

July 9, 1946.

J. O. OLSEN

2,403,546

METHOD AND APPARATUS FOR HONING

Filed Sept. 27, 1943

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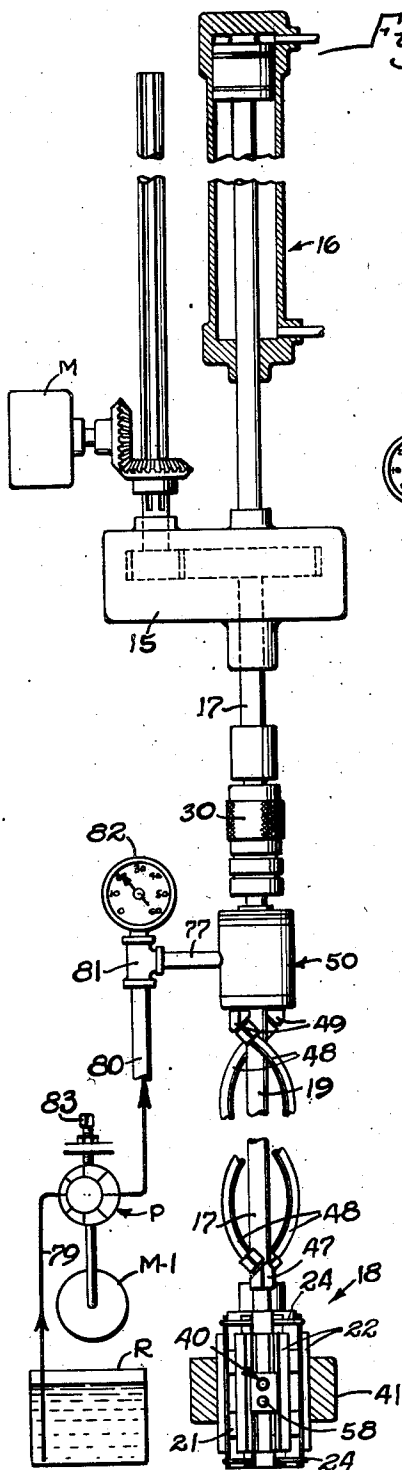


Fig. 1

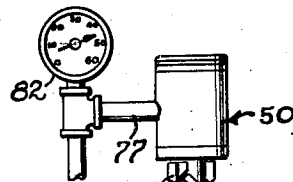


Fig. 2

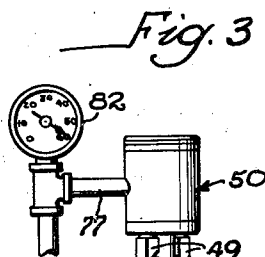


Fig. 3

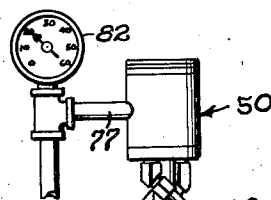


Fig. 4

INVENTOR
Joseph O. Olsen
By Parker, Coad & Wagner & Hubbard
ATTORNEYS

July 9, 1946.

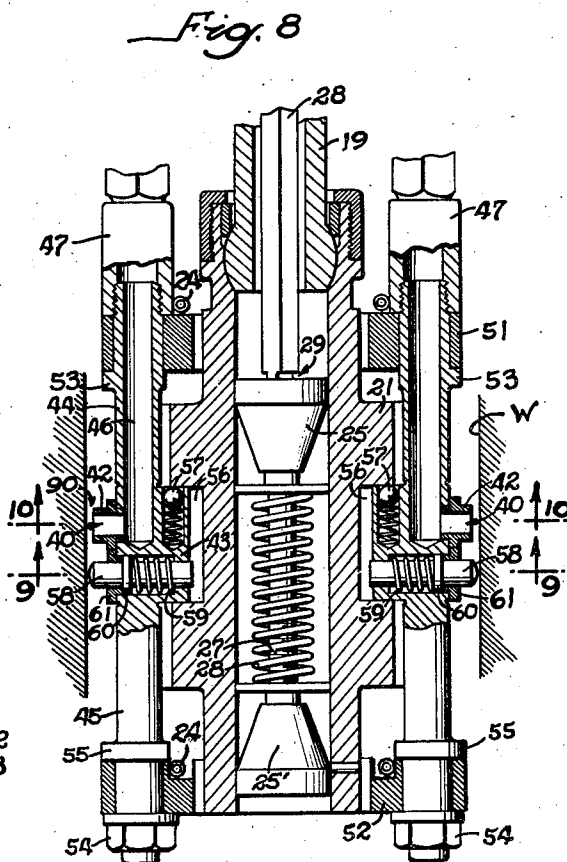
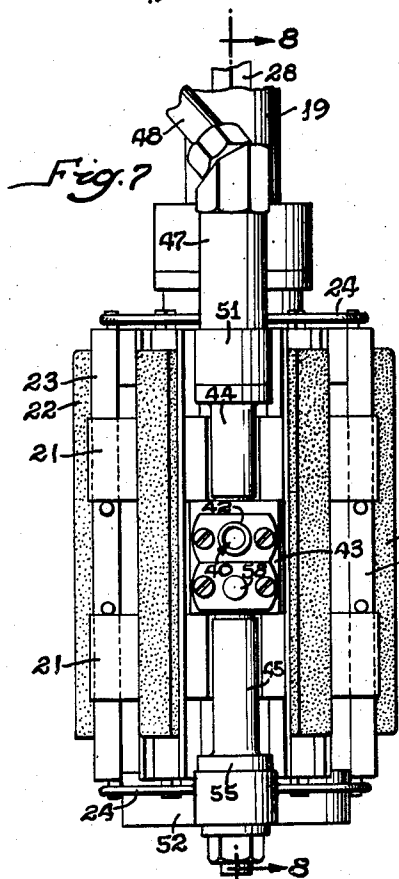
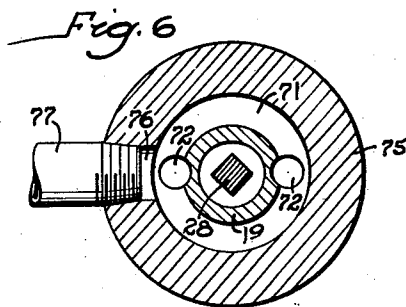
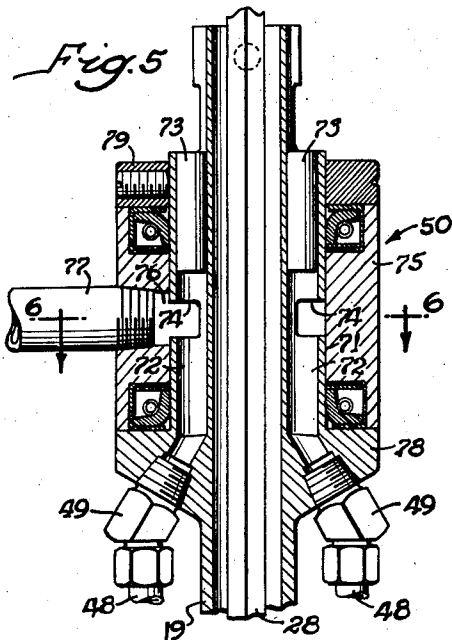
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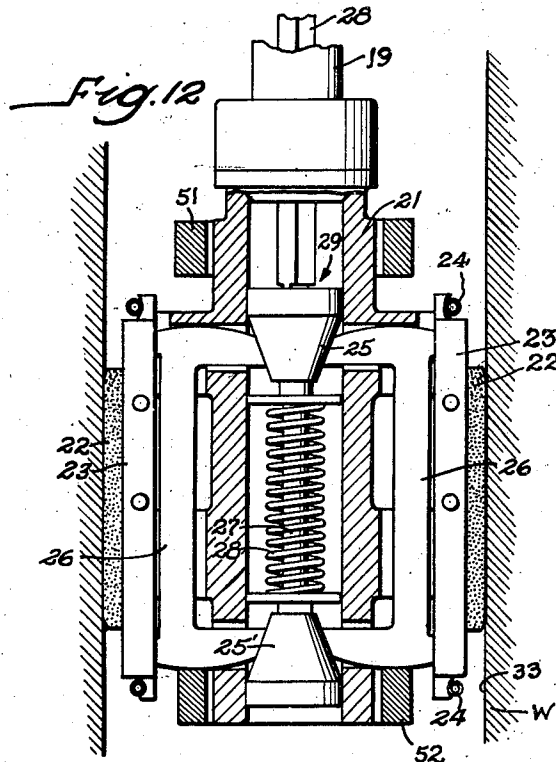
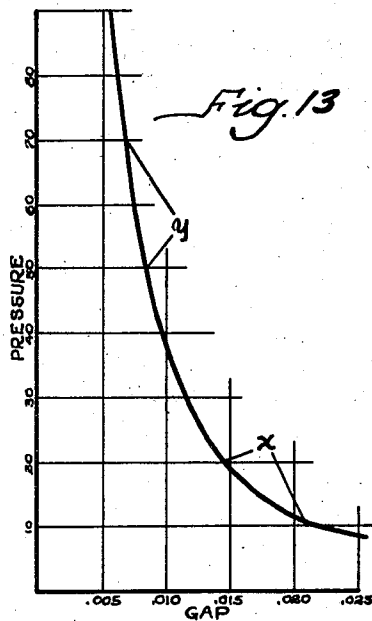
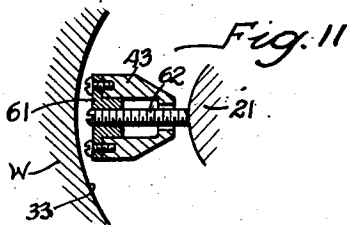
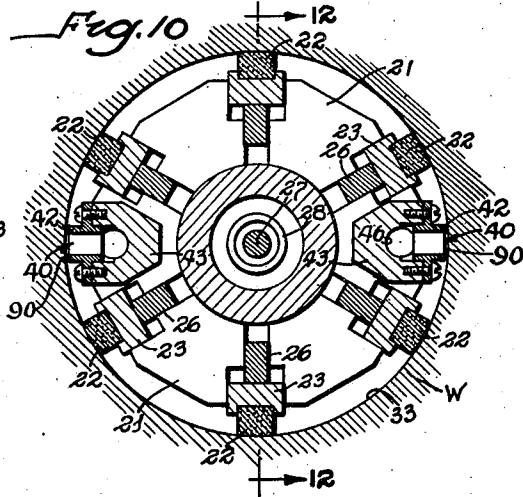
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INVENTOR
Joseph O. Olsen
By Parker, Gordon, Pitzer & Hubbard.
ATTORNEYS

2,403,546

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INVENTOR
Joseph O. Olsen
BY Parker, Gaudin, Pitzer & Hubbard.
ATTORNEYS

UNITED STATES PATENT OFFICE

2,403,546

METHOD AND APPARATUS FOR HONING

Joseph O. Olsen, Rockford, Ill., assignor to Barnes Drill Co., Rockford, Ill., a corporation of Illinois

Application September 27, 1943, Serial No. 503,886

11 Claims. (Cl. 51—184.3)

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The invention relates to the art of finishing cylindrical surfaces and more particularly to the honing art.

The honing process, in which a cylindrical abrasive tool and the work are relatively rotated and simultaneously relatively reciprocated axially, is employed extensively in finishing cylindrical surfaces where a smooth, true surface and a high degree of accuracy is required. This process is capable of finishing either internal or external cylindrical surfaces to precise dimensions, accuracy within limits as close as plus or minus .0001 inch being readily attainable. In order to maintain such accuracy it has been necessary heretofore to interrupt the operation frequently for gauging the size of the work, particularly as the desired final dimensions are approached. Such interruption substantially increases the finishing time required and consequently reduces the productive capacity of the machine upon which the honing operation is performed. Moreover, a high degree of skill is required to gauge the work within the close limits referred to and the gauging is especially difficult when the internal surface of cylindrical bores are involved. These considerations all contribute to increasing the cost of the finishing operation.

With the foregoing in view a general object of the invention is to provide an improved method of and apparatus for gauging work in process of being honed whereby the size thereof may be determined with a high degree of precision at any stage of the honing operation and without interrupting the operation whereby the machine time and labor required for finishing a workpiece is reduced to a minimum with a consequent reduction in the cost of the operation.

Another object is to provide novel means operative to automatically gauge the work and provide a continuous indication of the size thereof while the honing operation is in progress.

Still another object is to provide novel means whereby a cylindrical bore may be quickly and accurately gauged for size throughout its entire length.

It is also an object of the invention to provide an improved honing tool having novel work gauging means, incorporated directly therein.

Other objects and advantages of the invention will become apparent from the following detailed description of the preferred embodiment illustrated in the accompanying drawings in which:

Figure 1 is a fragmentary side view of a hon-

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ing machine and tool embodying the features of the invention.

Figs. 2, 3 and 4 are side views of the honing tool shown in different sections of a cylinder bore in process of being honed.

Fig. 5 is a vertical sectional view of the fluid distributing head associated with the tool.

Fig. 6 is a sectional view taken in a horizontal plane substantially on the line 6—6 of Fig. 5.

Fig. 7 is a side elevational view of the honing tool showing the location of the gauging mechanism associated therewith.

Fig. 8 is a sectional view taken in a vertical plane substantially on the line 8—8 of Fig. 7.

Figs. 9 and 10 are sectional views taken in horizontal planes substantially on the lines 9—9 and 10—10 of Fig. 8, respectively.

Fig. 11 is a horizontal sectional view of a modified form of nozzle adjusting mechanism.

Fig. 12 is a sectional view taken in a vertical plane substantially on the line 12—12 of Fig. 10.

Fig. 13 is a graph showing the relationship between the spacing of the coolant discharge orifices from the surface being honed and the pressure of the liquid coolant discharged through such orifices.

The improved gauging method may be carried out with various types of honing machines and tools for finishing either internal or external cylindrical surfaces. For purposes of illustration the apparatus for carrying out the method has been shown herein as constructed and arranged for the honing of internal cylindrical surfaces such as cylinder bores. The particular machine selected to exemplify the honing operation is of the type in which the honing tool is rotated and simultaneously reciprocated relative to a stationarily supported workpiece. It is to be understood, however, that the invention is not limited to use in the particular environment shown but is readily applicable to other types of machines and honing tools. The invention accordingly, embraces all modifications, adaptations and alternative constructions falling within the scope of the appended claims.

Referring to Fig. 1 of the drawings, a typical machine for honing cylinder bores comprises a head 15 adapted to be reciprocated by a pressure fluid operated actuator 16 of the cylinder and piston type. Journaled in the head and projecting from one face thereof is a spindle 17 to which a honing tool 18 is operatively secured by means of an elongated tubular driver 19. The spindle 17, driver 19 and tool 18 are rotatably driven by a motor M through suitable gearing.

The honing tool 18 may be of any preferred type. Such tools ordinarily include a generally cylindrical body 21 (Figs. 1, 7, 8 and 12) having a plurality of radially movable elongated abrasive stones 22 assembled thereon in a circular series. The abrasive stones are conveniently mounted in elongated carriers 23 (Figs. 8 and 12) which provide rigid support for the stones and guide the same for radial movement in the tool body 21. Annular springs 24 encircling the series of carriers yieldably urge the carriers and abrasive stones inwardly to a contracted position.

In operation, the tool is expanded, that is, the carriers 23 and abrasive stones 22 are shifted radially outwardly to force the working faces of the stones against the surface to be finished. In the exemplary tool, the means for effecting such expansion comprises a pair of generally conical cam members 25 and 25' slidable but non-rotatably held within the hollow tool body 21 for coaction with adjusting plates 26 (Fig. 12) associated with the respective carriers 23. The cam members are mounted in oppositely facing relation upon a shaft 27, the member 25 being rotatably anchored to one end of the shaft while the member 25' is threaded on the other end of the shaft.

By turning the shaft 27 in one direction, the cam members 25 and 25' are moved toward each other and act through the plates 26 to shift the carriers 23 and their abrasive stones 22 radially outwardly. A spring 28 interposed between the cam members yieldably urges the members away from each other when the shaft is turned in the opposite direction thus permitting the springs 24 to shift the carriers and abrasive stones radially inwardly and thus contract the tool.

The shaft 27 is adapted to be turned by an adjusting rod 28 connected to the upper end of the shaft by a flexible joint 29. The rod extends axially through the driver to a point at which it may be conveniently operated by an adjusting sleeve 30 (Fig. 1).

In honing a cylindrical bore such as the bore 33 of a metal block or workpiece W the tool 18 is inserted therein in a collapsed condition, that is, with the abrasive stones 22 withdrawn inwardly so that the overall diameter of the tool is less than the diameter of the bore. After insertion the tool is expanded until the working faces of the stones 22 are pressed against the walls of the bore. The stones are therefore effective to abrade or cut away the walls of the bore when the tool is rotated and reciprocated therein.

As the bore is gradually enlarged by the action of the abrasive stones 22, the tool is progressively expanded to maintain the required working pressure on the work. Throughout the entire operation the work and tool are flooded with a copious supply of liquid coolant which serves to flush away metal and abrasive chips and to prevent the tool and work from becoming overheated.

In finishing cylindrical work within the close limits demanded in precision honing, the honing operation must be terminated at the precise instant that the desired finished diameter is attained. This dimension can be determined with the required accuracy only by the actual gauging or measurement of the work. Numerous attempts have been made to develop automatic work gauging means with a view of reducing the labor required and avoiding the delays involved in manual gauging as now generally practised.

The use of automatic mechanism for inserting

plug gauges in the work in alternate strokes of the tool has been proposed, but has proven incapable of operating with the degree of precision required. Moreover, in apparatus of that type, the gauges are subject to excessive wear and, at best, are adapted only for gauging the extreme ends of the workpiece. Such apparatus, therefore, does not disclose irregularities intermediate the ends of the work. The use of leakage path air gauges has been suggested to overcome the latter difficulty. Air gauges have been found unsatisfactory however, due to the necessity of maintaining the tool and work flooded with liquid coolant.

I have discovered that the above difficulties may be completely avoided by employing the liquid coolant as the gauging medium and have provided the novel gauging method and apparatus herein disclosed for utilizing that discovery. The improved method of gauging contemplates the discharge of the liquid coolant under pressure through one or more restricted outlets defined jointly by the work surface and members 40 carried by or movable with the honing tool whereby the flow of liquid is restricted in accordance with the diameter of the work. Variations in diameter may therefore be determined with a high degree of accuracy by measuring changes in either the volume or the pressure of the liquid in the coolant system. In practice, I prefer to supply a constant volume of the liquid coolant to the tool and to determine size by measuring the pressure in the coolant supply system.

The members 40 coacting with the work surface to define the coolant outlets are preferably mounted directly on the tool body. These members, while adjustable relative to the tool, are held in fixed spaced relation during the honing operation. The spacing may be adjusted initially to provide a predetermined gap or outlet between each member and the unfinished work surface. Accordingly, the pressure in the coolant supply system is at its maximum when the tool is initially associated with the work, as for example, when it is inserted in a bore of small diameter. As the bore is progressively enlarged due to the gradual removal of stock by the tool, the gaps between the work surface and the members 40 increase and the pressure drops correspondingly. Thus, as the honing operation proceeds, the pressure gradually falls in accordance with the progressively increasing diameter of the bore. It will be evident therefore, that the pressure of the liquid coolant provides an accurate indication of the diameter of the work at the particular point at which the tool is positioned.

To establish a definite reference point for the accurate gauging of the work, the members 40 are preliminarily set by means of a ring gauge 41 (Fig. 1) or the like having an internal diameter corresponding exactly to the desired diameter of the finished work. With the members set so that they may be inserted in an unfinished bore, the pressure set up by the gauge corresponds to the pressure that will obtain when the work is finished to the desired size. Accordingly, the honing operation may proceed without interruption until the pressure in the coolant supply system indicates that the desired dimension has been attained. Moreover, localized constricted areas or taper in the work are indicated by appropriate pressure changes in the coolant supply system thus enabling the machine attendant to amplify

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the action of the tool in such areas by "short-stroking."

The apparatus for carrying out the improved gauging method may take various forms. In the preferred embodiment illustrated the members 40 which, in cooperation with the work surface define the coolant outlets, comprise tubular nozzles 42 supported on the body of the honing tool and positioned to direct the coolant against the work surface. As herein shown two such nozzles are located on diametrically opposite sides of the tool body so that the reaction from the discharge tends to center them in the work. Additional nozzles may be provided if desired to accommodate a greater volume of coolant.

In the exemplary apparatus, each of the nozzles 42 is fitted into and rigidly secured to a generally rectangular metal block 43 (Fig. 8) having cylindrical mounting studs 44 and 45 projecting from its upper and lower faces. The upper stud 44 is formed with an axial bore or passage 46 communicating at its lower end with the nozzle. A coupling 47 threaded on the upper end of the stud connects the passage 46 with a flexible tube 48 which has its other end connected by a coupling 49 with a coolant distributor 50 carried on the driver 19.

Cooperating with the mounting studs 44 and 45 to support nozzles on the tool body are a pair of yokes 51 and 52. The yokes are of similar form, each comprising a metal plate having a central aperture dimensioned to fit loosely over the end of the tool body 21 and having laterally projecting arms apertured to receive the studs. The couplings 47 engage the upper face of the yoke 51 and act to clamp it rigidly against stop shoulders 53 formed on the studs 44. Nuts 54 threaded on the lower ends of the studs 45 clamp the lower yoke 52 against stop flanges 55 formed on the studs. Thus the nozzles are supported by a rigid frame structure mounted for limited movement transversely of the tool body 21.

Adjustment of the nozzles with respect to each other may be readily effected either by shifting the studs toward or from each other in the yokes. Alternatively, the nozzles may be readily replaced by nozzles of different length or shape or having different size orifices.

To guide the nozzle supporting structure in its lateral movements, the tool body 21 is formed with radially opening recesses 56 adapted to snugly receive the inner ends of the nozzle supporting blocks 43 which have their side edges tapered as shown in Figs. 9, 10 and 11 to permit them to fit between the adjacent abrasive stone carriers. Detents 57, herein shown as spring pressed balls carried by the blocks 43, engage the walls of the recesses to prevent undesired movement of the nozzle supporting structure.

Means is provided for automatically effecting the adjustment of the nozzles and associated supporting structure to center the nozzles in a bore and maintain this central position throughout the honing operation and thus compensate for uneven wear of the abrasive elements of the tool. The means provided for this purpose comprises a pair of plungers 58 slidably fitted in recesses in the blocks 43 for movement radially of the tool body into engagement with the walls of the bore. Springs 59 acting on collars 60 integral with the plungers urge the latter outwardly against the bore walls. Stop plates 61 suitably attached to the plates for engagement by the collars 60 limit the outward movement of the plungers. In practice, the collars 60 are spaced inwardly from

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the tips of the plungers so that in their limit positions contact between the plungers and the work surface is interrupted during the final stages of the honing operation. In this way any possibility of the plungers marking the finished surfaces is effectually avoided.

When the honing tool is used for removing small amounts of stock, a single coolant outlet may be used if desired. Moreover the automatic centering plungers may be replaced by fixed adjusting screws 62 adapted to thread into the stop plates 61 and to bear against the tool body as shown in Fig. 11. Thus by appropriate manipulation of the screws 62, the nozzles 42 may be shifted toward or from the axis of the tool body and accurately centered with respect to the working faces of the abrasive stones.

As stated heretofore, the supply of liquid coolant is delivered to the nozzles 42 through the distributor 50 which acts to provide a connection between the rotating tool and a stationarily supported coolant source. As shown in Figs. 5 and 6, the distributor comprises a central body 71 in the form of a cylindrical enlargement of the driver 19. Vertical passages 72 in the body communicate at their lower ends with the tubes 48 leading to the nozzles 42. Each passage 72 is closed at its upper end by a plug 73 and it is provided with a radially opening port 74 formed by a circumferential groove in the body 71.

Rotatably mounted on the distributor body 71 is a sleeve 75 having an inlet opening 76 to which coolant is delivered through a pipe 77. The inlet is aligned with the groove forming the ports 74 whereby coolant is delivered to passages 72 during the rotation of the distributor body relative to the sleeve 75 which remains stationary. To prevent endwise movement of the sleeve relative to the distributor body, the sleeve is confined between a flange 78 projecting outwardly from the lower end of the body and a collar 79 clamped to the body.

Liquid coolant may be supplied to the distributor 50 for delivery to the nozzles 42 from any suitable source capable of delivering a substantially constant volume of liquid under pressure. As shown in Fig. 1, the coolant source comprises a constant volume adjustable delivery vane pump P driven by an electric motor M-1. The pump is adapted to draw liquid coolant through an intake line 79 from a settling tank or reservoir R and discharge it under pressure through a pipe 80 to which the pipe 77 is connected as by a T-fitting 81. A pressure gauge 82 is connected with the other outlet of the fitting 81 to visually indicate the pressure in the coolant supply system. Adjustment of the pump output is effected in well-known manner by means of a manually operable adjusting member 83.

Before the gauging apparatus is placed in operation the nozzles 42 are initially adjusted so that their outer ends are within but in close proximity to the cylindrical path described by the working faces of the abrasive elements 22 in the rotation of the tool. The nozzles are therefore separated by a relatively small gap 90 from the unfinished walls of the bore thus providing a restricted outlet for the fluid discharged from the nozzles. The output of the pump P may then be adjusted to provide any desired pressure for the outlet thus formed, the pressure being indicated by the gauge 82. As stock is removed by the tool (increasing the diameter of the work in the case of an internal cylindrical surface and decreasing the diameter in the case of an external cylindrical surface) the

spacing of the work surface from the nozzles increases thus increasing the area of the coolant outlet and causing a pressure drop in the supply system. This pressure drop provides an accurate indication of the change in the diameter of the work.

For rough honing, where a substantial amount of stock is to be removed, operation of the gauging apparatus with outlets of substantial area, that is, with relatively large gaps between the nozzles and the work surface and at relatively low pressure will ordinarily be found most satisfactory. For example, the nozzles may be set to provide an initial gap of .015 inches between the outer end of each nozzle and the work surface and the pump delivery adjusted to produce a pressure in the system of approximately twenty pounds per square inch. With this setting, removal of .010 inch of stock and the consequent enlargement of the gap at each nozzle to .020 inch will result in a pressure drop of approximately ten pounds as indicated by the bracketed section X of the pressure curve shown in Fig. 13. In other words, under the conditions stated each pound variation in the pressure corresponds approximately to .001 inch of stock measured on the diameter of the work.

For high precision finishing where relatively little stock is removed, greater sensitivity is obtained with a smaller outlet, that is, when the nozzles are set closer to the work surface and the pump adjusted for operation in the higher pressure range indicated by the bracket Y in Fig. 13. Thus with an initial gap of .007 inch between the outer end of each nozzle and the work surface and with the pump adjusted to produce a pressure of seventy pounds per square inch in the coolant supply system, an increase of .002 inch in the spacing of the nozzles from the work surface or an increase of .004 inch in the work diameter will result in a pressure change of approximately twenty pounds per square inch. Accordingly, much more accurate gauging may be effected due to the relatively large pressure changes produced by relatively small changes in work diameter.

It will be understood, of course, that with either type of adjustment, the gauging apparatus is calibrated initially with reference to a suitable gauge. When used with an external honing tool, a conventional cylindrical plug gauge is utilized for this purpose. For apparatus used with an internal honing tool, the ring gauge 41 is utilized as previously explained. The honing operation is started with a substantially higher pressure than that produced by the calibrating gauge and the operation is continued until the pressure indicated by the gauge 82 corresponds exactly with that produced by the calibrating gauge. It will also be understood that the gauging apparatus may be calibrated to indicate actual diameters, if desired.

The gauging apparatus above described is adapted to accurately indicate any variations in the diameter of a bore at any point throughout its length. Thus when the tool is operating in a cylindrical bore having a slight taper developed in a preceding operation, the pressure of the coolant is low when the tool is located in the large end of the bore as shown in Fig. 2, a pressure of forty-five pounds per square inch being indicated on the gauge 82 in this instance. As the tool is moved downwardly to the smaller end of the bore the pressure gradually rises to approximately sixty pounds as shown in Fig. 3, thus indicating

a substantial contraction of the bore at that point. With these indications for guidance, the attendant may operate the machine in well-known manner to "short-stroke" the tool within the constricted area until the diameter is substantially uniform throughout the length of the bore. The tool may then be traversed axially of the bore in the usual way until the honing operation is completed. When the desired final dimension is attained, the gauge 82 registers a pressure of twenty pounds per square inch (Fig. 4) corresponding exactly with the indication given when the hone is associated with the calibrating gauge 41 as shown in Fig. 1 thus enabling the attendant to terminate the honing operations at the proper time.

It will be apparent from the foregoing that the invention provides an improved method of gauging workpieces in process of being honed which permits the work to be finished precisely to desired dimensions without interrupting the honing operation. The time and labor required for precision finishing of cylindrical work by honing is substantially reduced thus increasing the productive capacity of the machine used for performing the honing operation and correspondingly reducing the cost of the finishing operation. Furthermore, due to the constant visible gauging, oversize honing of the work is avoided thus eliminating or substantially reducing spoiled or scrapped work.

The invention also provides new and improved apparatus for carrying out the improved method of gauging. In particular, the apparatus is designed to utilize liquid coolant as the gauging medium, thereby adapting the fluid gauging method for use in the honing process which requires a constant flow of liquid coolant over the tool and work. It should be understood, however, that the gauging apparatus can be operated with liquids other than the coolant ordinarily employed in honing provided such liquids do not interfere with the proper functioning of the coolant. As a matter of convenience, the gauging apparatus may be incorporated directly in the tool.

The improved apparatus is simple and rugged in construction and yet adapted to provide extremely accurate measure of the work size. When desired, a continuous indication of size is available thus providing for accurate gauging of a bore or the like during the entire operation. Moreover, a cylindrical workpiece may be gauged accurately throughout its length with a minimum of effort on the part of the operator and without loss of time.

While the exemplary gauging method and apparatus contemplates the discharge of a constant volume of liquid coolant through the gauging outlets with measurement of pressure variations, it will be appreciated that the pressure of the liquid could be maintained constant and the variations in the volume of discharge measured instead. In either case, the area of the outlets defined by the gauging member and the work surface affects the flow of liquid in a manner susceptible of accurate measurement. Accordingly, the term "flow" as used herein is intended to apply to either mode of operation.

I claim as my invention:

1. A honing tool having, in combination, a rigid body supporting a circular series of elongated abrasive elements, nozzle supporting members disposed on opposite sides of the tool body, studs projecting from the upper and lower faces of said members, and a pair of yokes connecting said studs to form a rigid frame structure, said tool

body being recessed for the reception of said members whereby to guide the frame structure for movement radially of the tool body, and adjustable means carried by said members coacting with said tool body to determine the position of said frame structure with respect to the tool body.

2. A honing tool having, in combination, a rigid body supporting a circular series of abrasive elements, nozzle supporting members disposed on opposite sides of the tool body, studs projecting from the upper and lower faces of the members, and yokes connecting said studs with the tool body, one of the studs associated with each of said members having a passage for conveying liquid to the nozzle supported by the member.

3. A honing tool having, in combination, a rigid body supporting a circular series of elongated abrasive elements, nozzle supporting members disposed on opposite sides of the tool body, studs projecting from the upper and lower faces of said members, and a pair of yokes at opposite ends of said tool body, said studs being rigidly clamped to said yokes for supporting the members on the tool body.

4. A honing tool having, in combination, a rigid body supporting a circular series of elongated abrasive elements, nozzle supporting members disposed on opposite sides of the tool body, studs projecting from the upper and lower faces of said members, and a pair of yokes connecting said studs to form a rigid frame structure, said tool body being recessed for the reception of said members whereby to guide the frame structure for movement radially of the tool body.

5. A honing tool having, in combination, a body, a plurality of abrasive elements supported on said body in a circular series, a pair of rigidly connected members mounted on said body for limited movement transversely of the axis of the body, said members adapted to coact with the surface of a cylindrical workpiece to define a pair of outlets located on opposite sides of the tool, spring pressed plungers mounted on said members adjacent the outlets adapted to engage with the work surface to center the outlets therein, and means limiting the movement of said plungers to interrupt their contact with the work surface as the workpiece approaches its finished dimensions.

6. A honing tool having, in combination, a body, a plurality of abrasive elements supported on said body in a circular series, a pair of members mounted on said body and rigidly connected together for limited movement transversely of the axis of the body, said members being adapted to coact with the surface of a cylindrical workpiece to define a pair of outlets located on opposite sides of the tool, and means operative automatically to center said members with reference to the workpiece.

7. A honing tool having, in combination, a rigid body, a plurality of elongated abrasive elements supported on said body in a circular series

and movable radially thereof for engagement with the cylindrical surface of a workpiece, members mounted on said body for limited movement as a unit transversely of the axis of the body, said members being adapted to coact with the surface of the workpiece to define a pair of outlets located on opposite sides of the tool and maintained substantially equal in effective area by the unitary movability of said members, and means connecting said outlets with a source of liquid under pressure.

8. In a honing tool in combination, a rigid body, a plurality of abrasive elements supported on said body in a circular series and movable radially thereof for engagement with a cylindrical work surface, a frame mounted on said body for movement transaxially of the body, a nozzle carried by said frame with its outlet disposed in close proximity to the work surface, means carried by said frame coacting with the work surface to center the frame within the work whereby to maintain uniform spacing of said nozzle from the work surface while the tool is traversed through the work, and means connecting said nozzle with a source of fluid under pressure.

9. The combination with a rigid body adapted to be traversed axially through a cylindrical bore, of a plurality of nozzles spaced circumferentially around said body for coaction with the surface of the bore, and a frame supporting said nozzles in fixed spaced relation, said frame being mounted on said body for movement transaxially thereof to enable said nozzles to be centered in said bore irrespective of the position of the body therein, and means connecting said nozzles with a source of fluid under pressure.

10. The combination with a rigid body adapted to be traversed axially through a cylindrical bore, of a frame mounted on said body for movement transaxially thereof, a nozzle carried by said frame with its outlet disposed in close proximity to the walls of said bore, a plurality of circumferentially spaced plungers mounted in said frame and yieldably urged into engagement with the walls of the bore to maintain said frame substantially centered therein independently of the position of said body, and means connecting said nozzle with a source of fluid under pressure.

11. The method of gauging a cylindrical bore in process of being operated on by a honing tool which comprises, traversing a plurality of circumferentially spaced nozzles axially of the bore with a honing tool, discharging a constant volume of liquid coolant through said nozzles against the walls of said bore, measuring changes in the pressure of the liquid to detect changes in the restrictive action of the bore walls upon the discharge of the liquid from said nozzles, and maintaining said nozzles substantially centered in the bore irrespective of the position of the honing tool therein.

JOSEPH O. OLSEN.