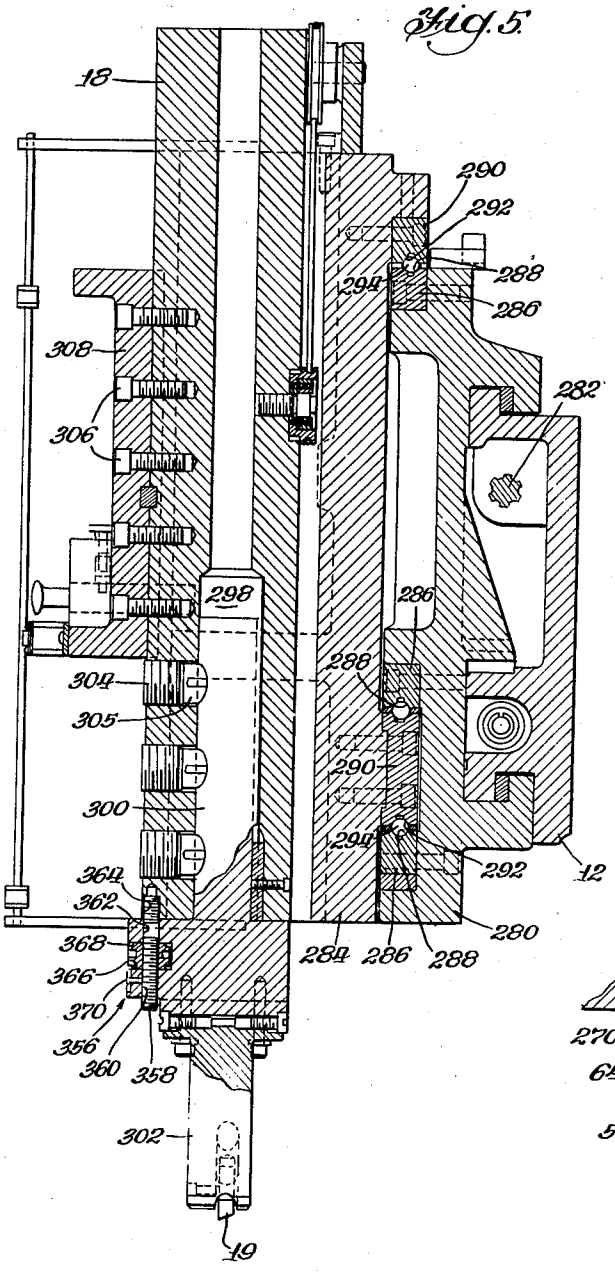


Fig. 9.

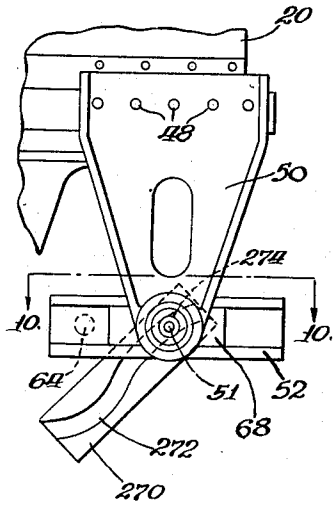
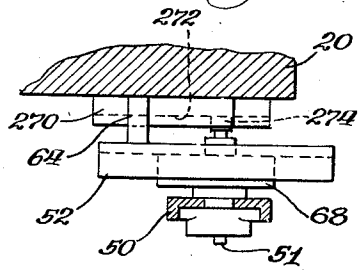


Fig. 10.



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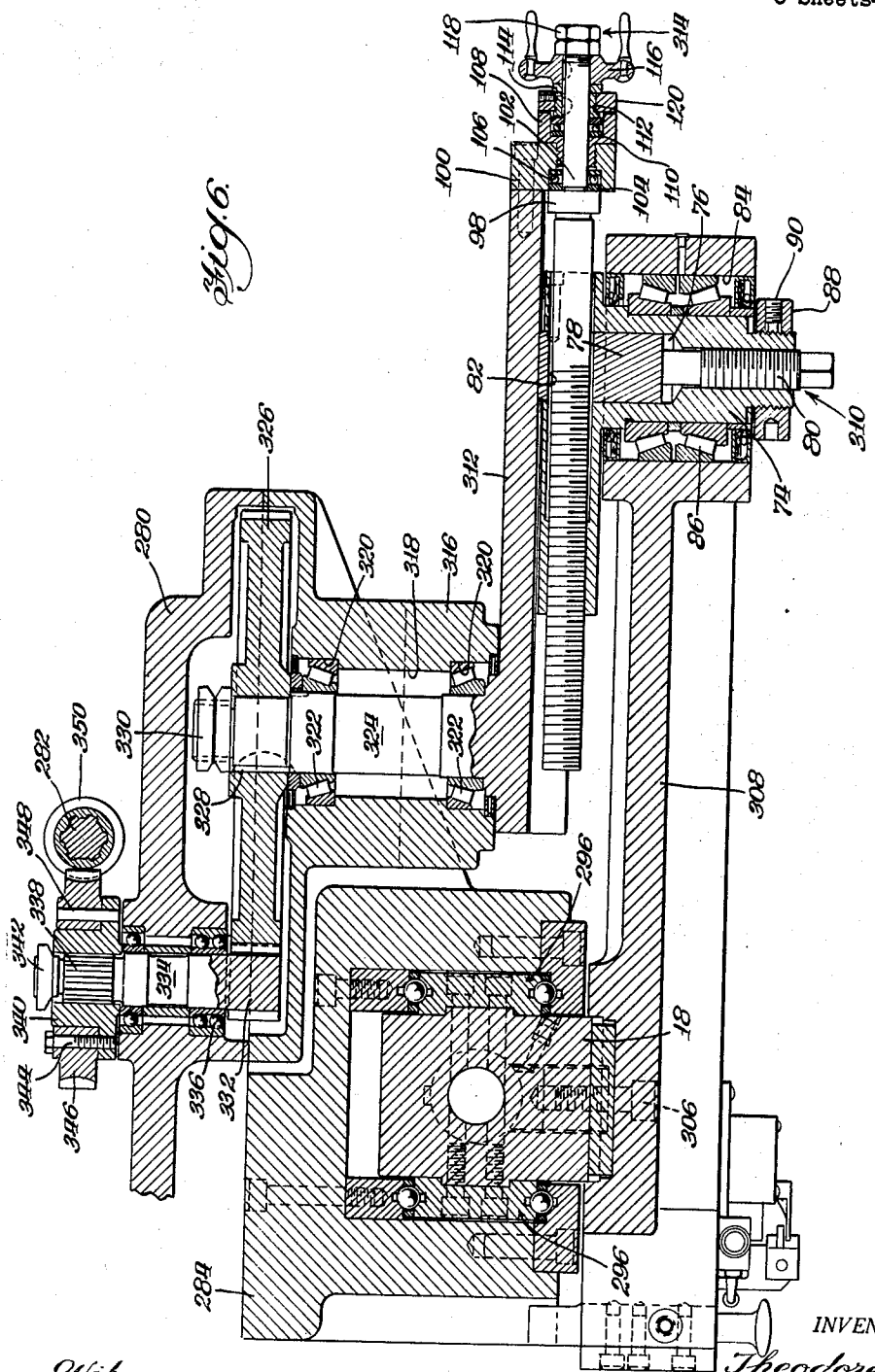
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SPHERICAL TURNING DEVICE

Filed April 24, 1956 6 Sheets-Sheet 6

Fig. 6.



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United States Patent Office 2,942,509 Patented June 28, 1960

2,942,509

SPHERICAL TURNING DEVICE

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Filed Apr. 24, 1956, Ser. No. 580,197

3 Claims. (Cl. 82—11)

This invention relates to vertical boring mills and particularly to novel tool motion control means therefor. It is a specific object of this invention to provide an attachment for a vertical boring mill by means of which internal or external spherical turning of a work piece may be accomplished.

Another object of the invention is to provide an attachment for a vertical boring mill adapted to accommodate offset internal or external spherical turning.

Still another object is to provide an attachment for a vertical boring mill, the attachment not only being capable of internal or external spherical turning but also adaptable for internal or external contouring.

Other objects and advantages will be apparent from an examination of the following specification and accompanying drawings, in which:

Figure 1 is a front perspective view of a vertical boring mill to which the spherical turning attachment has been adapted;

Figure 2 is a side view of the side head and external spherical turning device, with portions of the structure broken away to illustrate the construction thereof;

Figure 2*a* is a sectional view taken at the line 2*a*—2*a* of Figure 2;

Figure 3 is a transverse section taken at line 3—3 of Figure 2 and illustrating the side head ram construction;

Figure 4 is a transverse section taken at line 4—4 of Figure 2 showing the manual adjustment transmission means;

Figure 5 is a vertical section taken at the center line of the ram and tool of the internal spherical turning device as it would appear looking toward the left in Figure 1;

Figure 6 is a transverse sectional view illustrating the internal construction of and driving means for the internal spherical turning device;

Figures 7 and 8 are sectional views of typical contours obtainable by use of the present invention, and

Figure 9 is a front elevational view and Figure 10 is a fragmentary sectional view, taken at line 10—10 of Figure 9, of an embodiment of the device adapted for contour turning.

It should be noted that to clarify the figures, the radius turning arm is shown partially rotated in Figure 1, whereas in Figure 2 the arm has been shown in the vertical position.

Referring to the drawings and particularly to Figure 1, the vertical boring mill comprises generally a column portion 10 on which is mounted a horizontal rail 12, the rail being movable up and down on ways 14 provided on the column. A saddle 16 is movable in a generally horizontal direction across the rail, and the rail is provided wth horizontal ways to facilitate this movement. Carried by the saddle 16 for horizontal movement relative thereto is an auxiliary slide 284, which will be described in detail hereinafter. A ram 18 carrying a tool holder 302 and thereby a tool 19 (Figure 5) is mounted for vertical movement in the auxiliary slide.

Also movable vertically on the column ways is a side head saddle 20 which is provided with ways 22 (Figure 3) adapted to carry for vertical motion therealong an auxiliary slide 24. The auxiliary slide 24 in turn is provided with horizontally disposed ways 26 (Figure 2) adapted to carry a side head ram 28, to which is secured a tool holder 30, the ram being movable radially toward or away from a work piece carrying table 32 which, with the work piece (not shown), is rotatable about a vertically disposed axis. The above described parts are well known to those skilled in the boring mill art and are, therefore, not described in detail, except as they have been modified to specifically relate to the novel spherical turning attachments and the driving means therefor.

An internal turning attachment, generally indicated at 34, is carried by the rail 12 and an external turning attachment, generally indicated at 36, is carried by the side head saddle 20.

Describing first the external turning attachment and the driving arrangement therefor, it is seen (Figure 3) that the ways 22 comprise a plurality of raceways 38 secured to the side head saddle and having V-grooves 40 therein. Secured to the auxiliary slide 24 are a plurality of raceways 42 having V-grooves 44 therein which, with the respective V-grooves 40, provide a bearing track accommodating a plurality of balls 46. The side head ram 28 moves horizontally in the auxiliary slide 24 and the ways 26 (Figure 2) comprise ball bearing V-tracks similar to those utilized for ways 22. Secured by means of a plurality of cap screws 48 to the side head ram for movement therewith is a depending bracket 50. Pivotally secured as at 51 to the lower end of the bracket 50 is a radius turning arm indicated generally at 52. The radius turning arm is additionally pivoted (Figure 2) to the side head saddle 20 and driven therefrom in a manner to be explained hereinafter.

As more clearly illustrated in Figure 1, it will be seen that, as the radius turning arm 52 is caused to rotate on an axis 92 from a horizontal position in a clockwise direction toward a vertical position, the pivot point 51 will move in an arcuate path, and inasmuch as the auxiliary slide 24 is free to move downward and the side head ram 28 is free to move horizontally, the depending bracket 50 and the side head ram will move in the same arcuate path as the pivot point 51. If at this time a work piece were mounted on the table and rotating therewith, the tool 31 (Figure 3) carried in the tool holder 30, would form an external spherical contour on the work piece.

The detailed structure of the pivot 51, the radius turning arm 52, the radius adjusting mechanism generally indicated at 54, and the power transmission means for driving the radius turning arm are best illustrated in Figures 2 and 2*a*.

Referring now to Figures 2 and 2*a*, it is seen that the side head saddle 20 is provided with a bearing housing 56 (Figure 2) which is secured to the side head saddle preferably by a plurality of cap screws 58. The housing 56 is provided with a horizontally disposed opening 60 counterbored at each end to receive antifriction bearings 62. Mounted for rotation in the bearings 62 is a stud shaft 64 which may be secured to or formed integral with the body portion 66 of the radius turning arm 52. A radius adjusting slide 68 is dovetailed in the arm 52 and is positioned for sliding movement therealong by means of a tapered gib key 69 (Figure 2*a*). The slide 68 is provided internally thereof with a threaded opening 70 which operatively receives adjusting screw 72. A horizontally projecting boss 74 is formed integrally with the adjusting slide 68 and has an opening 76 therethrough adapted to receive at its large diameter inner end a clamping block 78 and at its smaller diameter outer end a clamping screw 80. The clamping block 78 is provided with an opening 82 which is aligned with the opening 70

and surrounds, with clearance, the adjusting screw **72**. The clamping screw **80** is threaded into the boss **74** and projects outwardly of the boss to afford wrench engagement means **75** whereby the screw may be tightened down on the clamping block. Inasmuch as the block **78** cannot move due to its contact with the portion **66** of arm **52**, the slide **68** is forced into clamping engagement against the surfaces **71** and **73** and is restrained from longitudinal movement relative to the arm **52**. A key **75** is provided to prevent rotation of the block **78**. The boss **74** is received within opening **84** in the depending bracket **50** and the boss and bracket are pivotally associated with each other by means of antifriction bearings **86**, the inner races of which are mounted on the boss **74** and the outer races of which are received within the opening **84**. A locking nut **88**, which is held in position by means of a set screw **90**, is utilized to maintain the assembled relationship of the slide and bracket.

The radius of the arc through which the tool moves is determined by and is equal to the distance between the axis **92** of the stud shaft **64** and the axis **94** of the boss **74**. The distance between axis **92** and axis **94** may be varied by means of the radius adjusting assembly generally indicated at **54**. The radius adjusting assembly comprises the adjusting screw **72** which, as has been explained previously, is threadably received within the slide **68**. The adjusting screw **72** is provided with a stop collar **98** (Figure 2) which may be formed integrally with the screw or alternately may be made as a separate piece and secured to the screw by means of a pin or set screw. The collar **98** abuts thrust bearing **104** located in end wall **100** of the arm, and a smaller diameter portion **102** of the screw, which extends below the arm, is rotatably supported in sleeve **108**. The bearing **104** is a thrust bearing seated against a shoulder **106** in the end wall and prevents downward movement of the adjusting screw. Successively received over the end portion **102** of the screw are a sleeve **108** carrying a thrust bearing **110**, a bushing **112**, a spacer collar **114**, an adjusting handle **116** and a pair of lock nuts **118**. As seen in Figure 2, tightening the lock nuts **118** will clamp the handle and collar against the thrust bearing **110** and the stop collar against the bearing **104** so that the entire assembly may be rotated as a unit due to the antifriction rolling action of the thrust bearings. Mounted on the bushing **112** and secured thereto for rotation therewith is a dial indicator **120** which is provided with graduated markings (not shown) indicative of the linear movement of the slide which occurs as the adjusting screw is rotated by means of the handle **116**.

Rotary motion is transmitted to the radius turning arm through the integral shaft **64** which is provided at its inner end with a gear segment **122** which is keyed to the shaft **64** and retained on the shaft by means of lock washer and nut assembly **124**. The gear segment **122** could be a complete gear, but space limitations in this particular design are more adaptable to merely a gear segment. The gear segment **122** mates with a pinion **126** which is preferably formed integrally with a pinion shaft **128**. The pinion shaft is rotatably mounted in the side head saddle **20** by means of antifriction bearings **130**. The end of the pinion shaft opposite the pinion is splined as at **132** to carry for rotation therewith a worm wheel hub **134** which is retained on the pinion shaft by means of a lock washer and nut assembly **136**. Secured to the worm wheel hub by means of a plurality of cap screws **138** is a worm wheel **140**. The reason that the worm wheel and hub are made separately is that in this manner, the hub may be made of steel to provide the necessary transmission strength in the spline whereas the worm wheel **140** is preferably made of bronze so that improved wear characteristics are obtained. The worm wheel **140** meshes with a hardened and ground worm **142** which is preferably formed integrally with a worm shaft **144**.

Worm shaft **144** and the driving means therefor are more clearly seen in the sectional view illustrated in Figure 4. In this view it is seen that the worm shaft is rotatably carried at one end by a bearing **146** mounted in an internal boss **148** of the side head saddle. The other end of the worm shaft is rotatably carried in an antifriction bearing **150** which is mounted in a conventional bearing container **152**, the bearing container being in turn mounted in an internal boss **154** of the side head saddle. Keyed to the worm shaft, as at **156**, is driven gear **158**. The assembly is maintained by means of a lock washer **160** and lock nut **162**. Power is delivered from a conventional feed box (not shown) which rotates an output shaft **166** in either direction as desired. Keyed as at **168** to the output shaft **166** is a gear sleeve **170** which is positionally retained on the shaft by means of a key **172** and a conventional lock washer and nut assembly **174**. Secured for rotation with the gear sleeve and output shaft is a driving gear **178**, said driving gear being operatively engageable with the driven gear **158**. It is seen, therefore, that rotation of the output shaft **166** in either direction as desired will cause the worm shaft **144** to rotate, and this motion will be transmitted through the worm and worm wheel to the shaft **128** and thence through the pinion **126** and gear segment **122** to the bearing shaft **64**. The bearing shaft **64** being integral with the radius turning arm will cause the arm to rotate thereby moving the pivot point **51** in an arcuate path having a preselected radius. The arcuate movement of the pivot point **51** will be duplicated in the tool **31** as described heretofore.

Close adjustment of the initial cutting position of the tool may be made by means of the hand adjustment assembly, generally indicated at **180**, which is mounted in the side head of the boring mill. The side head saddle **20** is provided with an opening **182** adapted to receive a bearing sleeve **184** which is flanged as at **185** at its outer end and secured to a mating flange **187** on the side head by means of cap screws **186**. Rotatably received within the bearing sleeve **184** is a hand adjustment shaft **188**. Secured to the hand adjustment shaft **188** for rotation therewith is a bevel pinion **190** operatively engageable with a bevel gear **191** which is keyed to the sleeve **170**. The bevel pinion **190** is preferably secured to the shaft **188** by means of a key **192** and a set screw **194**. The hand adjustment shaft **188** extends outwardly of the side head saddle as at **196**. Secured to the shaft extension **196** for rotation therewith is a hand wheel **198** held in position by a lock washer and nut assembly **200**. Rotatably mounted on the hand wheel hub adjacent the flange **185** of the sleeve **184** is a dial indicator **202**. Immediately adjacent the dial indicator **202** and keyed to the hand wheel hub as at **204** is a locking sleeve **206**. The locking sleeve is provided with a plurality of openings **208** adapted to receive T-bolts **210** therethrough, the T portion of the bolts **210** being received within an annular T-slot **212** in the dial indicator **202**. Knurled nuts **214** are provided for the T-bolts. It may be seen that the tightening of the knurled nuts **214** on the T-bolts **210** will clamp the locking sleeve **206** into tight frictional engagement with the dial indicator **202**, at which time rotation of the hand wheel **198** will also cause the sleeve **206** and the dial indicator **202** to similarly rotate. The amount of rotation may be indicated by graduations (not shown) on a tapered face **216** of the dial indicator with reference to a scribed zero line (not shown) on the tapered face **218** of the flange **185**. The output shaft **166** from the conventional feed box is provided with a conventional friction clutch (not shown) to permit the output shaft to be rotated by hand independently of the power drive.

Using the turning device in conjunction with the side head saddle of the boring mill as described above, an external spherical contour will be obtained as illustrated by the outside surface **230** on the exemplary work piece shown in Figure 7. It will be apparent to those familiar

with vertical boring mills that the side head 20 could be moved in a vertical direction while taking a cut on the work piece prior to the initiation of the spherical turning portion of the operation thereby forming a piece having a cylindrical section above the spherical shaped section, the cylindrical portion being illustrated, for example, by surface 232 in Figure 7.

As described above, the motion of the cutting tool will be in an arcuate path having a radius equal to the radius pre-set in the radius turning arm by device 54. This radius may be called R. If the cutting tool is positioned at a distance R from the rotatable axis of the work supporting table, a spherical contour as indicated by the line 230 in Figure 7 will be obtained. Figure 3, on the other hand, illustrates means for positioning the cutting tool at a distance from the axis of the table which is larger than R is which case an offset spherical contour will be obtained. This contour is represented by the line 234 in Figure 8. The amount of offset, which in the present instance may be any distance up to four inches, is shown by the numeral 236 in Figure 8.

Referring to Figure 3, it is seen that the tool holder 30 is carried in a conventional manner by a tool bar 240 which is slidably received within the side head ram 28. A key 242 is provided to prevent rotation of the tool bar 240, the key being received in a keyway 243 extending longitudinally of the tool bar. The inner end of the tool bar is provided internally thereof with a threaded nut 244 which receives the threaded portion of an adjusting screw 246. The adjusting screw extends beyond the end of the ram opposite the tool and is rotatably received within a bearing sleeve 248 which is received in an opening of a bearing plate 250 bolted or otherwise secured to the end of the ram. A collar 252 is provided adjacent the inside end of the bearing sleeve to prevent outward movement of the adjusting screw relative to the ram. A dial sleeve 254 surrounds the adjusting screw adjacent the outside of the bearing plate and carries for rotation therewith a dial indicator 256. Also keyed to the extending portion of the adjusting screw for rotation therewith is an adjusting handle 258 which is retained axially by means of a lock nut 260. Rotation of the handle 258, and with it the dial indicator and the adjusting screw, will move the tool bar and tool horizontally toward or away from the rotatable axis of the table whereby the desired initial tool position may be obtained. The approximate position of the tool may be determined by the graduations (not shown) on the dial indicator with reference to a scribed zero line (not shown) on the bearing plate 250. However, accurate positioning of the tool is determined by means of aligned gauge buttons 264 and 266 between which a gauge block may be placed, the gauge block being held parallel to the tool bar by means of a V-block 262.

Figures 9 and 10 schematically illustrate a modification of the device by means of which irregular contouring may be performed. In this modification the depending bracket 50, which is secured to the ram 28, and the radius turning arm 52 are essentially the same as in the basic device of Figures 2–4. However, the slide 68 is permitted to ride freely in the radius turning arm and the radius adjusting assembly 54 is omitted. Interposed (Figure 10) between the side head saddle 20 and the radius turning arm 52 is a cam plate 270 which preferably is bolted to the side head saddle 20. A cam track 272, having a contour corresponding to that which is desired to be obtained on the work piece, is machined in the cam plate, and the slide 68 is provided with a cam follower 274 adapted to ride in the cam track 272. Rotation in a clockwise direction, as seen in Figure 9, of the radius turning arm 52 about the bearing shaft 64 as a center, will move the cam follower 274 along the cam track carrying with it the bracket 50, the ram 28 and the tool 30. The tool then will form a corresponding contour on the work piece. The contouring modification as illustrated is also readily adaptable to internal contouring when used in conjunction with the internal spherical turning attachment to be described hereinafter.

The turning attachment as adapted to the boring mill to accomplish internal spherical turning is illustrated in Figures 5 and 6. In Figure 5 the horizontal rail 12 is fragmentarily shown together with a saddle 280 which is mounted for horizontal movement on suitable ways provided on the rail. Also shown is a vertical feed rod 282 which is conventionally, but not in the present embodiment, used to impart vertical motion to the ram toward or away from the work piece carrying table. Suitable ways are provided in the saddle to carry for sliding horizontal movement therealong an auxiliary slide 284. The ways comprise a plurality of raceways 286 secured to the saddle and having V-grooves 288 therein, and a plurality of complementary raceways 290 secured to the auxiliary slide and having V-grooves 292 therein which, with the V-grooves 288, provide suitable bearing tracks accommodating a plurality of balls 294. A tool carrying ram 18 is mounted in the auxiliary slide 284 and is adapted for sliding vertical movement therein by means of a plurality of V-grooved ball bearing raceways 296 (Figure 6) similar in design to those described heretofore.

The ram 18 is provided with an opening 298 adapted to receive the shank 300 (Figure 5) of a tool holder 302. The tool holder is held in position by a plurality of clamping bolts 304 threaded into the outer face of the ram and seated against clamping buttons 305, the inner faces of which are complementary to and engageable with the shank 300. Secured by means of a plurality of cap screws 306 to the ram 18 for movement therewith is a bracket 308 which is positioned to extend outwardly substantially at right angles to the ram as best seen in Figure 1.

Pivotally secured at the outer end of bracket 308 as at 310 is a radius turning arm 312. The detailed structure of the pivotal connection 310 is identical with connection 51 described heretofore relative to the external turning attachment and, as the same numerals have been applied to like parts in Figure 6, it is not deemed necessary to once again describe these various parts. A radius adjusting mechanism indicated generally at 314 is provided which is identical with the adjusting mechanism 54 as previously described and shown in Figure 2 and like numerals have been applied to like parts in Figure 6.

Referring to Figure 6, it is seen that the saddle 280 is provided with a bearing housing 316 which is secured to the saddle by means of a plurality of cap screws (not shown). An opening 318 in the housing is counterbored at each end as at 320 to receive antifriction bearings 322. Mounted for rotation in the bearings 322 is a stud shaft 324 which may be secured to or formed integrally with the radius turning arm 312.

Rotary motion is transmitted to the radius turning arm 312 through the stud shaft 324 which is provided at its inner end with a gear 326 keyed as at 328 to the shaft 324 and retained on the shaft by means of a conventional lock washer and nut assembly 330. The gear 326 is engaged and driven by a pinion 332 which is preferably formed integrally with a pinion shaft 334 rotatably mounted in the saddle 280 by means of antifriction bearings 336. The end of the pinion shaft opposite the pinion is splined as at 338 to carry for rotation therewith a correspondingly splined worm wheel hub 340 which is retained on the shaft 334 by means of a lock washer and nut assembly 342. Secured to the worm wheel hub by means of a plurality of cap screws 344 is a worm wheel 346. One or more dowel pins 348 serve to accurately position the worm wheel relative to the hub. The hub and worm wheel are fabricated of steel and bronze, respectively, for strength and wear characteristics as explained relative to the corresponding hub and worm wheel of the external turning attachment. The worm wheel 346 meshes with and is driven by a worm 350 which is bearing mounted in a worm box (not shown) bolted to

the saddle. The worm is matingly splined to the vertical feed rod **282** for sliding movement axially thereof. It should be noted that the worm **350** and the vertical feed rod **282** (Figure 6) have been rotated 90 degrees in a horizontal plane in order that engagement between the worm and worm wheel may be more clearly seen.

The vertical feed rod is driven in either direction from a conventional feed box (not shown) and rotation of the vertical feed rod is transmitted through the gear train described above to the radius turning arm **312** thereby imparting arcuate motion to the pivotal connection point generally indicated at **310**. Inasmuch as the ram **18** is free to slide downwardly on the ways **296** and the auxiliary slide **284** is free to slide horizontally relative to the saddle on the V-grooved bearing structure described heretofore, the bracket **308**, the ram **18** and the tool holder **302** will be moved through a corresponding arcuate path whereby a contour as represented by the line **352** in Figure 7 is cut on a work piece carried by the table **32** for rotation therewith.

Adjusting means **314** provide for varying the radius of the spherical contour to be cut on the work piece in the same manner as the corresponding mechanism described heretofore for the same external spherical turning attachment.

Offset internal spherical turning may be accomplished by moving the saddle horizontally on the rail a sufficient amount to provide for the desired offset and then operating the spherical turning attachment in which case a contour such as represented by the line **354** in Figure 8 will be obtained. The amount of offset obtainable in this manner is of course limited only by the length of the slide.

Referring to Figure 5, it is seen that means are provided to independently adjust the tool holder in a vertical direction. The vertical tool adjusting means is designated generally at **356** and comprises a threaded stud **358** received through aligned clearance holes **360** and **362** and snugly threaded into a tapped opening **364** in the ram **18**. A cut out opening **366** is provided in the tool holder to receive an adjusting dial **368** which surrounds the stud **358** and is threaded for operative engagement with the threads of the stud. Adjustment of the tool holder is accomplished by loosening the clamping bolts **304** and rotating the adjusting dial **368** which because of its threaded engagement with the relatively stationary stud **358**, moves axially thereof and carries with it the tool holder **302** together with the tool **19**. After adjusting the tool holder to the desired vertical position, the clamping bolts are once again tightened to clamp the tool holder in the adjusted position. A set screw **370** retains a pointer (not shown) for dial **368**.

The foregoing description demonstrates that a novel attachment has been provided which is adaptable to accomplish internal or external spherical turning, offset internal or external spherical turning and also internal or external contouring.

I claim:

1. A machine of the class described comprising means for rotating a work piece, a holder for a cutting tool, a radius arm having a pivotal connection to the machine, a slide mounted in said arm for movement lengthwise thereof, an actuator bracket secured to the holder for movement therewith and having a pivotal connection to the slide, a cam track, a cam follower carried by the slide for movement therewith, said follower being operatively engageable with the cam track for movement therealong as the arm pivots, and means for pivoting the arm.

2. In a vertical boring mill, the combination of a work piece carrying table rotatable about a vertical axis, ways secured to said mill, a member movable along said ways, a tool carrying ram carried by said member for movement therewith, said ram being movable relative to said member in a direction normal to the direction of movement of said member, an arm rotatably secured at one end thereof to said mill, power means to rotate said arm, and means affording adjustable pivotal connection between said arm and said ram whereby the arcuate movement of said arm is imparted to said ram, said last mentioned means comprising a bracket secured to said ram for movement therewith, a slide carried by said arm and adapted for movement longitudinally thereof, a hub carried by said slide, said hub being pivotally received within said bracket, means to selectively vary the position of said slide in said arm longitudinally thereof, and means to lock said slide in the desired position.

3. An arrangement for moving a cutting tool in a predetermined curvilinear path, said arrangement comprising: a linearly movable first member; a tool carrying second member carried by said first member for movement therewith and for relative movement angularly thereof; a bracket secured to said second member for movement therewith; a pivot arm; a slide carried by said arm and freely movable therein; a pivotal connection between said bracket and said slide; a cam track; and a cam follower carried by said slide and engageable with said cam track for movement therealong as the arm pivots.

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1,485,258	Dzus	Feb. 26, 1924
1,492,103	Parkes	Apr. 29, 1924
2,104,238	Nichols	Jan. 4, 1938
2,252,627	Gorton	Aug. 12, 1941
2,329,246	Bullard	Sept. 14, 1943
2,610,550	Touchmann	Sept. 10, 1952
2,652,731	Turchan	Sept. 22, 1953