This invention relates to honing apparatus for honing the bores of workpieces, such apparatus including reciprocable and rotatable spindle means carrying at one end thereof honing means which is adapted to enter one end of the bore. Such honing means includes honing or abrading elements adapted to be adjusted or expanded radially relative to the workpiece bore by an axially shiftable rod member or the like extending into the bore of the spindle means.

The present invention has for a particular objective thereof the provision of gauge means in the form of an annular gauge device encircling the spindle means and provided with annularly spaced radially projecting workpiece bore entry means preferably in the form of a series of gauge portions acting during operation on the same end of the workpiece bore as the honing means entering to hone the bore. The gauge device is mounted for limited lateral movement or transaxial floating relative to and transversely of the axis of the workpiece bore and is adapted to have operative entry into the bore in engagement therewith when the bore has been honed to substantially a predetermined size by the honing means. The provision of gauge means pursuant to the present invention renders it possible to improve materially the control of the workpiece bore sizing and the cessation of the honing operation. Accordingly, means is provided for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation.

A further object of the present invention is to provide improved means for continuously gauging the size of the bore being honed, said improved means being so constructed and arranged that as soon as the desired size of the bore is reached a control means is actuated whereby the abrading or honing elements are collapsed, the abrading or honing tool is withdrawn from the bore, and the rotary and reciprocatory movements of the spindle are stopped.

It is a further object of the present invention to provide an improved means for mounting the sizing element, preferably on the honing tool body above the abrading head, whereby the sizing element will be permitted to float laterally of the abrading head thereby to compensate for any axial misalignment of the longitudinal axis of the machine spindle relative to the longitudinal axis of the bore of the workpiece.

Further details and objects of the particular embodiment of the invention herein illustrated will appear in the following description, reference being had to the accompanying drawings forming a part of the specification wherein like reference numerals designate corresponding parts in the several views.

Fig. 1 is a sectional view of a honing apparatus having the sizing and control means embodied in the present invention mounted thereon.

Fig. 2 is a top elevation of Fig. 1.

Fig. 3 is an enlarged detail of the sizing ring element.

Fig. 4 is a sectional view of a modification of the present invention.

Fig. 5 is a sectional view taken substantially along line 5—5 of Fig. 4 looking in the direction of the arrows.

Fig. 6 is a sectional view taken substantially along line 6—6 of Fig. 5 looking in the direction of the arrows.

Fig. 7 is a fragmentary sectional view illustrating a portion of a machine head to which the abrading tools illustrated herein are adapted to be mounted for rotation and reciprocation thereby.

Fig. 8 is a fragmentary sectional view in part similar to Fig. 1 and more particularly illustrating a modification of the means providing for the lateral float of the sizing element.

Fig. 9 is a view in part similar to Fig. 8 illustrating another embodiment of the means mounting the sizing element and providing for lateral float thereof.

Fig. 10 is a sectional view taken substantially along line 10—10 of Fig. 9 looking in the direction of the arrows.

Fig. 11 is a sectional view taken along the line 11—11 of Fig. 12 and in part similar to Fig. 8 illustrating another means mounting the sizing element and providing for lateral float thereof.

Fig. 12 is a sectional view taken substantially along line 12—12 of Fig. 11 looking in the direction of the arrows.

Fig. 13 is an enlarged fragmentary view of a portion of Fig. 11 in order to show the same more clearly.

Fig. 14 is a view in part similar to Fig. 8 illustrating a further embodiment of the sizing element mounting means providing for lateral float thereof.

Fig. 15 is a sectional view taken substantially along the line 15—15 of Fig. 14 looking in the direction of the arrows.

Fig. 16 is an enlarged fragmentary vertical section illustrating particularly the floating gauge means and the position of the gauge ring with respect to the workpiece bore when the spindle and workpiece are out of alignment.

Fig. 17 is a view similar to Fig. 16 showing the gauge ring shifted laterally and entering the workpiece bore.

Fig. 18 is an enlarged fragmentary sectional view illustrating the floating connection between the cone carrying member and its actuating rod or shaft.

Before my explaining in detail the present invention it is to be understood that the invention is not limited in its application to the details of construction and arrangements of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

This application is a continuation in part of my application, Serial No. 212,254, filed February 23, 1951, now abandoned.

Referring first to Figs. 1 to 3 of the drawings wherein there is illustrated, by way of example, a certain embodiment of the present invention, the numeral 10 designates generally a honing device supported in a vertical position and having an abrading head 11 at the lower end thereof. The abrading head 11 may be of any suitable construction having a cylindrical enlargement 12 and an upwardly extending reduced tubular portion 13. The cylindrical enlargement 12 is formed with a plurality of slots 14 spaced equal distances from one another circumferentially of the enlargement and extending for the full length of the latter. Seated in each slot 14 is a holder 15 extending substantially for the full length of the slot and having its outer surface recessed to receive an abrading element 16.

Supported within the cylindrical enlargement is a cone
carrying member 17 having axially spaced cones 18 and 19 concentric with the axis of the abrading head. In accordance with conventional practice, the cones engage shoes 20 slidably supported in slots 21 formed in the cylindrical enlargement 12. The slots 21 are arranged in the enlargement 12 to open into the radially inner sides of the slots 14, so as to enable the shoes to engage the base portions of the holders 18. The respective holders are resiliently urged into bearing engagement with the shoes 20 by garter springs 22, which respectively encircle projections at opposite ends of the holders. Guide elements 23 of fibre or other material are supported on the cylindrical enlargement 12 between the abrading head 1 and the holder 18.

The uppermost extension 19 of the abrading head 11 is coaxially aligned with a tubular body member 24, the lower reduced cylindrical portion 25 of the tubular body member being received in the upper tubular portion 13. The body 24 and the tubular portion 13 are held against relative displacement by radially extending pins 26. At its upper end 24a, the tubular body member is provided with external threads 27 and internal threads 28. Threaded to the internal threads 28 is a tubular pilot member 30 adapted to be inserted into the hollow spindle coupling 30 (shown in dotted outline) of a conventional honing machine. The pilot member 29 and the upper portion 24a are held together against relative displacement by pins 31 insertable in aligned holes in both members after they are threaded together. Similarly, the pilot member 29 and the spindle coupling 30 have aligned holes adapted to receive pins 32 to lock the two together for coordinated rotational and reciprocatory movement. Suitable lock nut means 33 are threaded on the externally threaded portion 27 of the upper portion 24a of the tubular body member to lock the same against displacement relative to the spindle coupling 20.

Any suitable mechanism may be provided for rotating and reciprocating the honing apparatus 10 relative to the workpiece. In Fig. 7 a portion of such a mechanism is illustrated and will hereinafter be described.

It will be noted that the reduced cylindrical portion 13 of the head 11, the body member 24 and the pilot member 29 are shown and have been described as tubular. This is to accommodate a rod 34 having a pinned connection with the cone member 17. As shown in Fig. 18, the lower end 34a of the rod 34 is loosely fitted into a longitudinally bored bushing 35 or extension 17b of the cone carrying member. The extreme lower end of the rod end 34a is provided with a spherical surface adapted to seat in a corresponding spherical recess 17b at the base of the longitudinal bore in the core carrying member shoulder 17a. The end 34a of the rod 34 and the shoulder 17a of the cone carrying member 17 are adapted to receive a pin 35, the pin preferably being a press fit into the shoulder 17a and being very loose in the rod end 34a. The foregoing construction and arrangement provides in effect a universal connection which permits the core carrying member 17 to float on the end 34a of the rod 34. The holding member 17 will be able to axially maintain alignment with the abrading head 11. The rod 34 is adapted to be contacted at its upper end 34b by an incremental feed means illustrated in and to be described with reference to Fig. 7. The incremental feed means is adapted to force the rod 34 downwardly at periodic intervals thus causing the cones 18 and 19 on the cone member 17 to expand the abrading elements 16. A spring restoring means is provided to lift the rod 34 upwardly when the pressure of the feed means is released, the upward movement of the rod 34 causing the cones 18 and 19 to move upwardly thereby permitting the abrading elements 16 to move radially inwardly or to collapse. The spring means is preferably a coil spring 36 compressible between a shoulder 37 within the bore of the tubular body member 24 and a lateral pin 38 carried near the upper extremity of the rod 34.

The operation of the incremental feed means for expanding the abrading element 16 as well as the operation of the mechanism causing the rotation and reciprocation of the spindle 30 carrying the honing apparatus 10 are generally controlled by electrically actuated means. Upon the completion of a honing operation the operator is required to push a stop button on the machine which causes the rotation and reciprocation of the spindle to cease. However, movement of the incremental feed means continues but in a reverse direction so as to release the downward pressure rod 34. The spring means 36 will then cause the cone member 17 to move axially upwardly thus permitting the abrading elements to collapse. The collapse of the abrading elements is sequentially followed by an upward movement of the head 11. The abrading head being withdrawable from the cylinder bore being honed. It is readily apparent that for a most efficient rate of operation there should be no interruption of the honing operation until the bore has been honed to the desired dimension. Nor should the honing operation be permitted to continue beyond the dimensional tolerance allowed for the bore diameter since obviously this would result in a part good only for the scrap heap.

With the above in view the novel features of the present invention embody an improved means for continuously gauging the diameter of the bore being honed and for automatically actuating a control means to bring the honing operation to a conclusion as soon as the bore has been honed to the proper diameter. In the embodiment of the invention illustrated in Figs. 1 to 3 inclusive, the sizing and control means comprises a tubular body 39 adapted to be mounted on the tubular body member 24. The lower end of the body 39 has a reduced cylindrical portion 40 which is externally threaded. A collar 41 is threaded on the reduced portion 40 of the body 39 and is adapted to have mounted thereon by means of shouldered studs 42 a gauging or sizing ring member 43, hereinafter described in more detail. The gauging or sizing member 43 is in effect a plug having gauging means effective at a given diameter corresponding to the diameter desired to be honed in the bore of a workpiece. As will hereinafter be explained, the honing operation will continue at least until after the gauging means of the member 43 is forced into the bore of the workpiece.

It will be noted that the tubular body 39 is journaled on the tubular member 24 by two spaced bushings 44 and 45. A snap-ring 46 is fitted into a groove in the tubular part 24 and is adapted to act as a stop to prevent the tubular body 39 from dropping below a predetermined position on the tube member 24. The snap-ring 46 is press-fitted into the bore of the tubular body 39 and bottoms against a ring or wall 47 at the upper end of the reduced portion 40 of the tubular body 39. The upper surface of the bushing 44 is grooved to receive a number of small ball bearings 48 on top of which is placed a ring 49. The lower end of the snap ring 46 is pressed against a coil compression spring 50. The coil compression spring 50 reacts against another ring 51 which in turn carries a series of ball bearings 52 in contact with a groove in the lower surface of the upper bushing 45. The upper bushing has a slip fit relative to both the tubular body 39 and the tubular part 24 but is retained in proper relation.
thereto by a retainer or snap ring 53 fitted into a groove in the tubular part 24. As illustrated in Fig. 3 the sizing gauge 43 is preferably in the form of a generally square sided ring having a circular bore 54. This ring is preferably made in two cylindrical pieces adapted to be clamped together by bolts 55. This two piece construction permits the interchange of rings of different sizes without requiring the dismounting of the honing apparatus. The sizing gauge 43 is provided at the four corners thereof with two pairs of oppositely disposed hardened wear inserts 43a, the upper portions of which are accurately machined to provide arcuate gauge or sizing surfaces 43b of the required diameter to correspond to the desired diameter of the finished bore of the workpiece. The inserts or gauging elements 43a terminate in tapering lead portions or lead means 43c which progressively narrow in effective diameter and, hence, are adapted to enter in varying amounts the unfinished bore of the workpiece. As above described, the sizing ring or member 43 is adapted to be held on the mounting collar 41 by studs 42 which may have a press fit in holes in the collar, the studs being additionally retained in place by snap rings 42c secured to the upper ends thereof. The stud receiving holes 56 in the sizing ring are of predetermined greater diameter than the corresponding shoulders 42a on the shoulder portions 42. The lengths of the shoulder portions 42 are great enough to prevent the gauge ring 43 from being clamped tightly between the heads 42b on the studs and the lower face of the collar 41. This construction forces the sizing ring 43 and enables it to freely float or shift a predetermined amount laterally or transversely of the spindle to compensate for uneven stone wear or misalignment of the longitudinal axis of the tool spindle with the longitudinal axis of the bore of the workpiece being honed.

The operation of the gauging device described above is as follows: When the abrading head 11 is at the upper portion of the cylinder bore being honed, the tubular body 39 carrying the sizing gauge or ring 43 is at its lowermost position on the spindle of the honing apparatus or tool 10. As the abrading head 11 travels downwardly in the bore B being honed and the sizing gauge engages the end of the bore the tapered lead or cam portions 43 of the gauge, being of reduced effective diameter, will be able to enter the unfinished bore whereas the gauging portions 43b above the lead portions will not be able to enter the bore until it is finish honed to the desired size. When the bore diameter is too small to permit entry of the gauging or sizing portions 43b of the gauge the latter is rotated to a position 43a laterally to a position in which the spring 50 will disengage the angle lead 43c at the left of this figure and the spring will, however, force the gauge ring by camming action laterally and center it with the axis W of the workpiece. When, therefore, the workpiece bore B has been honed to the desired size the gauge portions 43b will be forced into the bore, as shown in Fig. 17, and due to the fact that the gauge, ring has been centered with the axis W of the workpiece bore and the honing operation is stopped as soon as the gauge portions enter the bore, the bore will not be honed oversize or appreciably so.

From the foregoing it will be seen that the spring acting on the gauge means 41, 43 and the gauge lead portions 43c acting on the end of the bore B serve to shift or displace the gauge axially 43 radially to a position in which it is substantially centered with the workpiece bore. Hence, when the bore has been honed to the correct size the spring of the action will also force the gauge and its sizing portions fully into the bore whereupon control means hereinafter described operates to discontinue the honing operation. By mounting the gauge so as to freely float transversely of the spindle it is possible to center the gauge with the workpiece bore and, hence, the gauge will fully enter the bore when honed to the desired diameter, thus eliminating the disadvantage of honing the bore to any appreciable or objectionable oversize. The floating gauge not only compensates for spindle runout but also for uneven abrading stone wear which frequently occurs owing to the fact that the stones often vary in relative hardness.

The ball bearings 48 and 52 between the annular rings 49 and 51 and the respective bushes 44 and 45 are for the purpose of minimizing frictional drag on the ends of the spring 50. It will be understood that the tubular body 39 would tend to rotate at the same rate as the honing device 10 rotates and would continue to do so until the lower edge of the gauging element 43 came in contact against the edge walls of the bore of the workpiece. At this time the frictional engagement of the gauge ring with the edge walls of the workpiece would generally be sufficient to slow down or completely stop rotation of the tubular body 39. However, the upper bushing 45 which, as has been stated, has a slip fit relative to the inner wall of the tubular body 39, because of the frictional contact between its upper surface and the retaining ring 53 would continue to rotate with the tubular body portion 24. It is thus apparent that if the spring 50 were seated directly against the lower surface of the upper bushing 45 while the bushing was rotated at a faster rate than the lower end of the spring, the spring would tend to be twisted. One of the more undesirable effects of these would be that the spring, due to being twisted, would be internally reduced in diameter thereby causing it to bind on the tubular body portion 24. The interposition of the ball bearings 48 and 51 ensures that there will be no such twisting action on the spring or that it will be minimized to such a degree as to be negligible. But as will be hereinabove explained, the tubular body is preferably restrained against rotation at all times and thus the foregoing arrangement for eliminating frictional drag on the spring ends is an important feature of construction in the present embodiments.

As soon as the bore of the workpiece has been honed to the desired size, at which time the spring 50 will force the gauge and its sizing portions fully into the workpiece bore, the honing operation is discontinued. This is accomplished in the present embodiments by means controlled by the travel of the gauge ring 43 into the finished bore. A longitudinally extending arm member 57 is bolted to the side of the tubular member 39 by means of bolts 58. Mounted on the upper end thereof is an adjustable block 59. The block 59 may be locked in adjusted position by any suitable means, such as a set screw 60 carried therein. In order to prevent the tubular body member 39 from rotating with the honing device 10, an angle bracket 61 is fastened to the table of the honing machine, this bracket being disposed in abutting rela-
tion to the block 59 thereby restricting the block 59 to movement in the direction parallel to the axis of the spindle of the honing machine and holding the tubular body member 39 against rotation. It will be understood that the block is in the form of a ring, as disclosed in my copending application, Ser. No. 212,234, now abandoned, it would not be necessary to hold the same and the tubular body member 39 against rotation. The angle member 61 is positioned so that the block 59 is in alignment with the actuating finger or lever 62 of a limit switch 63 mounted on the table of the honing machine in any convenient place, herein illustrated as mounted on the fixture frame 64 supporting the fixture guide bushing 65. However, the contact block 59 will not trip the actuating finger or lever 62 until the gauging element 43 is able to enter the bore of the workpiece thereby permitting the tubular body 39 to travel the full downward stroke of the honing apparatus or tool 10. When the sizing gauge fully enters the finished bore of the workpiece as above described, the contact block 59 will trip the actuating lever 62 which will cause the limit switch 63 to operate. The limit switch 63 is actuated by contacting the arm of the rotation and reciprocation of the honing spindle, to cause the abrading elements to collapse and to cause the withdrawal of the abrading head from the workpiece.

The embodiment of the invention illustrated in Figs. 4 to 6 inclusive is similar in many respects to the previously described embodiment and is mainly concerned with a modified construction and arrangement for mounting the floating gauge ring so that it will be urged by spring action into the bore of the workpiece upon the bore being honed to the desired dimension. In Figs. 4 to 6 there is illustrated by way of example an abrading head 70 which is somewhat simpler in construction than the previously described abrading head 11. The abrading head 70 has a cylindrical enlargement 71 and an upwardly extending reduced tubular portion 72. The cylindrical enlargement 71 is formed with a plurality of slots 73 spaced equal distances from one another circumferentially of the enlargement and extending for the full length of the latter. Seated in each slot 73 is a holder 74 extending for the full length of the slot and having its outer surface recessed to receive an abrading element 75. The abrading elements are movably and radially outwardly by the same type mechanism as described with regard to the previous embodiment. That is, a cone carrying member 17 having cones 18 and 19 thereon movable downwardly by the operative relationship of a rod 34 with an incremental feed means extending through the honing machine spindle coupling 30. The one shown in the figure is collapsible upon release of the downward feed pressure through the restoring action of a spring 36 reacting between a portion of the tubular body member 24 and the laterally extending pin 38 carried by the rod 34, as in the previous embodiment.

The tubular body member 24 of the present embodiment is connected to the honing machine spindle coupling 30 for rotation and reciprocation in the same manner as in the previous embodiment.

In the present embodiment the sizing and control means comprises a cylindrical sleeve 76 mounted on the tubular body member 24 and held against displacement relative thereto by a set screw 77 engageable within a groove 78 in the body portion 24. The sleeve 76 has an externally threaded portion 76a at the lower end thereof which is adapted to receive a collar 79. The collar 79 is adapted to be engaged by the shoulder studs on the gauging or sizing ring 81. As in the previous embodiment the shoulder studs 80 are smaller in diameter than the holes 82 in the gauging ring and the latter is free on the studs so as to permit the gauging ring to float laterally relative to the longitudinal axis of the tool or honing device in order to permit compensation for any slight misalignment of the tool spindle with the bore being honed. As in the previous embodiment the sizing or gauging element is provided with four equally spaced hardened wear inserts 83 accurately machined to the required diameter. The operation of the gauging means is the same as described above.

In the present embodiment the gauging or sizing element 81 is spring urged in the direction of the workpiece bore by spring means carried between the sizing element or ring 81 and the mounting collar 79 rather than by spring means between the gauging element body portion and the honing device body portion as in the previous embodiment. As shown in Fig. 6 the embodiment is provided with pins 84 extending upwardly into cylindrical recesses 85 in the mounting collar 79. Each cylindrical recess is provided with a small coil spring 86 retained within the cylindrical recess at the upper end thereof by a small set screw 87. Downward movement of the gauging element is limited by the caps 88 on the shoulder studs 80. In operation the springs 86 will be compressed each time the sizing element attempts to enter the bore of the workpiece if the bore has not been honed to the desired size. As soon as the bore reaches the desired dimension the springs will urge the sizing ring into the bore.

In the present embodiment the contact block 59 adapted to engage the contact finger 62 of the limit switch 63 is carried on an arm member 83 which is fastened directly to the sizing ring by means of a screw 89. The reason for mounting the contact block in this manner is that the assembly of the sizing element is the only part of the sizing device which is restrained against movement in the direction of downward movement of the spindle until the bore has been honed to proper dimension. Upon the bore being honed to the proper dimension the sizing element and therefore the contact block will be permitted to move downwardly a sufficient distance to trip the limit switch. The mounting sleeve 76 is held against rotation with the tubular body member 24 by means of an arm member 90 fastened thereto by means of a screw 91, which arm member has a portion 92 contacting an angle bracket similar to the angle bracket 61 described in the previous embodiment.

In Fig. 7 there is illustrated an exemplary machine head 100 adapted to reciprocate and rotate the abrading or honing tool 10 and also provided with means for shifting the rod 34 and the cone carrying member 17 in abrading element expanding direction. The mechanism illustrated in Fig. 7 comprises a head casting 101 which is adapted to be slidably mounted on the upper surface of a machine bed 102 (not shown). The head casting 101 is operatively coupled to a hydraulic ram mechanism (not shown) which sequentially raises and lowers the head casting 101. As will be described, the honing tool 10 is coupled to the head casting and the raising and lowering of the head casting 101 imparts to the honing tool the necessary reciprocatory motion, which is one of the component motions of the honing stroke of the tool.

The head 101 has rotatably journaled therein a hollow spindle 102. In the illustration the spindle 102 is journaled in spaced thrust bearings 103 and is provided at its upper end with a gear toothed portion 104. The gear 104 is in mesh with a driving gear 105 carried on a shaft 106 journaled on suitable bearings 107 in the head casting 101. The shaft 106 is adapted to be geared by any conventional gearing system to an electric motor (not shown). The spindle 102 is adapted to receive a tapered shank portion 108 of a coupling device 109 adapted to connect the upper end or pilot end 29 of the honing tool 10 to the spindle 102. The tapered shank 108 is an extension of a cylindrical member 110. The cylindrical member 110 is located at its lower end 111 to the upper end 102 of a sleeve member 113, the connection between the
cylindrical member 110 and the sleeve member 113 being in the nature of a conventional universal joint. The lower end 114 of the sleeve member is provided with suitable bayonet slots 115 adapted to receive the pins 32 mounted in the pilot portion 29 of the honing tool body. It will be noted that all of the various spindle and sleeve members illustrated in Fig. 7 are provided with a central passageway therethrough aligned to receive a ram 116. The ram 116 is adapted to engage the upper end of the rod 34 and to exert a downward pressure thereon. The ram 116 has mounted thereon at its upper end a piston 117 slidably in a cylinder 118. Oil under pressure is fed through the alternative valve system and is controlled in relation to the honing operation. That is, during the abrading of the metal of the workpiece, oil is fed through the port 119 to the piston 117 downwardly with the ultimate result that the cone member 17 is urged in a direction to cause expansion of the abrading elements. Upon completion of the honing operation, oil under pressure will enter the cylinder 118 through the port 120 causing the piston 117 to rise thereby relieving the ram pressure on the rod 34. The springs 22 will thus become effective to cause the abrading elements to collapse, i.e., move inwardly radially of the abrading head 117.

It will be understood that a workpiece to be honed is generally mounted in a fixture or holding means on the work supporting table of the honing machine. Under ideal conditions the axis of the workpiece bore and the axis of the machine spindle would coincide. But in practice it has been found necessary to make allowances for the inherent misalignment found in the machine and resulting from the setting-up thereof. The modern trend is toward multi-spindle machines which only multiplies the difficulties in securing substantially accurate alignment of the work to the operative parts of the machines. As has been described previously, it is required that the abrading head and the abrading elements to float relative to the honing tool body; and the coupling between the machine spindle and the honing tool also provides for float of the latter relative to the former. The described structure in effect permits the effective center of the abrading elements to shift laterally so that it will at all times coincide with the center of the workpiece bore regardless of any slight misalignment of the abrading head supporting means and the workpiece. This provision for lateral displacement is also desirable to permit automatic compensation of the uneven wear of the abrading elements which frequently occurs.

In order accurately to measure the bore being honed, it is important that the center of the gauging device be permitted to move so as to coincide with the effective center of the abrading elements. This ensures the gauge entering the bore of the workpiece immediately upon the bore being honed to the predetermined size. Since the abrading head is permitted to shift so as to find the true center of the bore, the gauging or sizing element correspondingly is permitted to shift so that the gauging or sizing element maintains true axially alignment with the abrading head. This ensures that the gauging or sizing element is properly indicating the true center of the abrading elements and not an erroneous one from the misalignment of the abrading head supporting means and the workpiece.

In Figs. 8 to 15 inclusive there are illustrated several embodiments of the present invention relating to different methods of incorporating provision for lateral float in the mounting of the sizing or gauging element.

In the embodiment of Fig. 8, a collar 121 is threaded onto the threaded portion 40 of the cylindrical or tubular body member 39. A spacer nut 122 is provided to position and lock the collar 121 in place. At its lower end the collar 121 is provided with a circumferential recess 123 and a ring-like portion 124. In the present embodiment the sizing or gauging element or ring 125 is provided with a circumferential groove 126 running around the bore wall 127 thereof. It will be noted that the groove 126 cooperates with the ring-like portion 124 in the nature of a tongue and groove effect. The sizing element 125, although held by the tongue and groove against longitudinal displacement relative to the tubular body member 39, is free to shift laterally. In order to provide for free lateral float of the gauge ring and, as shown in Fig. 8, there is clearance in a radial direction between adjacent surfaces of the sizing element 125 and the collar 121. This radial clearance permits the sizing element to shift or float radially relative to the tubular body member 39 thereby permitting the sizing element to compensate for misalignment of the honing tool with the workpiece bore being honed. The operation of the gauge ring is the same as described above.

The gauging ring of the present embodiment is a two piece device as was the gauging element shown in Fig. 3 and accordingly may readily be mounted on the collar 121 by first being separated into two halves and then being bolted together in place on the retaining ring 124 of the collar 121.

In the embodiment illustrated in Figs. 9 and 10, the cylindrical or tubular body 39 which is adapted to be mounted on the tubular body member 24 of the honing tool is provided with a ring appendage or flange 128 at the lower end thereof. The flange 128 supports a sleeve member 129 thereon as follows: The sleeve member has internal threads at the upper end 130 thereof engaged by external threads 132 on an elongated member 131 adapted to be drawn down by a suitable tool. The flange 128 is engaged at the upper and lower edges thereof by the lower end of the member 131 and the upper surface of a shoulder 133 on the sleeve 129. It will be understood that the member 131 is threaded into the sleeve 129 only so far as is necessary to provide a loose fit between the flange 128 and the adjacent surface of the sleeve member 129 and the member 131. Radial clearance is provided between the peripheral surface 134 of the flange 128 and the adjacent outer surface 135 of the sleeve member 129 thus permitting the sleeve member 129 to have free limited movement radially of the tubular body 39 or, in other words, permitting the sleeve to float radially of the honing tool body 24.

At its lower end the sleeve member 129 is provided with additional internal threads 136 adapted to be engaged by the external threads 137 on another sleeve 138. The sleeve 138 at the lower end 139 thereof has a size and groove connection 140 with a sizing or gauging element or ring 141. However, the tongue and groove connection 140 of the present embodiment is distinguished from that of the embodiment of Fig. 8 in that no radial clearance is provided since the float is not intended to take place at this connection but at the upper connection or mounting of the sleeve member 129 on the flange 128. As in the previous embodiments, the gauging element or ring 141 is of a split ring construction to permit the rapid mounting and interchange thereof.

The operation of the gauge means, including ring 141 and its support 129, is also the same as above described.

In the embodiment of Figs. 11, 12 and 13 the tubular body member 39 is similar to that shown in Fig. 1. That is, it is provided with a reduced cylindrical portion 40 at the lower end thereof which is externally threaded. A collar or gauge ring adaptor 142 is threaded on the reduced portion 40 and is adapted to mount thereon in depending relation by means of screws or shoulder studs 42 the gauging or sizing element 143. The holes 144 in the gauging or sizing element 143 which receive the shoulder studs 42 are of greater diameter than the diameter of the shoulder studs. To this point the construction is similar to that described with respect to Fig. 1. That is, the enlarged holes 144 permit the gauging or sizing element to float and be...
shifted laterally relative to the collar or gauge ring 142, similarly to the embodiments of Figs. 1 to 5. However, in the present embodiment a means has been provided which automatically centers the sizing element every time it is lifted from the workpiece bore edge and maintains it centered until the next contact with the bore edge is made and which time it permits it to float or be displaced to center with the workpiece bore. The construction of the present embodiment is of particular advantage when the honing operation takes place when the machine spindle is at an angle rather than straight up and down. There are many present applications in which the honing operation is done with the spindle at an angle or in a horizontal position. Accordingly, without a gauge element centering means, the gauge element would always drop down to the low side when out of engagement with the workpiece bore edge and in some instances might not satisfactorily center itself upon attempted entry into the bore.

A gauge ring or gauge ring adapter is provided with four equally spaced steel balls 145 which are adapted to project beyond the lower edge 146 of the collar. Each ball is backed up by a plug 147 under pressure of a coil spring 143 retained within an aperture 149 in the collar. Each spring 149 is held in place by a plug screw 150. The upper surface of the gauge ring 143 is provided with four correspondingly equally spaced concave indentations 151, see Fig. 13, the surface of each being in contact with the projecting portion of a ball 145. The component of force exerted by each spring urged ball 145 on the surface of each indentation is such that the gauging or sizing element is continually being urged to a centered position with respect to the centerline of the honing tool.

The embodiment of Figs. 14 and 15 illustrates a second method of construction relating to a centering means for yieldingly maintaining the sizing or gauging ring centered relative to the honing tool centerline. The present embodiment differs from the embodiment of Figs. 11 to 13 inclusive, in that the sizing ring 152 is spaced below the bottom edge of the gauge adapter ring or collar 142, the shoulder studs 153 being longer than the previously described shoulder studs 42 used in the embodiment of Figs. 11 to 13. The gauging or sizing ring is provided with spaced pins 154. As shown in Fig. 15 there are provided leaf springs 155 having centrally coiled portions 156 and leaf portions 157. The central coil portion 156 of each spring 155 is wrapped around the shoulder of a stud 153 and each leaf portion 157 is engaged at the end thereof with a pin 158.

The spring 156 is sufficiently resilient so that the sizing element will be permitted to move laterally as necessary upon engagement of the gauge surfaces 43a with the edge of the workpiece bore, such movement being limited only by the clearance between the walls of the stud receiving holes 144 and the shoulder on the housing of the honing tool. As the pressure forcing the gauging element laterally is released, the springs 156 will force the gauging element to a central position with respect to the tool centerline.

I claim:

1. In a honing apparatus for honing the bore of a workpiece having reciprocable spindle means and having honing means mounted adjacent the lower end thereof, a gauge support mounted for vertical shiftable movement relative to said honing means, a gauge ring carried by said support and adapted to engage the end of the workpiece through which the honing means enters to hone the workpiece bore, said gauge ring on said support for limited free movement laterally relative thereto, resilient means for yieldingly urging said gauge ring to a position in which it is centered with respect to said support when out of engagement with said workpiece, said gauge ring being of predetermined size ineffective to enter the unfinished bore but effective to enter said bore upon the finishing thereof to a predetermined size, and resilient means adapted to be compressed upon downward movement of the spindle means relative to said gauge support, said resilient means being effective to force said gauge ring into the bore upon the finishing thereof to said predetermined size, and means of the gauge ring to engage said workpiece bore for rendering said honing means ineffective to hone the bore.

2. A honing apparatus for removing excess material from a surface of a workpiece, comprising a honing tool supported for movement along the surface of the workpiece and having a head mounted carry means adapted to engage the surface of the workpiece, means for moving said honing tool together with said head along the surface of the workpiece to remove excess material therefrom, a gauge for determining when the workpiece has been finished to the desired size, means mounting said gauge on said honing tool for limited movement relative to said honing tool and in the direction of movement of the latter, resilient means for yieldingly moving said gauge to a position in which it is centered with respect to said honing tool, said gauge having gauging means positioned at one end of the surface for engagement with the excess material to be removed, and means for engaging said gauge against movement in one direction along the surface with said honing tool as the latter moves along the surface, and means interposed between said honing tool and gauge for moving the gauge in said one direction along the surface in response to removal of the excess material from the surface by the abrading elements.

3. In a honing apparatus for honing the bore of a tubular workpiece, said apparatus being characterized by the provision of a reciprocable honing tool having honing means mounted adjacent the end thereof, a gauge support extending around said honing tool for axial shiftable movement relative thereof, a sizing gauge device adapted to hold the support for limited free displacement transversely relative to said support, said gauge device having annularly spaced radially projecting gauge means of predetermined size ineffective to enter the unfinished bore but effective to enter said bore at the end thereof through which the honing means enters upon the finishing thereof to substantially a predetermined size, said gauge device also having load means adapted to enter the unfinished bore, resilient means for urging said gauge device toward the bore to force said load means into the bore and thereby displace the gauge device transversely so as to dispose the center of the gauge device substantially in line with the centerline of the workpiece bore, said resilient means also being effective to force said gauge means into the bore upon the honing thereof to substantially said predetermined size, and means operative after entry of said gauge means into the bore for rendering said honing means ineffective to hone the bore.

4. In a honing apparatus for honing the bore of a tubular workpiece, said apparatus being characterized by the provision of reciprocable honing tool means having honing means mounted adjacent the end thereof, gauge means for gauging the size of the bore to be honed and comprising an annular gauge member shiftable with said honing tool means toward and from the workpiece, said gauge member having a series of gauge elements spaced therearound and formed with gauging portions terminating in inwardly tapered lead portions adapted to guide the gauge elements into the end of the bore of the workpiece through which the honing means enters, said gauge member for limited displacement transversely of said honing tool means to compensate for misalignment of the longitudinal axis of the honing tool means with the longitudinal axis of the bore of the workpiece, resilient means for urging said gauge member toward the workpiece to force one or more of said lead portions to enter the end of the workpiece bore and by engagement
thither shift the gauge member laterally so as to cause the center of the gauge member to coincide substantially with the center of the workpiece bore, said resilient means being effective to force said gauging portions into the workpiece bore upon the same being honed to substantially the effective diameter of said gauging portions, and means operative after entry of said gauging portions into the bore to render said honing means ineffective to hone the bore.

5. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable spindle means and having honing means mounted adjacent one end thereof, comprising a gauge support mounted for shiftable movement relative to said honing means, a gauge ring carried by said gauge support, said gauge ring adapted to enter the workpiece bore and effective to said bore upon the finishing thereof to a predetermined size, means for controlling said gauge ring and means to insert the gauge means into the workpiece bore and ineffective during predetermined engagement with said end of the bore.

6. In a honing apparatus for honing the bore of a tubular workpiece having a reciprocable spindle and having honing means mounted adjacent one end thereof, reciprocable means including a cylindrical gauge support through which said spindle extends, a gauge device having annularly spaced radially projecting gauge means adapted to engage the workpiece through which the honing means enters to hone the bore of the workpiece, means for connecting said gauge device and gauge support to said spindle means for shifting relative to and axially of the spindle, and also for limited shiftable movement transversely of the spindle, said gauge means being of a predetermined diameter ineffective to enter the workpiece bore; and effective to enter said bore upon the finishing thereof to a predetermined size by the operation of said honing means, a coil spring mounted between said spindle and gauge support interiorly of the latter, relatively axially movable means acting on opposite ends of said spring to compress the same upon axial movement of said spindle relative to said gauge support during the honing thereof to a predetermined size, means extending into the bore upon the finishing thereof to said predetermined size, and control means including a switch operating member connected to said gauge device for movement in unison therewith and controlled by the entry of said gauging means into the workpiece bore for ineffective engagement of the honing operation.

7. In a honing apparatus for honing a reciprocable honing tool spindle means provided with honing means adjacent the outer end thereof for honing the bore of a workpiece, an annular sizing gauge extending around said spindle means, means for supporting said gauge for limited displacement transversely relative to said spindle means, said gauge having gauge means of an effective diameter adapted to enter the workpiece bore at the end thereof through which the honing means enters upon the honing thereof to substantially a predetermined size and also having lead means of less effective diameter adapted to enter the unfinished bore, means for controlling said gauge device for sequentially forcing said lead means into the bore to displace the gauge transversely and substantially centering the same with the workpiece bore and forcing the gauge means into the bore, and resilient means for urging said gauge means transversely of the spindle means into a position in which it is substantially centered with the spindle means when the gauge is out of engagement with the workpiece.

8. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, said spindle means being free of any effective universal joint action within the workpiece bore during the honing operation, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, an annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having radially projecting annularly spaced workpiece bore entry means operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation, and actuating means controlled by said gauge device for actuating said signalling means.

9. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, said spindle means being free of any universal joint action within the workpiece bore during the honing operation, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, an annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having a series of circumferentially spaced gauge portions having annular spacing clearance therebetweentimes and operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation, actuating means controlled by said gauge device for actuating said signalling means for preventing rotation of said actuating means and gauge device with the honing means in all positions of said actuating means.

10. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, an annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having a series of circumferentially spaced gauge portions having annular spacing clearance therebetweentimes and operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation, and actuating means controlled by said gauge device for actuating said signalling means.

11. In a honing apparatus for honing the bore of a tubular workpiece having a reciprocable spindle and honing means mounted adjacent one end thereof, an annular plug gauge device encircling said spindle and through which the spindle extends, means for controlling said gauge device for predetermined lateral floating movement relative to the honing means, said gauge device having workpiece bore entry means including a series of spaced gauge portions having annular spacing clearance therebetweentimes operative at the end of the workpiece bore and ineffective during predetermined engagement with said end of the bore to have operative gauge entry.
into the unfinished bore, said gauge device means having operative entry into the bore in engagement therewith when the bore is honed to substantially a predetermined size by the honing means, means for signalling operative entry of the gauge device means into the work bore preparatory to initiating cessation of the honing operation and disposed free of operative control by said gauge device in all positions of the gauge device when the latter is prevented from operative gauge entry into the unfinished bore, and means controlled by said gauge device for actuating said signalling means after said operative entry of the gauge device means into the bore.

12. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, and annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having annularly spaced radially projecting workpiece bore entry means operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation, actuating means controlled by said gauge device for actuating said signalling means, and means for preventing rotation of said actuating means with the honing means in all positions of said actuating means.

13. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, an annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having circumferentially spaced workpiece bore entry means operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for mounting said gauge device for limited lateral movement transversely of the axis of the workpiece bore, and means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation.

14. In a honing apparatus for honing the bore of a tubular workpiece having reciprocable and rotatable spindle means and honing means carried thereby and adapted to enter one end of the workpiece bore, shiftable means extending into a bore portion of the spindle means for adjusting the honing means relative to said bore, an annular gauge device encircling said spindle means and through which the spindle means extends, said gauge device having annularly spaced radially projecting workpiece bore entry means operative at the end of the bore through which the honing means enters to hone the bore and having operative entry into the bore in engagement therewith when the bore has been honed to a predetermined size, means for mounting said gauge device for limited transaxial floating relatively to the workpiece bore, means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation, and actuating means controlled by said gauge device for actuating said signalling means.

15. In a honing apparatus for honing the bore of a tubular workpiece having a reciprocable spindle and honing means mounted adjacent one end thereof, an annular plug gauge device encircling said spindle and through which the spindle extends, said gauge device having annularly spaced radially projecting workpiece bore entry means operative at the end of the workpiece bore through which the honing means enters to hone the bore and ineffectual during predetermined engagement with said end of the bore to have operative gauge entry into the unfinished bore, said gauge device means having operative entry into the bore when the bore is honed to substantially a predetermined size by the honing means, means for mounting said gauge device means for limited lateral movement transversely of the axis of the workpiece bore, and means for signalling operative entry of the gauge device means into the workpiece bore preparatory to initiating cessation of the honing operation and disposed free of operative control by said gauge device in all positions of the gauge device when the latter is prevented from operative gauge entry into the unfinished bore.

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