

[54] **METHOD OF AND APPARATUS FOR RAPIDLY AND SIMULTANEOUSLY ABRADING METAL WORKPIECES IN PRESELECTED PLURAL NUMBERS**

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[51] Int. Cl. **B24b 21/00; B24b 1/00**

[58] Field of Search **51/135 R, 141, 145 T, 326, 51/328**

[56] **References Cited**

UNITED STATES PATENTS

2,405,417	8/1946	Fruth.....	51/145 T
3,816,998	6/1974	Crivna.....	51/145 T

Primary Examiner—Othell M. Simpson

[57] **ABSTRACT**

The surfaces of a plurality of workpieces are simultaneously ground by two abrading heads, each having a fast moving power driven endless abrasive belt and a backup member engaging the back of the belt. The workpieces are presented to the abrading heads by an indexable turntable that supports a plurality of turrets on which the workpieces are mounted. The abrading heads are located at diametrically opposite sides of the turntable axis so that indexing rotation of the turntable successively brings the turrets and the workpieces thereon under the abrading heads. Forceful engagement between the abrasive belts and the top surface of the workpieces is effected by imparting hydraulically produced pressure on the backup members. The nature of the grinding action performed by the two abrading heads is determined by the shape of the backup members. The depth to which the workpiece surfaces are ground and the rate at which it is done, are accurately adjusted and maintained.

47 Claims, 10 Drawing Figures

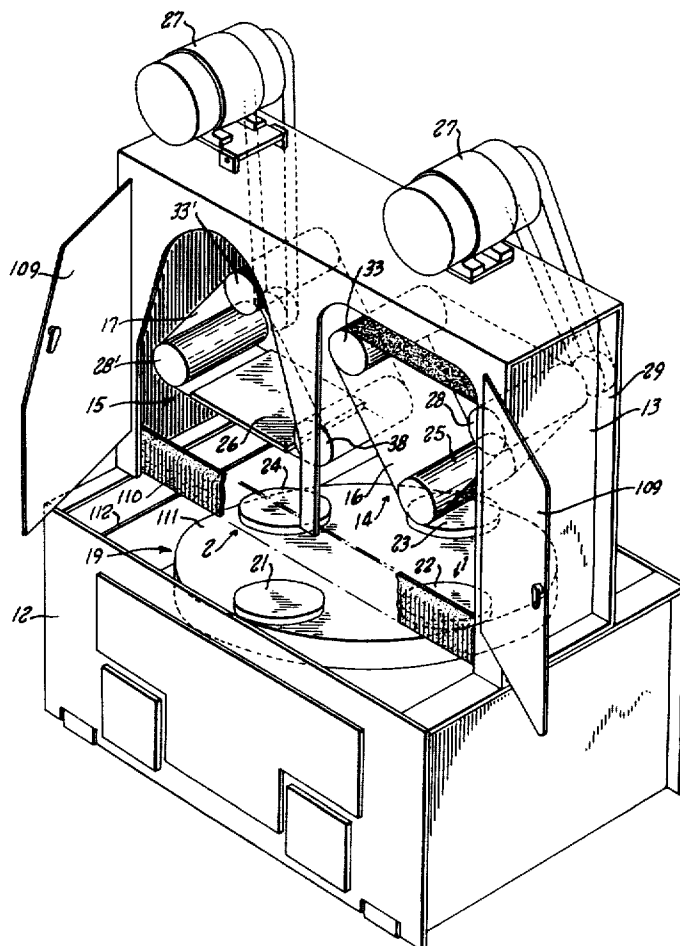
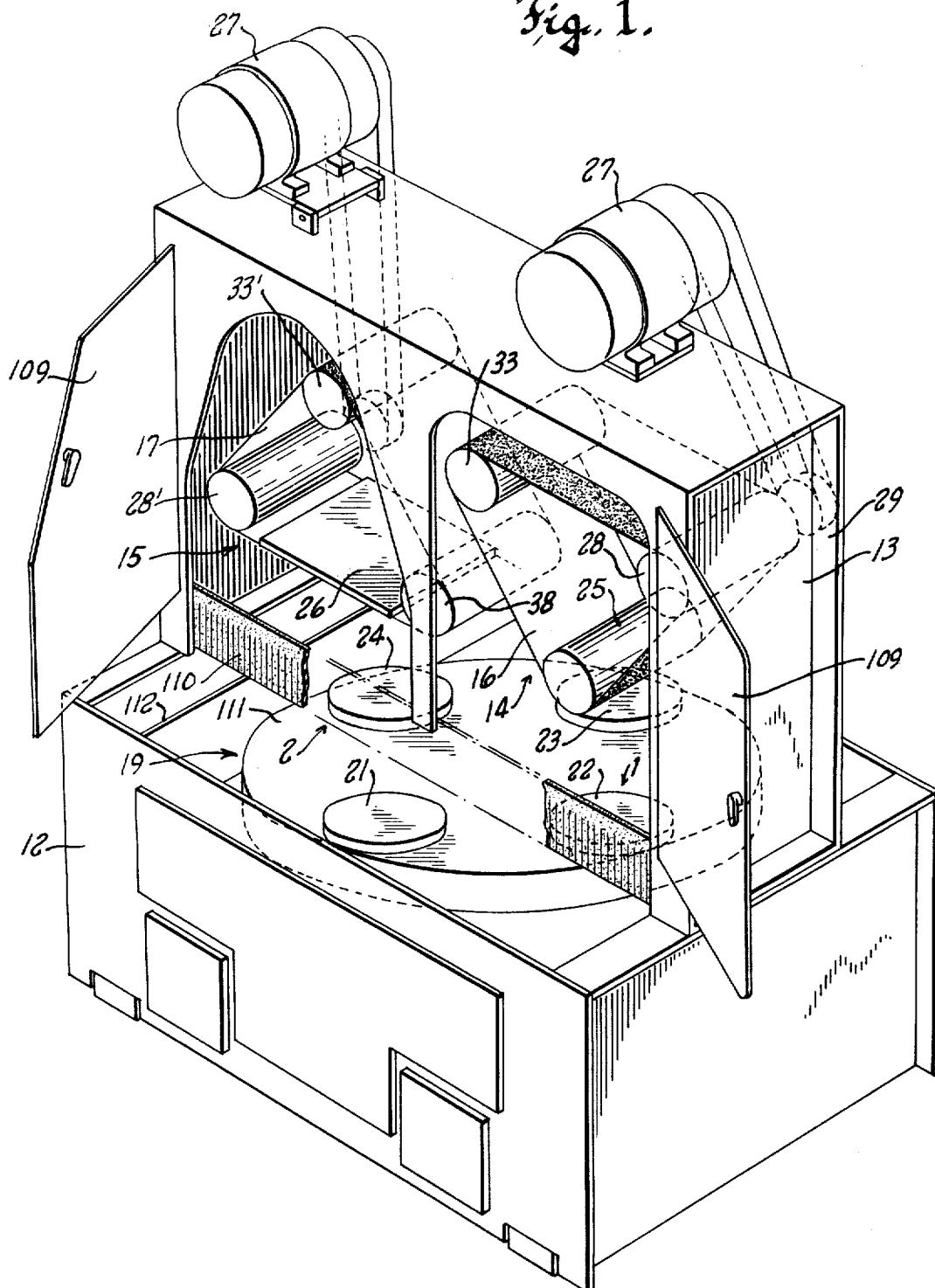


Fig. 1.



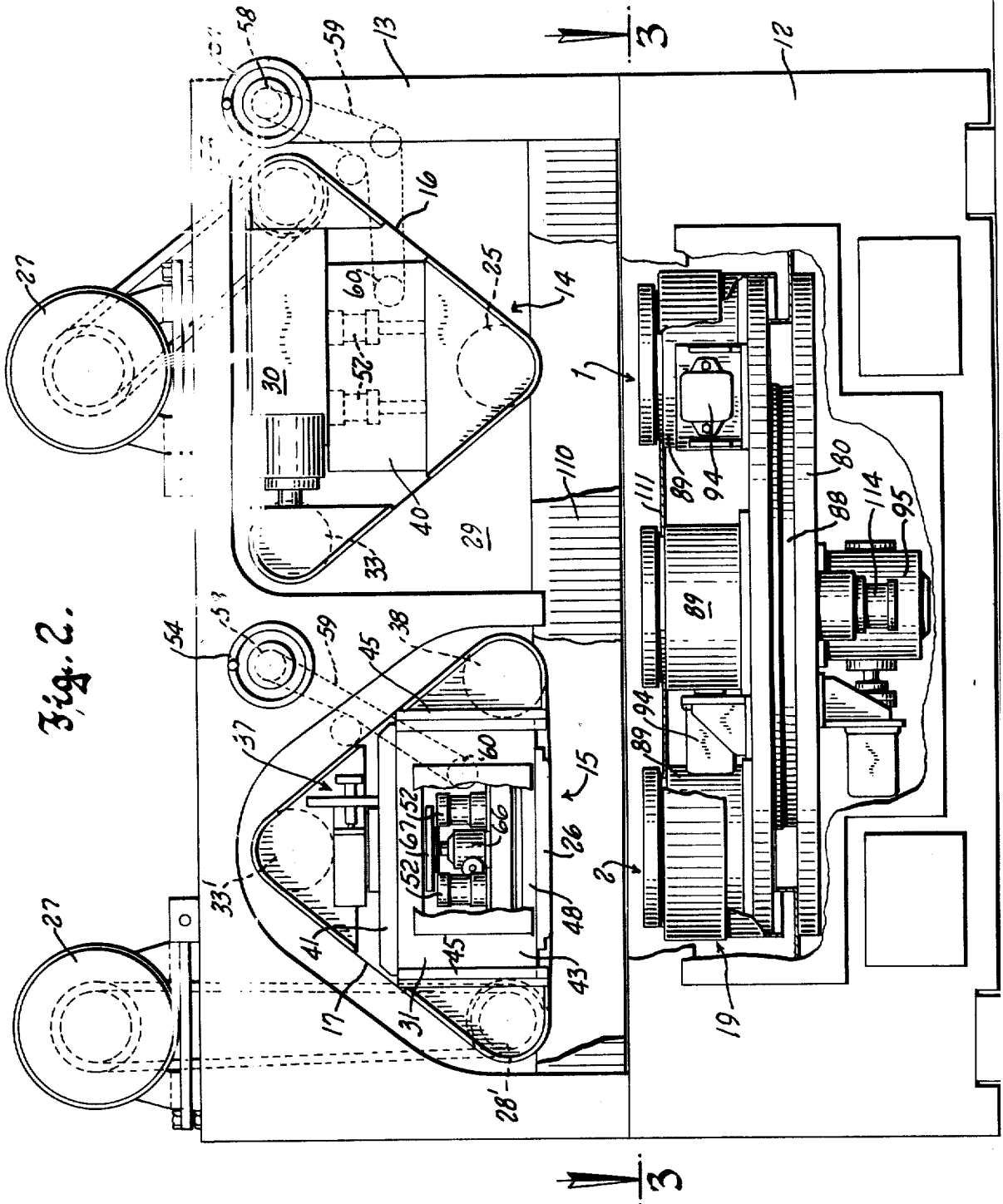


Fig. 3.

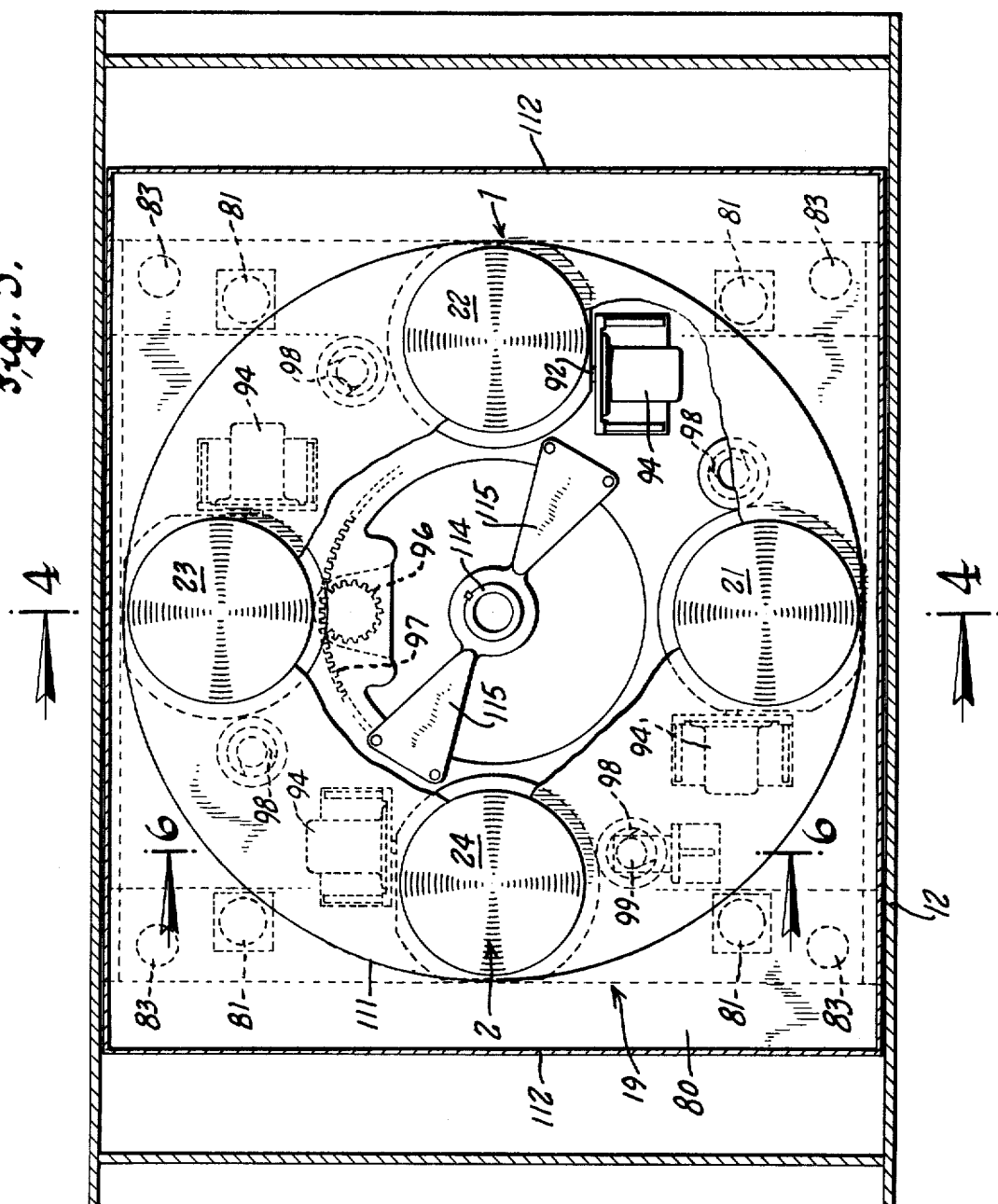


Fig. 4.

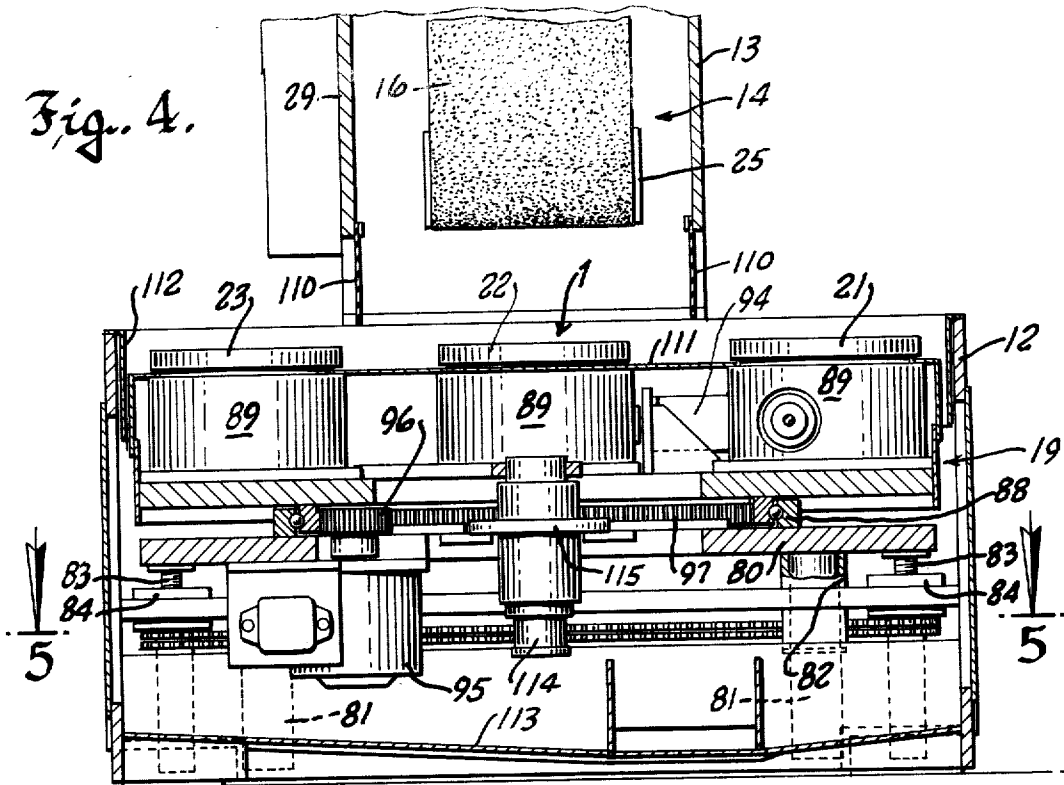


Fig. 5.

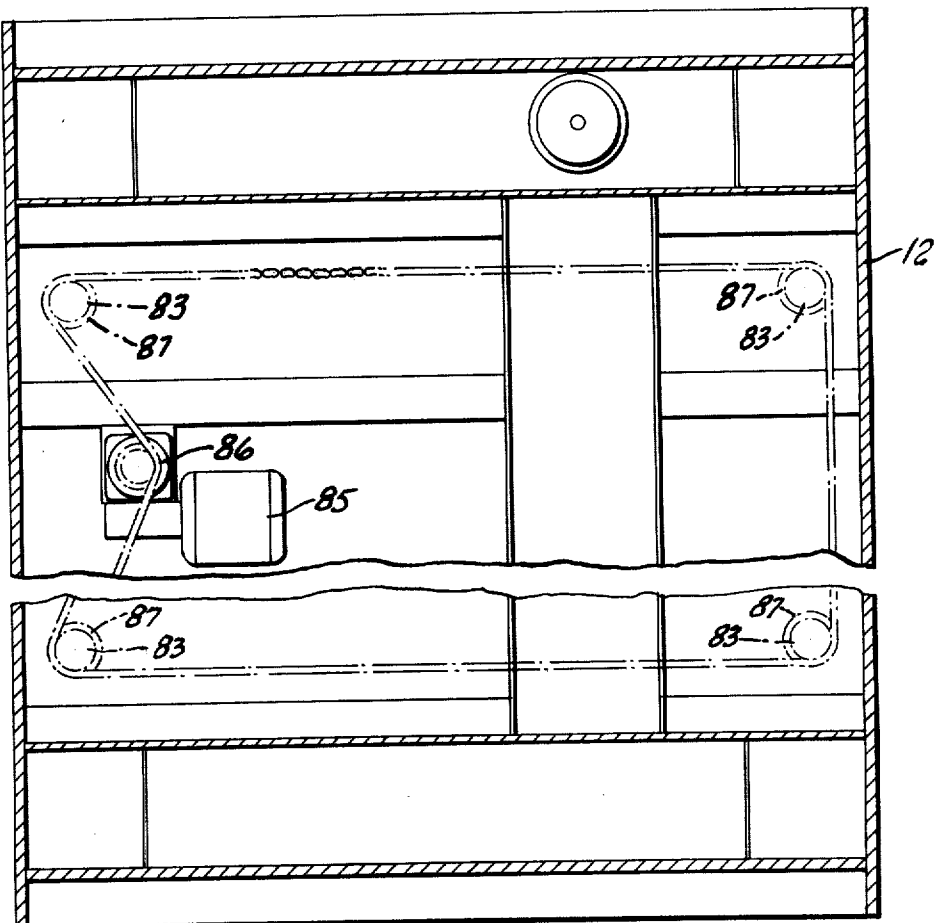


Fig. 6.

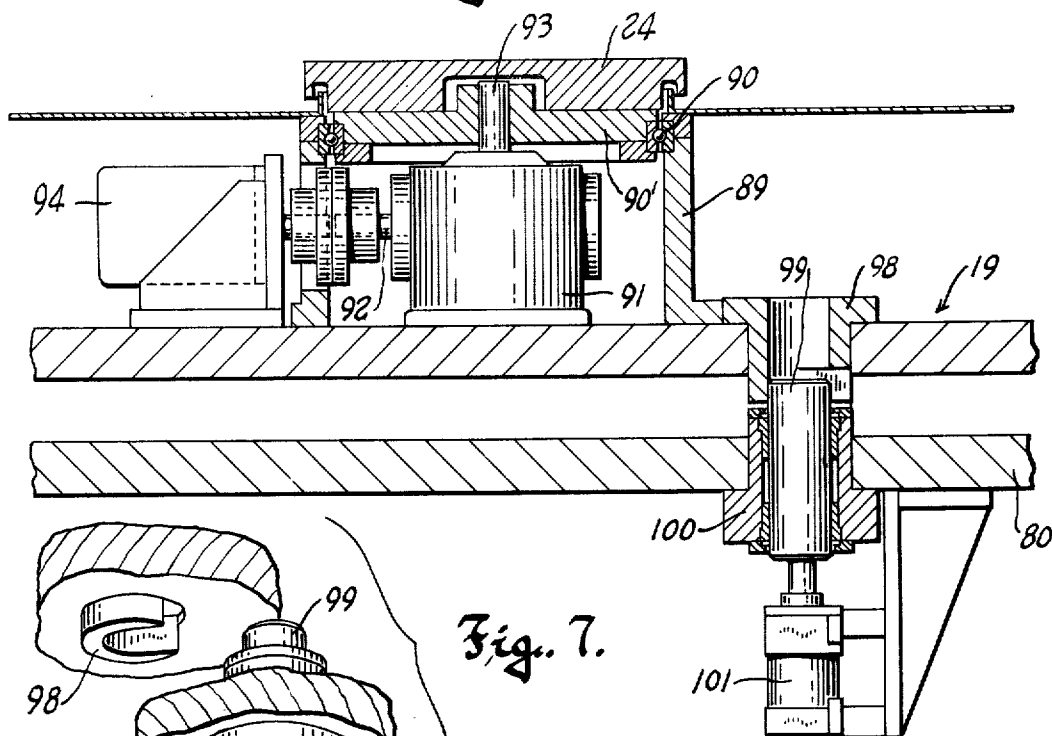


Fig. 7.

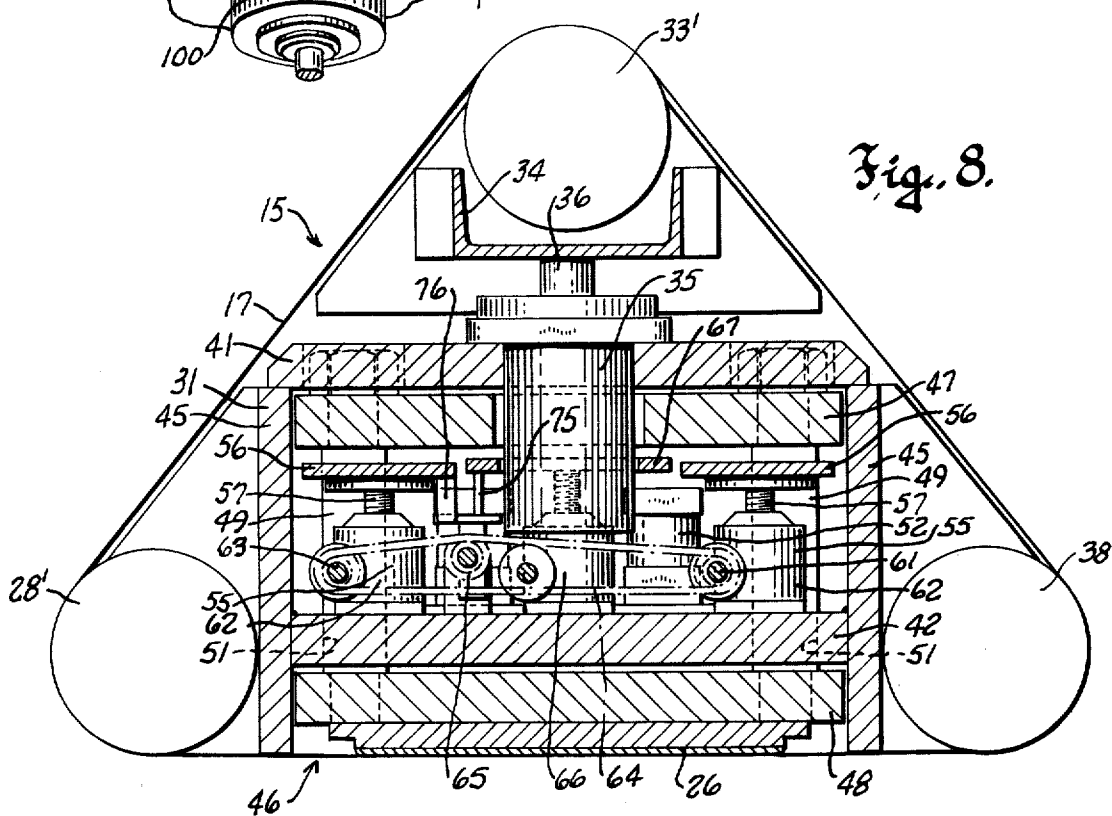


Fig. 9.

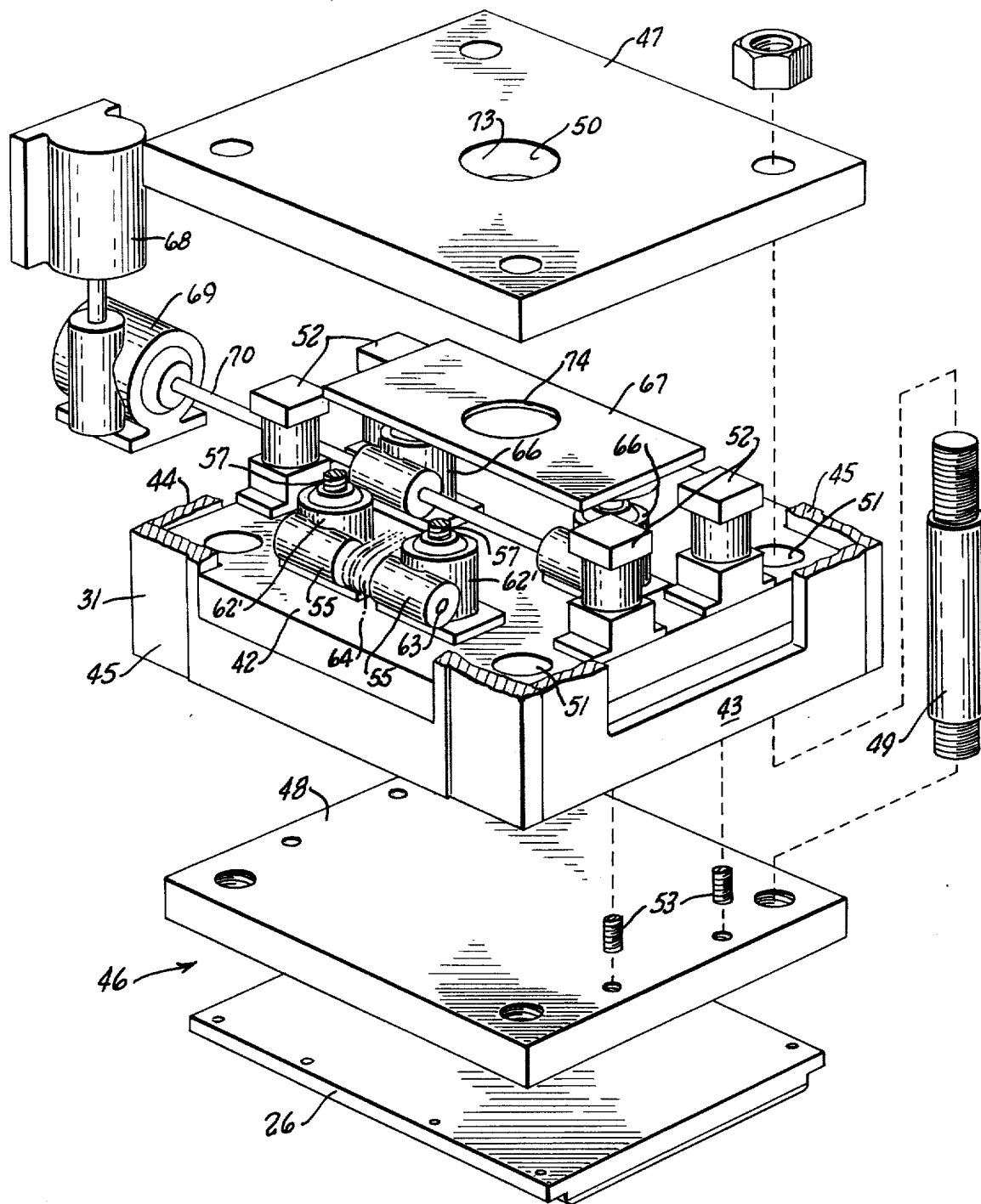
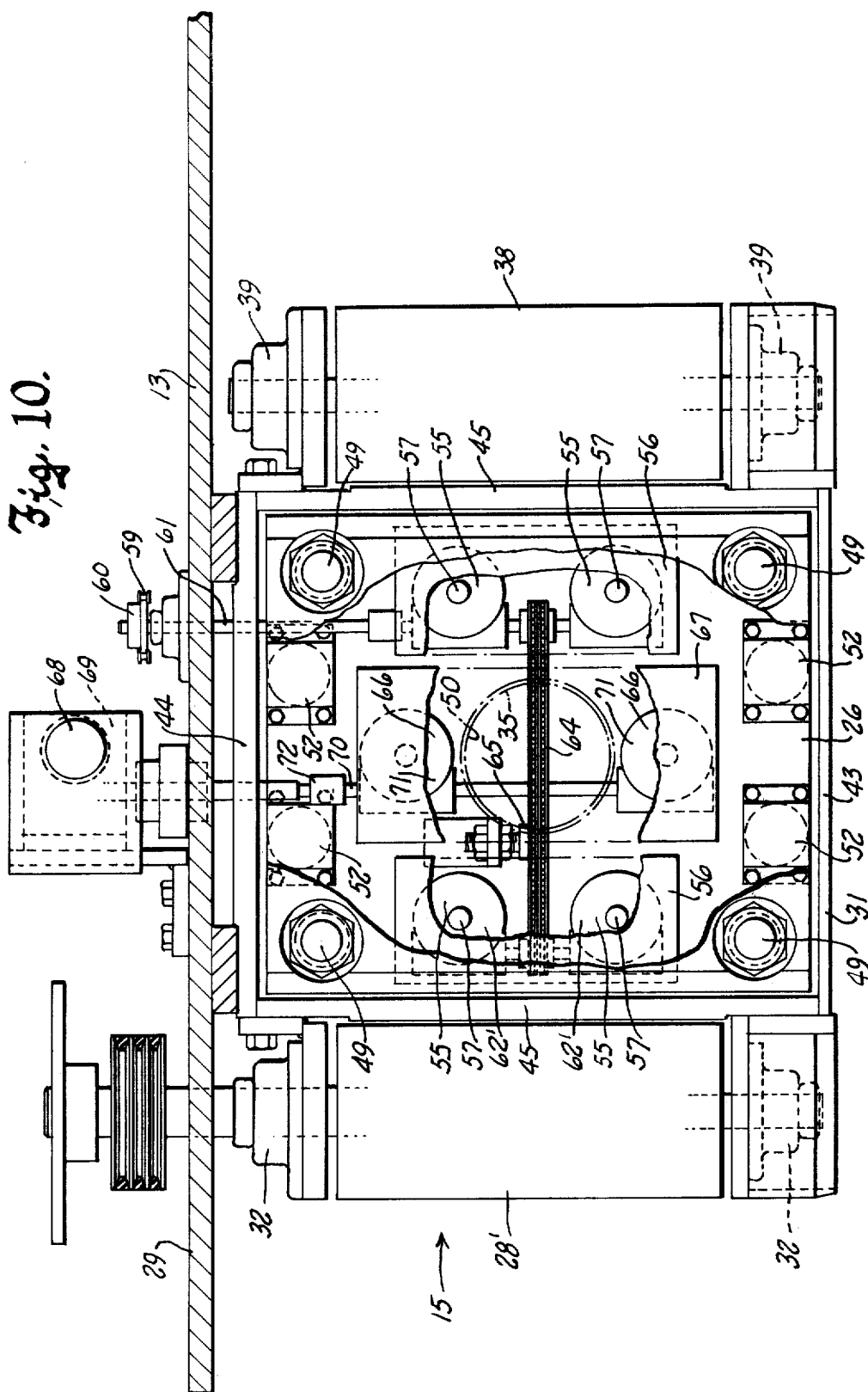


Fig. 10.



METHOD OF AND APPARATUS FOR RAPIDLY AND SIMULTANEOUSLY ABRADING METAL WORKPIECES IN PRESELECTED PLURAL NUMBERS

This invention relates to the abrading or grinding art, and is an outgrowth of the invention disclosed and claimed in the copending Grivna et al. application Ser. No. 360,001, now U.S. Pat. No. 3,816,998, which is assigned to the assignee of this invention.

The primary purpose and object of this invention is to provide a metal surface grinding machine that is capable of achieving high speed production in the machining of metal workpiece surfaces to absolute flatness and a desirable fine finish.

To this end, the invention contemplates a metal grinding machine having a pair of spaced apart abrading heads, each of which has a power driven rapidly traveling endless abrasive belt; a turntable beneath the abrading heads with upwardly facing rotary work supports thereon to successively present workpieces first to one and then the other of the abrading heads as the turntable is unidirectionally indexed; and a backup member for each abrading head to hold a downwardly facing stretch of its abrasive belt against the workpieces as they are successively presented to the abrading heads, but most important is the fact that the backup member at the abrading head to which the workpieces are first presented is a rotatable contact drum while that of the other abrading head is a flat relatively large-area platen.

By virtue of this significant difference between the two abrading heads, fast material removal in a rough grinding operation performed by the first abrading head, and finish grinding to absolute flatness and desirable fine finish by the second abrading head is accomplished in an impressively short time.

Another advantageous aspect of the invention stems from the fact that the abrading heads are at diametrically opposite sides of the turntable axis - i.e. 180° apart - so that by indexing the turntable in 90° increments, the machine has two work stations, a first for rough grinding and a second for finish grinding; and two intermediate stations at one of which the finished workpieces are removed from the machine and replaced by others to be ground, and at the other of which the rough-ground workpieces can be inspected or simply left to "relax" before being advanced to the second work station.

It is also an object of this invention to provide improved position defining means for stopping the rotatable turntable that carries the rotary work supports by which the successive indexing advances of the turntable are accurately defined and the turntable is positively held against movement while the workpieces are being ground.

With respect to the indexing of the turntable, in a modified embodiment thereof, the invention has as another of its purposes to advance the turntable in unequal increments, so that the axes about which the several rotary work supports turn are differently located with respect to the width of the abrasive belts, to thereby achieve more uniform wear of the abrasive belt and of the backup member.

Another important feature and object of the invention resides in the provision of a feed rate control for each of the abrading heads that is capable of being set to become effective after a predetermined degree of

relative feeding motion has taken place between the abrasive belt and the work support carrying the workpiece being acted upon by that belt.

A further object of the invention is to provide a grinding machine in which a plurality of belt-type abrading heads simultaneously perform grinding operations on workpieces, and wherein the depth to which each of the separate abrading heads cuts can be selectively preset.

With these observations and objectives in mind, the manner in which the invention achieves its purpose will be appreciated from the following description and the accompanying drawings, which exemplify the invention, it being understood that changes may be made in the precise method of practicing the invention and in the specific apparatus disclosed herein without departing from the essentials of the invention set forth in the appended claims.

The accompanying drawings illustrate one complete example of the embodiment of the invention constructed according to the best mode so far devised for the practical application of the principles thereof, and in which:

FIG. 1 is a simplified view in perspective of an abrasive belt-type grinding machine embodying the novel features of this invention;

FIG. 2 is a view of the machine in front elevation with parts broken away to show the power drives to the abrasive belts and multiple work supports, respectively;

FIG. 3 is a horizontal sectional view through FIG. 2, on the plane of the line 3—3, with parts broken away to show the power input and positioning index control;

FIG. 4 is a fragmentary view in transverse vertical section taken on the plane of the line 4—4 in FIG. 3;

FIG. 5 is a fragmentary view in horizontal section taken on the plane of the line 5—5 in FIG. 4 and showing the power drive for elevating the indexable work-carrying turntable of the machine;

FIG. 6 is a fragmentary, transverse vertical section taken on the plane of the line 6—6 in FIG. 3 and showing the index control mechanism;

FIG. 7 is an enlarged fragmentary view in perspective of the extensible index pin about to enter an open index stop dog;

FIG. 8 is an enlarged view in longitudinal vertical section through one of the abrading heads;

FIG. 9 is an exploded fragmentary view in perspective of the different parts of the structure that mounts and adjusts the pressure applying platen of the abrading head shown in FIG. 8 and also at the left in FIG. 2; and

FIG. 10 is an enlarged horizontal plan view of the structure shown in FIG. 9.

Referring to the accompanying drawings, FIG. 1 diagrammatically illustrates an abrading machine which embodies the apparatus aspect of the invention and by which the method of the invention can be practiced. As shown in FIG. 1, the machine has two abrading heads, each equipped with a power driven endless abrasive belt, and multiple work supports cooperating with the abrading heads in a manner that brings about improved results and facilitates adjustment of the machine to different sized workpieces.

Referring again to FIG. 1, the abrading machine there shown as exemplifying the invention, comprises a lower stationary frame 12 having fixedly secured thereto an upwardly extending rectangular frame structure 13 of somewhat narrower proportions. Preferably

the lower frame or base 12 and the upwardly extending frame or vertical column 13 comprise one unitary and stationary structure, all of which is fabricated of heavy gauge weldments, though it will be understood that other suitable materials and fabrication practices can be employed therefor.

The two abrading heads, identified generally by the numerals 14 and 15, are mounted in the upper one of the two frame sections with the work engaging portions of their abrasive belts 16 and 17 facing downward.

To position workpieces to be simultaneously acted upon by the two abrasive belts, an indexable turntable 19 is rotatably mounted in the lower frame or base section of the machine for positioning movement in increments of 90° or a multiple thereof, depending upon the selected operating mode, as will be explained. Rotatably mounted on the turntable 19 are four independently rotatable work tables or turrets 21, 22, 23 and 24, each of which is positionable beneath each of the two abrading heads by indexed rotation of the turntable. Whether the indexing is done in 90°, 180°, 270° or 360° increments, one of the four work tables 21-24 is always in place at each of the two work or operating stations of the machine, identified by the numerals 1 and 2 in FIGS. 1 and 2, so that two separate grinding operations can take place at the same time.

In the machine, as illustrated in the drawings, the abrasive belts of the two abrading heads engage the work differently. At the head 14 which is located at the first work or operating station, the backup member by which the abrasive belt is held against the workpiece is a rotating contact drum 25, so that the belt engages the work essentially with a "line" contact, whereas at the other station the backup member is a flat platen 26 that holds a relatively large area of the belt in contact with the work.

The line type of contact that characterizes the abrading head 14 is especially well suited for rough grinding. In fact, as brought out in the copending application of Howard W. Grivna and Donald C. Elm, Ser. No. 360,001, now U.S. Pat. No. 3,816,998 which is assigned to the assignee of this invention, it is possible with that form of grinding action to remove a considerable amount of stock in a few seconds. A coarse grit belt is best suited for rough grinding. The flat-platen-supported work performing engagement of the abrasive belt that takes place at the second operating station is better suited for finish grinding but it should be noted that the grit size of the belt used for finish grinding can be the same as that employed for the rough grinding, since even with the most severe contact pressure on the platen, stock removal is limited due to the low unit pressure that characterizes the use of a platen as the backup member.

It follows, therefore, that the machine of this invention is well adapted for production type machining of a wide variety of work. Metal castings, ferrous and non-ferrous, that require a smooth flat surface, as for instance, the endbells of electric motors, and the housing sections of rotary engines, are examples of workpieces that are most efficiently machined by the method and apparatus of this invention, since work of that nature is best performed in two stages — course grinding followed by finish grinding.

Moreover tests have demonstrated that with the machine of this invention flatness of the ground surface is within 0.001 inch, dimensions are held within $\pm .001$

inch, and a finish of 100 micro inches or better is achieved with 24 grit abrasive belts and at a production rate of 500 cycles per hour.

But the invention is not tied to such two-stage work performance. By simply using the same type of abrading head at each of the operating stations, the same operation can be performed simultaneously at both stations. In fact, in an actual working embodiment of the invention, both abrading heads are of the platen type.

Despite their different modes of effecting engagement between the abrasive belts and the workpieces, there is considerable similarity between the two heads 14 and 15. In each, the endless abrasive belt (16-17) is trained over three rolls, the axes of which are at the corners of a triangle, and in each, one of the three rolls is driven by an electric motor 27 to impart high speed orbital motion to the abrasive belt. At the head 14 it is the upper right hand roll 28 (FIGS. 1 and 2) that is drivingly connected with the motor, while at the other head, it is the lower left hand roll 28'. Hence, at the first head the belt travels in a counterclockwise direction when the machine is viewed as in FIG. 1, while at the other head the belt travels in the clockwise direction so that in each instance the abrasive belt is pulled across the work.

Each of the abrading heads has a rigid supporting structure solidly secured to the back wall 29 (FIG. 10) of the upper frame 13 and projecting forwardly therefrom cantilever fashion so as not to interfere with placement and removal of the abrasive belts. For the head 14, this rigid supporting structure is an arm 30 located directly below the horizontal upper stretch of the belt, and for the head 15, that rigid supporting structure is a box-like weldment 31 that is located above the horizontal bottom stretch of the abrasive belt. In each case the rigid supporting structure (30-31) has bearings 32 (not shown for the head 14) fixed thereto in which the driven roll is journaled to rotate about an axis that is fixed with respect to the supporting structure.

The supporting structure of each abrading head also adjustably mounts that one of its three rolls by which the abrasive belt is tensioned or relaxed for removal and replacement. In the head 14, the belt tensioning roll 33 is at the upper left hand corner of the triangle opposite the driven roll 28, and in the head 15 the belt tensioning roll 33' is above the supporting structure. In each case the adjustable mounting of the belt tensioning roll comprises a yoke 34, best shown in FIG. 8, the arms of which mount the bearings in which that roll is journaled. A pneumatic jack consisting of a cylinder 35 fixed to its respective rigid supporting structure (30-31) and a piston, the rod 36 of which is connected to the yoke, adjustably mounts the yoke and the roll (33-33') journaled therein. By controlling the supply of pressure fluid to the cylinder, belt tightening or loosening adjustment of the roll 33-33' is readily accomplished. This manner of controlling belt tension is conventional, as is also the mechanism, only indicated at 37 in FIG. 2, by which the yoke 34 can be oscillated about the axis of its supporting piston to effect and control edgewise shifting of the abrasive belt.

The third of the three rolls at the head 14 is the contact drum 25 by which the abrasive belt is pressed against the work. For this purpose the contact drum is vertically movable, as is also the platen 26 at the head 15.

The third roll 38 of the abrading head 15 is simply an idler, the bearings 39 of which, like the bearings 32, are fixedly mounted on the supporting structure 31.

In the machine of this invention, as distinguished from that of the aforesaid U.S. Pat. No. 3,816,998, it is downward pressure exerted upon the vertically movable contact drum 25 and platen 26 that produces the relative motion between the workpieces and the abrasive belts needed to effect grinding. The instrumentalities by which that downward pressure is developed and controlled is best illustrated in FIGS. 8 and 9 which concern the platen type abrading head 15, and while only diagrammatically depicted by the "box" 40 in FIG. 2, it is to be understood that the pressure producing and motion controlling instrumentalities of the head 14 are essentially the same as those of the other head, which will now be described.

The box-like weldment which forms the rigid supporting structure 31 of the abrading head 15, has horizontal top and bottom plates 41 and 42, respectively, connected by vertical front and back walls, 43 and 44, the latter being secured to the back wall 29 of the main frame. The top and bottom plates 41 and 42 are also connected by vertical end walls 45 to which the bearings 32 and 39 are secured. All of these vertical walls have their central portions cut out to reduce the weight of the weldment 31, and also to afford access to the mechanism inside the box-like weldment.

The cylinder 35 of the pneumatic belt tensioning jack is fixed to the top plate 41 and projects through a hole therein, into the center of the box-like weldment, as best seen in FIG. 8.

A platen carrying assembly 46 is mounted in the box-like weldment for vertical movement with respect thereto between defined upper and lower limits. This assembly comprises substantially square horizontal top and bottom plates 47 and 48 respectively, held in fixed parallel relationship by four parallel tie bolts 49. The lower ends of the tie bolts are threaded into holes at the corners of the bottom plate; and their upper ends are reduced in diameter and threaded to receive nuts by which the top plate is clamped against the shoulders that result from the reduced diameter of the upper ends of the tie bolts. A hole 50 in the top plate 47 accommodates the belt tensioning cylinder 35, and the bottom plate 48 has the platen 26 detachably secured thereto.

Up and down motion of the vertically movable assembly is guided by having its four tie bolts slidably received in appropriately sized holes 51 in the bottom plate 42 of the rigid supporting structures.

Four hydraulic jacks 52 that have their cylinders fixed to the bottom plate 42 of the stationary supporting structure, and their pistons connected through rods 53 with the bottom plate 48 of the movable platen carrying assembly 46 provide power means for raising and lowering the latter. It is these hydraulic jacks that provide the downward pressure on the platen by which the abrasive belt is pressed against the workpiece being acted upon. The length of the stroke of the hydraulic jacks determines the upper and lower limits of the vertical motion that can be imparted to the platen. Upward vertical motion of the assembly 46 to retract the platen is always stopped at the same elevation by the bottoming of the pistons of the hydraulic jacks at their retraction strokes. With the cylinders of the hydraulic jacks seated directly on the bottom plate 42, that elevation is such that the bottom face of the platen is slightly

below a plane tangent to the undersides of the rolls 28' and 38, so that the abrading belt is always in contact with the platen as shown in FIG. 2. For some work, especially in wet abrading, that condition is desirable, but for other work, and particularly dry abrading, the abrading belt does not have to be in engagement with the platen when the latter is in its retracted position, and bearing in mind that the belt travels at a very high speed, any avoidance of sliding contact with the platen, significantly reduces wear not only of the belt but also the platen. To eliminate that contact when the platen is retracted, it is only necessary to place shims between the bases of the hydraulic jack cylinders and the bottom plate 42.

The extent of downward motion imparted to the platen carrying assembly is adjustable so that the depth of the cut or amount of material removed from the workpiece by the abrasive belt can be set at any desired magnitude within the capacity of the machine. To illustrate, while the stroke of the hydraulic jacks 52 and consequently the distance the platen carrying assembly can be raised and lowered may be as much as one inch it would seldom be necessary to use that full range of motion. Even if as much as one-quarter of an inch (0.25 inch) were to be ground off a workpiece, far less than the full available range of up and down movement of the platen would be needed.

With the platen carrying assembly fully retracted, placement of the workpiece with its surface to be ground at an elevation half an inch below the platen would be easily accommodated. Under these circumstances the platen carrying assembly would move down a quarter of an inch before the abrasive belt contacted the workpiece, and in the absence of some controllable limitation upon the descent of the platen it would be difficult to know when the desired depth of cut had been reached. For this reason, the limit of downward motion that can be imparted by the hydraulic jacks 52 is adjustable.

The bottom limit adjustment is made manually by means of a handwheel 54 that is drivingly connected through chain and sprocket motion transmitting means with the nuts of four vertically oriented jack screws 55. Two stop plates 56 are attached to the upper ends of the screws 57, one to each of a pair of these screws. The two stop plates are at all times coplanar and in position to have the top plate 47 of the platen carrying assembly collide with them during descent of the latter.

For completeness of description, the aforesaid chain and sprocket motion transmitting means comprises, in addition to a sprocket 58 directly driven by the handwheel and a chain 59 trained thereover, a sprocket 60 on a shaft 61 journaled in bearings that are seated in housings 62 that contain the nuts of two of the jack screws. These housings are fixed to the bottom plate 42 of the stationary supporting structure. Another shaft 63 that is journaled in bearings mounted in the housings 62' of the other two jack screws, is drivingly connected with the shaft 61 by a sprocket chain 64 trained over sprockets on both shafts and maintained properly tensioned by an idler sprocket 65. When properly adjusted, this driving connection from the handwheel to the four jack screws enables both stop plates 56 to be raised and lowered in unison and without disturbing the coplanar relationship needed to assure simultaneous engagement of the descending platen carrying assembly with both stop plates.

Connection of the hydraulic jacks 52 rotatable a pressure source to effect ascent or descent of the platen carrying assembly 46 may be controlled in any desired way. Thus, for instance, a solenoid actuated valve connected in a conventional hydraulic circuit could be manually operated by the closure of push-button actuated switches in appropriate control circuits, or operated automatically by programming instrumentalities, to selectively pressurize the jacks to either elevate the platen or force it downward. But since this invention is not concerned with the manner in which control is effected over the operation of the hydraulic jacks 52 or for that matter, any of the various motors — hydraulic or electric — no attempt has been made to include such controls in the disclosure.

Elevation or retraction of the platen carrying assembly to its upper limit of vertical motion may be as fast as the available power can effect it, but the rate at which the hydraulic jacks 52 feed the platen - and hence the abrasive belt - downward, should be accurately controlled. To provide that control, a pair of jack screws 66 support a stop plate 67 beneath the top plate 47 of the platen carrying assembly 46, to engage the underside thereof during its descent. The elevation or location of the stop plate 67 at the moment the plate 47 collides with it, determines how much of the remainder of the adjusted down feed of the platen takes place at the controlled rate, which is a function of the speed of a hydraulic motor 68 that is drivingly connected with the nuts (not shown) of the jack screws 66.

As best seen in FIGS. 9 and 10, the drive transmission from the motor 68 to the jack screws 66 comprises a speed reducer 69 and a shaft 70 journaled in bearings that are mounted in the housings 71 from which the jack screws project, and in which the nuts of the jack screws are rotatably caged. In practice, the shaft 70 consists of coaxial sections connected by flexible couplings, not shown in FIG. 9 to avoid complicating the same, but indicated at 72 in FIG. 10.

Again, it should be understood that the operation and control of the motor 68 to have its operation properly coordinated with the operation of the hydraulic jacks 52 which produce the downward pressure on the platen and hence force the abrasive belt against the workpiece, can be governed by any desired programmable control instrumentalities. By such control instrumentalities the location or elevation of the stop plate 67 with respect to the range of vertical travel of the platen carrying assembly can be selectively set, and the operation of the motor 68 can be controlled to have it start the instant the descending platen carrying assembly contacts the plate 67.

From the instant the platen carrying assembly contacts the stop plate 67 its further descent is at the rate governed by the speed of the motor 68 since that determines how fast the nuts of the jack screws turn and permit descent of the plate 67.

To accommodate the belt tensioning cylinder 35, the top plate 41 of the stationary supporting structure — and the stop plate 67, have holes 73 and 74, respectively.

One further observation should be made with respect to the abrading heads. In each of the two, the pressure in the cylinder 35 by which belt tensioning is effected maintains a constant tension on the abrasive belt despite up and down movement of the contact drum 25 in the head 14 and the platen 26 in the head 15.

The described manner of adjustably limiting descent of the platen carrying assembly also lends itself to accomplishing this purpose without actual physical collision of the descending assembly with the jack screw supported stop plates 56. By providing the feed rate controlling plate 66 and one of the stop plates 56 with coating proximity sensors - or a micro switch on one of these relatively movable elements and an actuator for that switch on the other, as diagrammatically indicated at 75 and 76 in FIG. 8 - an electric control circuit can be activated to stop further descent of the platen the instant the coating sensors reach predetermined relative positions; or, in the other case, the instant relative movement between the descending feed rate control plate and the stop plate trips the microswitch.

For the described feed stroke limiting instrumentalities of the abrading heads to accurately control the depth of cut or the amount of material removed from the workpieces by the abrasive belts, and have that depth of cut accurately selectable by adjustment of the hand wheel 54, the elevation of the workpiece surface to be ground must be properly coordinated with the abrading heads and this depends upon the vertical dimension or size of the workpieces. Up and down adjustment of the turntable 19 with the work supporting turrets 21-24 thereon is thus required. To this end, the turntable is freely rotatably mounted on a rectangularly shaped platform 80 that is vertically adjustable in the bottom section 12 of the main frame of the machine. Four guide posts 81 projecting upwardly from the bottom of the lower frame section 15 at the corners of the platform, are slidably received in sleeves 82 that are fixed to and depend from the underside of the platform to guide and constrain the platform to translatory up and down movement.

The platform is adjustably supported by four jack screws 83. The screws of these jack screws are fixed to the underside of the platform and the nuts (not shown) that are threaded thereon are rotatably caged in bearings 84 that are fixedly mounted in the main frame. Synchronized rotation of the nuts of these jack screws thus effects vertical adjustment of the platform and the turntable carried thereby. Such synchronized rotation is produced by a motor 85 drivingly connected through a gear reduction transmission 86 and an endless chain that meshes with sprockets 87 on all of the nuts of the jack screws. Operation of the motor 85 can be controlled in any desired way.

The turntable 19 is freely rotatably mounted on the platform 80 by means of a large diameter combination radial and thrust bearing 88, the outer race of which is fixed to the platform and the inner race to the underside of the turntable. This detail is best illustrated in FIG. 4.

The four turrets 21-24 are rotatably mounted on the turntable with their axes equispaced from the axis of the turntable and 90° apart. The manner in which the turrets are mounted is illustrated in FIG. 6. As there shown cylindrical housings 89 fixed to the top of the turntable project upwardly therefrom to rotatably support the turrets, the actual support being provided by combined radial and thrust bearings 90 which freely rotatably mount discs 90' on which the turrets (21-24) are detachably secured. In practice, the turrets are equipped with conventional workpiece securing means (not shown).

Within each of the cylindrical housings 89 there is a transmission unit 91 with a horizontal input shaft 92 and a vertical output shaft 93, the discs 90' being fixed to these output shafts. Hydraulic motors 94 mounted on the turntable, and drivingly connected with the input shafts 92, impart rotation to the turrets at a preselected speed and at times governed by the control instrumentalities of the machine, it being understood that such rotation of the turrets occurs when they are at the operating stations presenting workpieces thereon to the abrading heads, but not when the turrets are at the loading and unloading stations.

Indexing of the turntable to bring the turrets from one to another of four defined positions is produced by controlled operation of a motor 95 mounted at the underside of the platform 80 and drivingly connected with the turntable 19 through a pinion 96 fixed to a drive shaft driven by the motor and meshing with an internal ring gear 97 that is cut directly into the inner race of the bearing 87.

The positions to which the turrets 21-24 are brought by indexing rotation of the turntable are defined by the collision of each of four stop dogs 98 that project down from the underside of the turntable with a retractable stop pin 99 mounted on the platform 80. The stop pin is constrained to vertical movement by being slidably mounted in a bearing 100 fixed to and projecting through the platform. A hydraulic cylinder 101 at the underside of the platform with its piston connected to the stop pin provides means for moving the stop pin to and from its operative position in the path of any approaching stop dog 98.

As best seen in FIG. 7, the stop dogs 98 have cylindrical sockets with open sides facing the stop pin so that as a stop dog approaches the pin, it will embrace the pin and arrest further indexing rotation of the turntable, provided the pin is in its operative position.

Obviously the location of the four stop dogs 98 with respect to the turrets must be such that no matter which of the dogs engages the stop pin, one of the turrets (21-24) will be accurately positioned at each of the operating stations 1 and 2.

Since the motor 94 which imparts the indexing rotation of the turntable, continues to maintain torque on the turntable even when that rotation has been arrested by collision of one of the stop dogs 98 with the stop pin, it follows that the turntable will be firmly held against displacement from its indexed position, until the stop pin is retracted.

By controlled energization of the cylinder 101, the angle through which the turntable is indexed can be either 90°, 180°, 270°, or even 360°, if desired. In every one of the indexed positions of the turntable, two diametrically opposite work supporting turrets are at the operating stations, and the other two are at intermediate stations, one in front of and the other in back of the upper frame section 13.

The operating stations are housed within the upper frame section 13, at the front of which there are hinged access doors 109 to enable removal and replacement of the abrasive belts. The bottom edges of these doors and also the bottom edge of the back wall 29 of the upper frame section, are spaced from the top of the turntable to provide entry and exit openings through which the workpieces enter and leave the operating stations, and preferably these openings are closed by flexible curtains 110 to keep the sparks that result from the grind-

ing action from flying out onto the intermediate stations. These curtains also keep the coolant that is used in wet grinding from splashing onto the intermediate stations. To keep such coolant from reaching the mechanism by which the turrets are mounted, a cover 111 closes the spaces between the turrets. The coolant that flows off the cover 111 is caught in a splash pan 112 which drains into a collecting hopper 113 (FIG. 4) from which it is pumped into a reservoir (not shown).

The hydraulic lines (not shown) that lead to and from the various hydraulic motors, are connected with the feed and return lines of the hydraulic circuit through a suitable multiple port rotary coupling, diagrammatically indicated at 114, and centrally mounted by arms 115 fixed to the turntable (FIG. 3).

OPERATION

The machine of this invention can be used to successively perform two different grinding operations on the same surface of a workpiece without disturbing the position of the workpiece on the work support on which it is mounted, and do so in such a way that the two operations take place simultaneously on two different workpieces.

It can also be used to simultaneously perform the same grinding operation on two different workpieces, in which event its output would be doubled, insofar as that particular operation is concerned.

Bearing in mind that the feeding motion necessary to effect work performance is produced by applying hydraulically produced pressure on the backup member of each of the two abrading heads to force the abrasive belts against the workpieces, and that the downfeed of the backup members resulting from the application of that pressure is limited, the accommodation of different workpiece dimensions and - more particularly - the height of the surface to be ground above the turret on which the workpiece is mounted, must be achieved by adjusting the elevation of the work supporting structure. Hence, regardless of the mode in which the machine is to be operated, the elevation of that structure - which is everything on the platform 80 - must be set in accordance with the size of the workpiece to be machined.

With the backup members of the abrading heads retracted to their uppermost positions, and the work supporting structure at a low level, a turret with a workpiece thereon is brought into position under either one of the two abrading heads. The work supporting assembly is then elevated to bring the workpiece surface to be ground to an elevation above the lowermost limit of downfeed motion of the backup member, which ordinarily is the same for each of the two abrading heads. This adjustment of the work supporting assembly effects an approximate height adjustment of the workpiece surface to be ground. Regardless of the amount of material that must be removed from the workpiece to reach the prescribed dimension, that approximate height adjustment brings the unground workpiece surface to a level that is not only within the range of the downfeed motion of the backup member but sufficiently above the lowermost limit thereof to allow for somewhat more than the required downfeed after the abrasive belt contacts the workpiece.

Assuming now that rough grinding is to take place at the first operating station, and finish grinding at the second, the limit of downfeed motion at the second op-

erating station would be set to bring the finish ground surface to the prescribed dimension. At the other station, the limit of downfeed motion would be set at a level high enough to allow sufficient stock to be removed in the finish grinding operation to assure satisfactory results. In each case, the downfeed limits are set by adjustment of the handwheels 54 which actuate the mechanism that elevates and lowers the downfeed stops 56.

Through adjustment of the control instrumentalities with which the machine is equipped, the elevation of the feed rate control element 67, at each of the abrading heads is then set to initiate feed rate control, either directly at the instant the descending abrasive belt contacts the work, or at some increment before contact, to accommodate irregularities in the unground workpiece surface since collision of a rapidly descending abrasive belt with the workpiece could result in damage to the machine. Different materials, of course, require different feed rates.

The machine is now set up and work performance can commence. The drive motors for the abrasive belts are turned on, as well as the pump which provides hydraulic pressure. Likewise, the control instrumentalities with which the machine is equipped are activated.

If the work to be done is successive rough and finish grinding, the workpieces are secured to the turrets at the intermediate station in front of the machine, and when so secured, the turntable is indexed 90° by the control instrumentalities initiating the operation of the indexing drive after the stop pin has been disengaged from the stop dog with which it was in engagement, and returned to its operative position in the path of the advancing stop dog. By the time the just-loaded turret reaches the first work or operating station, its drive motor has been turned on by the programmed control instrumentalities, so that it and the workpiece thereon are rotating. To achieve better belt utilization, the paired diametrically opposite turrets turn in opposite directions.

The backup member of the abrading head at the first work station then descends and presses its abrasive belt into the workpiece surface, and since rough grinding is most quickly effected by having the abrasive belt engage the workpiece with a "line" contact, the abrading head at the first work station is like that shown at the right in FIGS. 1 and 2.

Either upon initiation of or at some selected time during the downfeed of the contact drum supported abrasive belt at the first work station, its feed rate control automatically takes over and governs the rate at which further descent occurs and the grinding operation proceeds.

Upon completion of that first rough grinding operation, the contact drum supported belt is retracted and, immediately thereafter, another turntable indexing operation occurs - again through 90°. This brings the turret with the just-rough-ground workpiece thereon to the intermediate station at the back of the machine, and the second turret onto which a workpiece has been mounted, to the first work or operating station. During the cycle that follows, only a rough grinding operation takes place, but following with the next cycle, every one thereafter will have both rough grinding and finish grinding (at the second work or operating station) taking place at the same time.

Obviously, of course, at the loading and unloading station in front of the machine, an operator removes the machined workpiece and replaces it with an unmachined workpiece; and at the other intermediate station at the back of the machine, the just-ground workpiece can be inspected, or simply left to relax before being finish ground.

If it is desired to use the machine to do the same grinding operation simultaneously at both work stations, both abrading heads are of the same type and have the same grit size abrasive belt. In this operating mode, loading and unloading of the turret is done at both of the intermediate stations, i.e. by operators stationed in front of and in back of the machine.

In the foregoing description, both of the machine and its operation - the turntable was indexed in equal increments. As a result, the axis about which every turret turns during the grinding of the workpiece thereon, at both abrading heads, intersects the zone of contact between the workpiece and the abrasive belt at exactly the same location with respect to the width of the belt. Depending upon the shape of the workpieces, that same positional relationship between the rotary turrets and the zone of contact between the abrasive belts and the workpieces could result in uneven wear of the abrasive belts. That objection has been overcome to a substantial degree in the grinding machine of the aforesaid Grivna et al. U.S. Pat. No. 3,816,998, by oscillating the turntable during the grinding operation. This shifts the zone of contact between the workpiece and the abrasive belt back and forth transversely of the belt and thereby spreads belt wear more uniformly across its entire width.

The same objective can be at least partially achieved by indexing the turntable in unequal increments, rather than always through 90° or multiples thereof. Thus, considering that the indexing of the turntable is done in substantially quarter turns - as it is in most operating modes - a first index of 87°, a second of 89°, a third of 91° and a fourth of 93° will bring the workpieces to sufficiently different locations with respect to the width of the abrasive belts as the workpieces are successively brought to the two work performing stations, that more of the belt widths will be utilized than if the workpieces are always brought to the same location at the work performing stations.

Obviously to have the turntable indexed in such unequal increments merely requires that the stop dogs 98 that project down from the underside of the turntable be located in accordance with the desired differences in the angle through which successive indexing takes place, rather than the 90° spacing of those stop dogs shown in FIG. 3.

Those skilled in the art will appreciate that the invention can be embodied in forms other than as herein disclosed for purposes of illustration.

The invention is defined by the following claims.

I claim:

1. A grinding machine comprising the combination of:

A. a turntable having a plurality of work supports positioned to travel in a circular orbit upon rotation of the turntable, there being an even number of said work supports arranged in substantially diametrically opposite pairs with respect to the turntable axis;

- B. a pair of abrading heads above the turntable at substantially diametrically opposite locations on the circular orbit of the work supports, so that said locations constitute work stations, each of said abrading heads having a power driven endless abrasive belt and a backup member to hold a downwardly facing stretch of the belt against a workpiece on a work support therebeneath;
- C. means to effect relative motion towards one another between the abrasive belts and the work supports then at the work stations, to thereby produce and maintain work performing engagement between both abrasive belts and the workpieces on said work supports; and
- D. means for indexing the turntable in increments so related to the orbital distance between the work supports that with each index a pair of opposite work supports is brought to said work stations and another such pair is brought to intermediate stations on the circular orbit of the work supports, so that during the intervals between indexing of the turntable, the two workpieces at the work stations can be ground while loading and unloading of workpieces can take place at at least one of said intermediate stations.
2. The invention defined by claim 1, further characterized in that
- at one of said abrading heads the endless abrasive belt is trained over three rolls arranged in a triangle, the base of which is horizontal so that two of said rolls are at the bottom of the triangle and the third roll is at the apex thereof,
- and wherein the backup member for said abrading head is a flat horizontal platen overlying a substantial area of the stretch of the belt extending between the rolls at the bottom corners of the triangle.
3. The invention defined by claim 2, wherein the indexing of the turntable is always in the same direction so that workpieces are brought first to one and then the other work station,
- wherein said abrading head at which the backup member is a flat platen is at said other work station, and the backup member of the abrading head at the first work station is a contact drum,
- so that at said first work station the abrasive belt engages the workpieces along a narrow linear zone while at said other abrading head a substantial area of the abrasive belt engages the workpieces,
- wherein the work supports are rotatably mounted on the turntable,
- and further characterized by:
- means for rotating the work supports during the time the workpieces thereon are being abraded, so that during operation of the machine workpieces are rough ground by the abrading head with the contact drum as its backup member, and finish ground by the abrading head at which the flat platen provides the backup member.
4. The invention defined by claim 1,
- wherein said relative motion between the abrasive belt and the work supports results from downward motion of the backup members,
- and means for imparting downward motion to the backup members.

5. The invention defined by claim 4,
- wherein said means for imparting downward motion to the backup members of the two abrading heads function independently of one another.
6. An abrading machine comprising:
- A. a main frame;
- B. a plurality of spaced apart endless abrasive belts mounted on said main frame for continuous orbital motion along defined paths that include work engaging stretches;
- C. a plurality of work supporting means, each adapted to releasably carry a workpiece and present the same to each of the work performing stretches of said abrasive belts;
- D. backup means for each of said endless abrasive belts operative to hold the work engaging stretch thereof against a workpiece in position to be acted upon by its respective abrasive belt; and
- E. separate power drive means for each of said backup means to effect movement thereof towards the work supporting means in position presenting a workpiece to its associated abrasive belt and thereby force the work performing stretch of the belt into grinding engagement with a workpiece on said work supporting means,
- said power drive means for the different backup means being independent of one another so that the distances the different backup means move towards said work supporting means need not be the same.
7. The abrading machine of claim 6, further characterized by:
- rate control means operative to govern the rate at which said backup means move towards the work supporting means.
8. The abrading machine of claim 6, further characterized by:
- rate control means for each of said power means operative to cause the same to move its respective backup means at a fast rate during the advance of its associated abrasive belt towards the workpiece in position to be acted upon and at a slower rate while the abrasive belt is in contact with the workpiece.
9. The abrading machine of claim 6,
- wherein said power drive means for all of said backup means act simultaneously but independently of one another, so that either the same or different work can be performed simultaneously by all of said abrasive belts.
10. The abrading machine of claim 9, wherein said backup means are movable between defined projected and retracted positions towards and from the work supports, and further characterized by:
- adjustment means individually operative to adjust the limit to which each of said backup means can be projected,
- whereby the distance said backup means move the work engaging stretches of their respective abrasive belts towards the work supports and the amount ground off the workpieces by each of the different abrasive belts may be predetermined, and the workpieces being simultaneously acted upon can be ground to different predetermined depths.
11. An abrading machine comprising:
- A. a main frame;

- B. a plurality of spaced apart abrading heads mounted in the main frame, each of said abrading heads having a power driven endless abrasive belt traveling orbitally along a defined path that includes a work performing stretch; 5
- C. a frame structure mounted in the main frame for relative translatory movement toward and from said plurality of spaced apart abrading heads;
- D. a plurality of spaced apart rotatable work supports carried by said frame structure, 10
each of said work supports being adapted to releasably hold a workpiece in position to be abraded by the work performing stretch of the abrasive belt of one of the abrading heads;
- E. power drive means operatively connected to effect simultaneous rotation of said plurality of work supports and the workpieces thereon; 15
- F. power drive means operatively connected to effect simultaneous relative work feeding movement between the work performing stretch of said spaced apart plurality of abrading heads and said work supports, to thereby effect work performing engagement between the rotating workpieces and the orbitally traveling endless abrasive belts; and 20
- G. adjustable stop means for selectively and individually limiting relative work feeding movement between the work performing stretch of each of said abrasive belts and said work supports, 25
so that the depth to which the abrasive belts of the different abrading heads cut may be individually predetermined. 30
- 12. The abrading machine of claim 11, further characterized by:
adjustable feed rate controlling means for each of said plurality of abrading heads, operative to govern the rate at which its respective abrasive belt cuts into the workpiece being acted upon by it. 35
- 13. An abrading machine comprising:
A. a pair of cooperatively disposed supports relatively movable vertically toward and away from one another; 40
- B. a plurality of horizontally spaced power driven endless abrasive belts carried by one of said supports to perform different grinding operations; 45
- C. a plurality of work supports carried by the other of said supports;
- D. means connected to move preselected ones of said work supports into vertically aligned and horizontally spaced apart operating positions relative to said abrasive grinding belts; and 50
- E. feed drive means connected to move said abrasive belts different vertical distances toward workpieces carried by said preselected work supports in a manner to remove different vertically measured amounts of material from different workpieces. 55
- 14. In combination with a rotatable work support adapted to hold a workpiece to be abraded and means for rotating the same:
a. a power driven orbitally traveling endless abrasive belt; 60
- B. a backup member engaging the back side of said belt;
- C. first power drive means operable to urge said backup member in a direction to move the portion of said abrasive belt in engagement therewith toward the rotating face of a workpiece on said work support; 65

- D. second power drive means selectively operable to so regulate said first power drive means that said backup member initiates a regulated continuous feeding movement of said abrasive belt into direct grinding engagement with the workpiece on said rotating work support; and
- E. control means selectively operable to regulate the extent of feeding movement controlled by said second power drive means in a manner to selectively control the amount of material removed from a workpiece during an abrasive grinding operation.
- 15. The invention defined by claim 14, further characterized by:
A. hydraulic means connectable to continuously actuate said first power drive means to continuously exert power to actuate said first drive means for movement in the direction to force the abrasive belt into engagement with the workpiece; and
- B. wherein said second power drive means exerts a preselected restraining or braking action on the operation of said first drive means in a manner that the resultantly combined power effects feeding movement of said abrasive belt at a rate sufficiently reduced to perform a selected grinding operation.
- 16. The invention defined by claim 14, further characterized by:
A. reversible hydraulic means connectable to first move said first drive means in the direction to bring said backup member to a retracted position relative to the work support;
- B. means for reversing said hydraulic means for actuating said first drive means for sustained movement in the direction to force said belt into the workpiece; and
- C. power operable feeding means connected to so actuate said second drive means as to exert a preselected braking action on the operation of said first drive means.
- 17. An abrading machine comprising:
A. a plurality of horizontally spaced apart power driven abrasive belts, each having a stretch supported by a backup member engaging the back side of said belt;
- B. a plurality of horizontally spaced apart work supports below the abrasive belts for holding different workpieces to be abraded and for rotating the workpieces about spaced axes that intersect said backup supported stretches of the abrasive belts;
- C. power drive means operative to independently urge said spaced apart backup members downward and thereby effect grinding engagement of the stretches of the abrasive belts supported thereby with the workpieces that are carried by said horizontally spaced apart work supports; and
- D. control means presettable to selectively regulate the extent of downward movement of the backup members respectively effected by energization of each of said power drive means.
- 18. The abrading machine of claim 17, wherein said power drive means yieldingly urge their respective backup members downward, and further characterized by feed rate control means operable to govern the rate at which said backup members move downward.
- 19. In an abrading machine having a plurality of spaced apart abrading heads, each of which has a power driven orbitally travelling endless abrasive belt

and a backup member bearing against a stretch of the belt to define a work performing zone, means for bringing workpieces to be ground to said work performing zones, comprising:

- A. a turntable mounted to turn about a fixed axis that is equispaced from said work performing zones;
 - B. a plurality of work supporting members mounted on said turntable and so positioned thereon that upon indexed unidirectional rotation of the turntable, workpieces on the work supports are successively presented to said work performing zones;
 - C. stop means for defining the indexed positions of the turntable, said stop means comprising
 1. a plurality of stop dogs on the turntable, one for each of the work supports, all equispaced from the axis of the turntable and spaced from one another,
 2. a retractable stop member, and
 3. stationary means mounting said stop member for movement between an operative position in the circular path defined by the stop dogs as the turntable turns, to have an advancing stop dog collide therewith and thus arrest further indexing rotation of the turntable, and a retracted position allowing the turntable to continue its indexing rotation;
 - D. yieldable power means to impart indexing rotation to the turntable and by which, upon engagement of a stop dog with the retractable stop member, the turntable is held firmly against said stop member; and
 - E. controlled power means to momentarily retract the stop member from engagement with a stop dog that has collided therewith, to thereby free said yieldable power means to effect indexing rotation of the turntable to its next position.
20. The abrading machine of claim 19, wherein said stop dogs are uniformly spaced from one another so that with each index of the turntable, the positional relationship between the work supporting members and the abrading heads is always the same.
21. The abrading machine of claim 19, wherein said stop dogs are spaced different distances from one another, so that with each index of the turntable the positional relationship between the work supporting members and the abrading heads changes, with the result that the workpieces on the work supporting members contact the abrasive belts at different areas thereof across the width of the abrasive belts.
22. The abrading machine of claim 19, further characterized in that
- the stop member is a pin and its stationary mounting means is a sleeve in which the pin slides, and the stop dogs have sockets that open in the direction of indexing rotation of the turntable, and in which the operative end portion of the pin is received as a stop dog collides therewith.
23. An abrading machine comprising:
- A. a main frame;
 - B. an abrading head mounted on the main frame and including a power driven endless abrasive belt traveling orbitally along a defined path that includes a work performing stretch;
 - C. work supporting means mounted on the main frame in position to present a workpiece thereon to the work performing stretch of the abrasive belt at

a fixed predetermined distance from the abrading head;

- D. backup means for the work supporting stretch of the abrasive belt;
 - E. means mounting the backup means on the abrading head in position to engage the back of the work performing stretch of the abrasive belt and for movement of the backup means towards and from the work supporting means;
 - F. power means on the abrading head operable to project the backup means towards the work supporting means and thereby force the work performing stretch of the abrasive belt into work performing engagement with a workpiece on the work supporting means; and
 - G. rate controlling means arranged when activated to react between the backup means and the abrading head to oppose said power means and govern the rate at which projection of the backup means towards the work supporting means can take place.
24. The abrading machine of claim 23, wherein the backup means is at all times in engagement with the back of the work performing stretch of the belt.
25. The abrading machine of claim 23, wherein the backup means has a defined retracted position in which the backup means is spaced from the back of the work performing stretch of the abrasive belt.
26. The abrading machine of claim 23, further characterized by
- adjustable stop means to limit the projection of the backup means towards the work supporting means; and means for adjusting said stop means, whereby the depth to which the workpiece is ground may be selectively fixed.
27. The abrading machine of claim 26, wherein said power means retracts as well as projects the backup means.
28. The abrading machine of claim 27, wherein said power means is a hydraulic jack with a fixed stroke, and wherein the retracted position of the backup means is fixedly defined by the bottoming of the retraction stroke of the hydraulic jack.
29. The abrading machine of claim 23, wherein the rate controlling means is adjustable with respect to the point in the projection of the backup member at which the rate controlling means is activated, and means for effecting such adjustment.
30. The abrading machine of claim 23, wherein the means for mounting the backup means comprises:
1. a frame structure rigid with respect to the main frame;
 2. movable carrier structure for the backup means; and
 3. guide means connecting said two structures and constraining the latter to translatory motion; and wherein said rate controlling means comprises
1. jack screw means on said frame structure with the screw thereof in position to resist movement of said movable carrier structure during projection of the backup means towards the work support, so that projection of the backup means after such engagement is at the rate the jack screw operates to effect retraction of its screw, and

2. variable speed motor means drivingly connected with said jack screw means to operate the same at a selected rate.
31. The abrading machine of claim 23, wherein the means for mounting the backup means comprises:
1. a frame structure rigid with respect to the main frame;
 2. movable carrier structure for the backup means; and
 3. guide means connecting said two structures and constraining the latter to translatory motion; and wherein said adjustable stop means comprises
 1. jack screw means on said frame structure with the screw thereof in position to arrest movement of said movable carrier structure during projection of the backup means towards the work support; and
 2. control means for said jack screw means by which its screw may be extended or retracted to effect said adjustment of the stop means.
32. The method of simultaneously machining a surface of each of a plurality of workpieces to predetermined different levels by simultaneously grinding the same with an equivalent number of power driven orbitally traveling endless abrasive belts, each having a work performing stretch thereof supported by a backup member which engages the back of the belt, which method comprises:
- A. fixing each workpiece on a work supporting member that is rotatable about an axis that passes substantially perpendicularly through the workpiece thereon;
 - B. rotating the work supporting members about said axes;
 - C. while the work supporting members and the workpieces thereon are rotating, applying to the backup member of each of the abrasive belts a feed force to thereby project the backup member towards a workpiece in position to be acted upon by the abrasive belt associated with that backup member and effect work performing engagement between the abrasive belt and said workpiece;
 - d. during the time the abrasive belts are in engagement with the workpieces maintaining the rate at which said feed force projects the backup members towards the work supporting members constant regardless of interruptions in the surfaces of the workpieces being ground; and
 - E. by independently adjustable stop means, arresting the projection of the backup members towards their respective workpieces when their respective workpieces have been ground to their predetermined levels.
33. A grinding machine comprising the combination of:
- A. a turntable having a plurality of work supports arranged to travel in a circular orbit upon rotation of the turntable;
 - B. a pair of separate and independent abrading heads above the turntable at circumferentially spaced locations on the circular orbit of the work supports, so that said locations constitute work stations, each of said abrading heads having a power driven endless abrasive belt and a backup member to hold a downwardly facing stretch of the belt against a workpiece on a work support therebeneath;

- C. means independent of one another to effect relative motion towards one another between the backup members of the two abrading heads and the work supports then at the work stations, to thereby produce and maintain work performing engagement between both abrasive belts and the workpieces on said work supports; and
 - D. means for indexing the turntable in increments so related to the circumferential distance between the work supports that with each index two of said work supports are brought to said work stations and another work support is brought to an intermediate station on the circular orbit of the work supports, so that during the intervals between indexing of the turntable, the two workpieces at the work stations can be ground while loading and unloading of workpieces can take place at said intermediate station.
34. The grinding machine of claim 33, wherein at one of said work stations the abrading head does rough grinding and at the other the abrading head does finish grinding; and wherein the direction in which the turntable is indexed brings a workpiece from said intermediate station sequentially to said rough grinding and then said finish grinding stations.
35. The invention defined by claim 33, wherein said relative motion between the abrasive belts and the work supports results from downward motion of the backup member, and means for imparting downward motion to the backup member.
36. The invention defined by claim 35, wherein said means for imparting downward motion to the backup members of the two abrading heads function independently of one another.
37. The invention defined by claim 33, wherein the backup member of at least one of said abrading heads is a flat platen.
38. The invention defined by claim 34, wherein the backup member of the abrading head that does the rough grinding is a contact drum and the backup member of the abrading head that does finish grinding is a flat platen.
39. The invention defined by claim 34, wherein there are four work supports on the turntable, and wherein said work stations are substantially diametrically opposite with respect to the axis of the turntable.
40. The invention defined by claim 33, wherein said relative motion towards one another between the abrasive belts and the work supports is effected by power drive means for each abrading head operative to force its backup member towards the work support therebeneath; and further characterized in that the rate at which said power drive means forces its associated backup member towards the work support therebeneath is controllable; and means for maintaining said rate constant at a preselected value regardless of discontinuity in the surface of the workpiece being ground.
41. A surface grinding machine comprising the combination of:
- A. a plurality of separate and independent abrading heads, each having a power driven endless abrasive belt;
 - B. a plurality of work supports adapted to have workpieces secured thereto with the surface thereof that

is to be ground positioned for presentation to the abrading heads;

- C. means operatively connected with the work supports to simultaneously bring one of the same into cooperative relationship with each of the abrading heads;
- D. a backup member to hold the abrasive belt of a first one of said abrading heads in engagement with a workpiece surface presented thereto, with the contact between the belt and the workpiece limited to a narrow zone extending transversely across the belt;
- E. a backup member to hold the abrasive belt of a second one of the abrading heads in area-wide flat grinding engagement with a workpiece surface presented thereto; and
- F. means independent of one another to effect relative motion through selected distances towards one another between the backup members of the abrading heads and the work supports in cooperative relationship therewith, to thereby produce and maintain the aforesaid narrow linear zone of contact between the workpiece surface and the abrasive belt at said first identified abrading head while at said second identified abrading head the abrasive belt is held against the surface of the workpiece thereat with the aforesaid area-wide flat grinding engagement.

42. The invention defined by claim 41, wherein the abrasive belt of the abrading head at which the backup member is a flat platen is trained over three rolls arranged in a triangle, the cylindrical surfaces of two of which are tangent to a plane that is perpendicular to the axis about which the work support in cooperative relation with said abrasive belt rotates, and wherein said flat platen overlies a substantial area of the stretch of said abrasive belt extending between said two rolls.

43. A grinding machine comprising the combination of:

- A. a turntable having four work supports thereon positioned to travel in a circular orbit upon rotation of the turntable, said work supports being arranged in substantially diametrically opposite pairs with respect to the turntable axis;
- B. a pair of abrading heads above the turntable at substantially diametrically opposite locations on the circular orbit of the work supports, so that said locations constitute work stations, each of said abrading heads having a power driven endless abrasive belt and a backup member to hold a downwardly facing stretch of the abrasive belt against a workpiece on a work support therebeneath;
- C. power drive means for the backup member of each abrading head to effect movement thereof towards the work support in position presenting a workpiece to its associated abrasive belt and thereby force the work performing stretch of the belt into grinding engagement with a workpiece on said work support, said power drive means for the backup members of the two abrading heads being independent of one another, so that different amounts of stock can be removed from a workpiece successively presented to the two abrading heads;
- D. means for indexing the turntable in increments so related to the orbital distance between the work

supports that with each index one of said pairs of work supports is brought to said work stations and the other pair is brought to intermediate stations on the circular orbit of the work supports,

so that during the intervals between indexing of the turntable, the two workpieces at the work stations can be ground while loading and unloading of work pieces can take place at at least one of said intermediate stations; and

- E. adjustable means for limiting the distance said power drive means effects movement of the backup member of each abrading head towards the work support therebeneath,

so that the distance the backup members are moved towards the work supports may be the same or alternately different with the successive presentation to the abrading heads of the workpieces on the two pairs of work supports.

44. The grinding machine of claim 43, further characterized by rate control means operative to govern the rate at which said backup members are moved towards the work supports.

45. In an abrading machine having a plurality of spaced apart abrading heads, each of which has a power driven orbitally travelling endless abrasive belt and a backup member bearing against a stretch of the belt to define a work performing zone, means for bringing workpieces to be ground to said work performing zones, comprising:

A. a turntable mounted to turn about a fixed axis that is equispaced from said work performing zones;

B. a plurality of work supporting members mounted on said turntable and so positioned thereon that upon indexed unidirectional rotation of the turntable, workpieces on the work supports are successively presented to said work performing zones; and

C. stop means for defining the indexed positions of the turntable with each such position different from the rest with respect to the width of the abrasive belts so that workpieces on the work supporting members contact the abrasive belts at different areas thereof across the width of the abrasive belts.

46. The surface grinding machine of claim 41, wherein there are two abrading heads, and

wherein at said first identified abrading head the backup member is a contact drum and at said second identified abrading head the backup member is a flat platen.

47. The surface grinding machine of claim 46, wherein said means for simultaneously bringing said work supports into cooperative relationship with the abrading heads comprises a turntable mounted to turn about a vertical axis that is equispaced from the abrading heads,

wherein the abrading heads are positioned above the turntable at substantially diametrically opposite sides of the turntable axis; wherein the work supports, of which there are more than the number of abrading heads, are mounted on the turntable at substantially equiangularly spaced locations,

and further characterized by:

means for indexing the turntable in increments so related to the angular distance between the work supports that upon securement of a workpiece to a work support not in position at an abrading head, while two other work supports are cooperatively positioned at the abrading heads, that workpiece can be successively presented to the abrading heads without being removed from the work support.

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