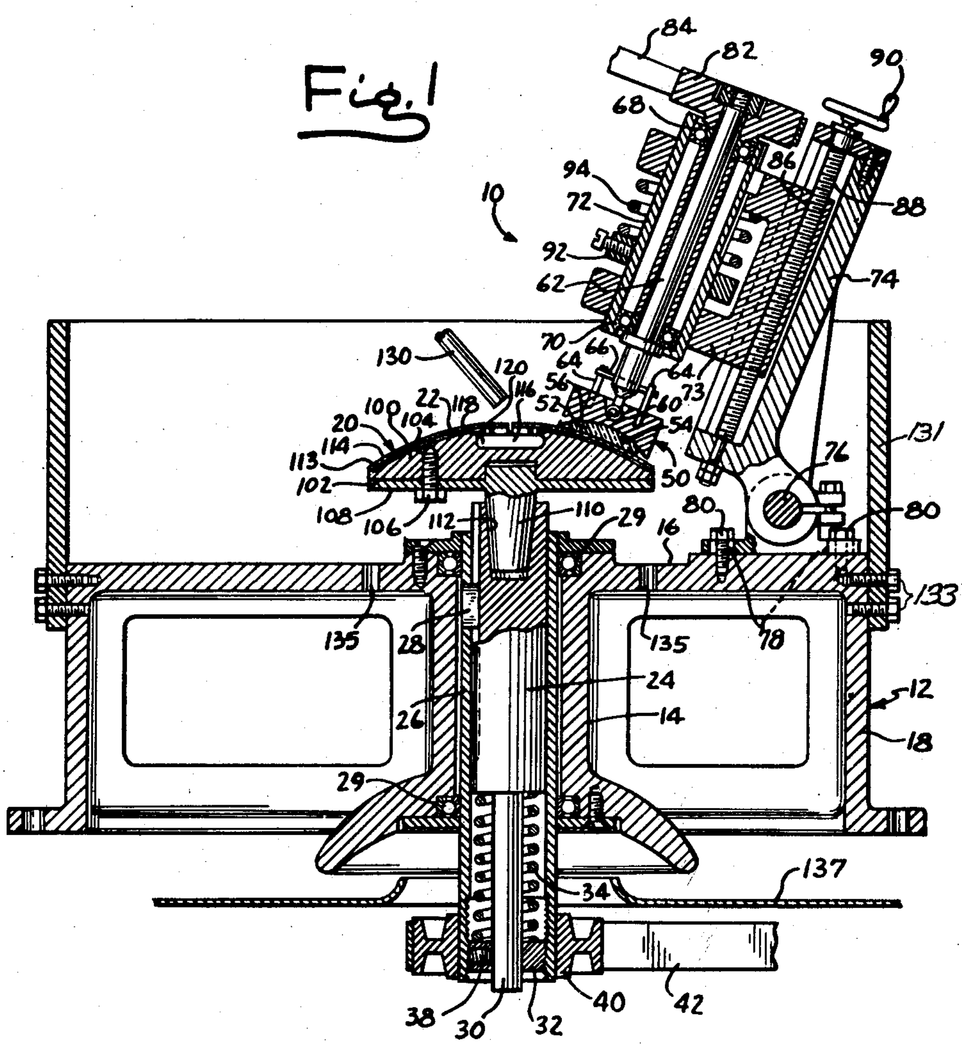
April 14, 1964 W. E. DAVIS 3,128,580

COMPOSITE LAP FOR GRINDING AND POLISHING MACHINES

Filed Jan. 30, 1963 5 Sheets-Sheet 1

Fig. 1



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COMPOSITE LAP FOR GRINDING AND POLISHING MACHINES

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Fig. 2

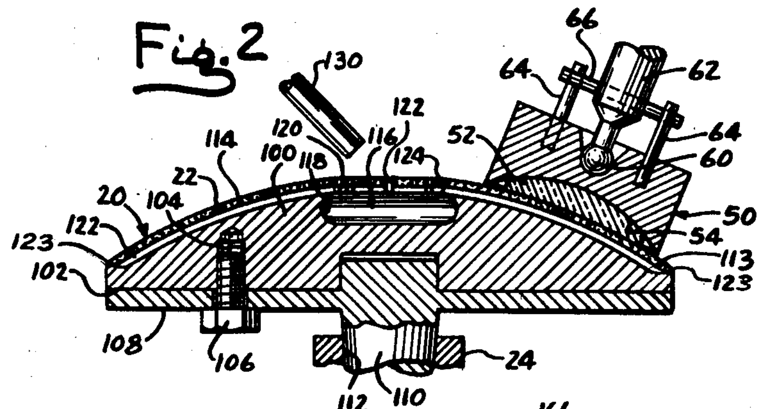
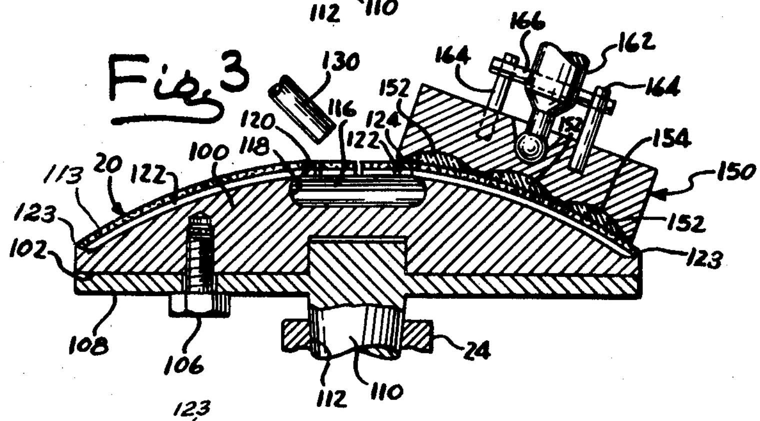


Fig. 3



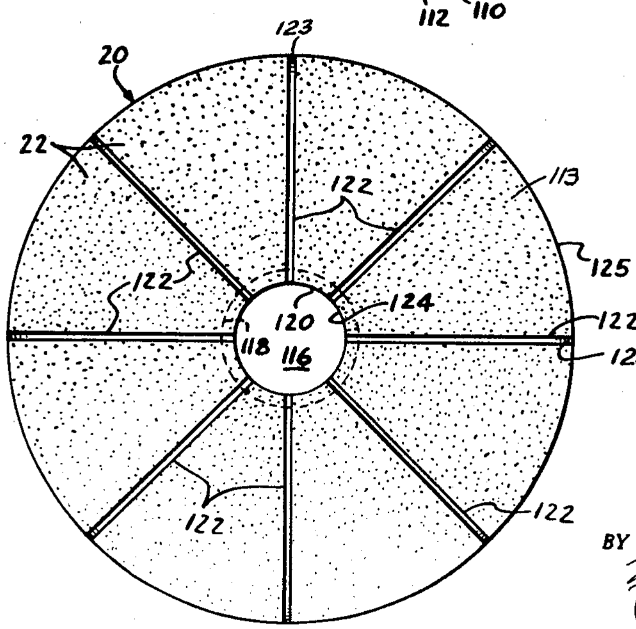


Fig. 4

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COMPOSITE LAP FOR GRINDING AND POLISHING MACHINES

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Fig. 5

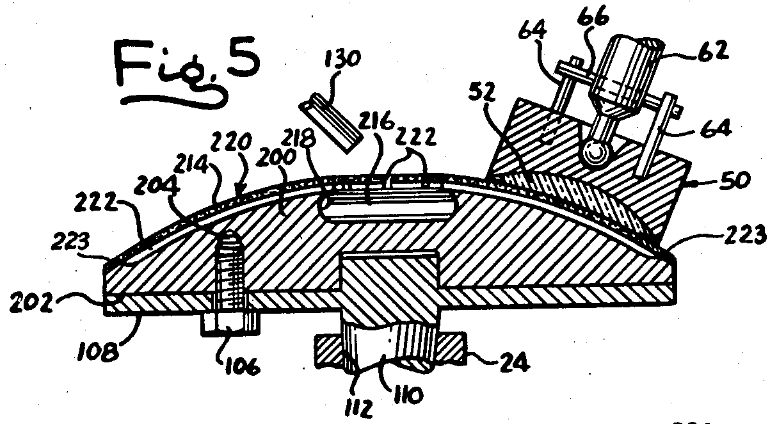

Fig. 6

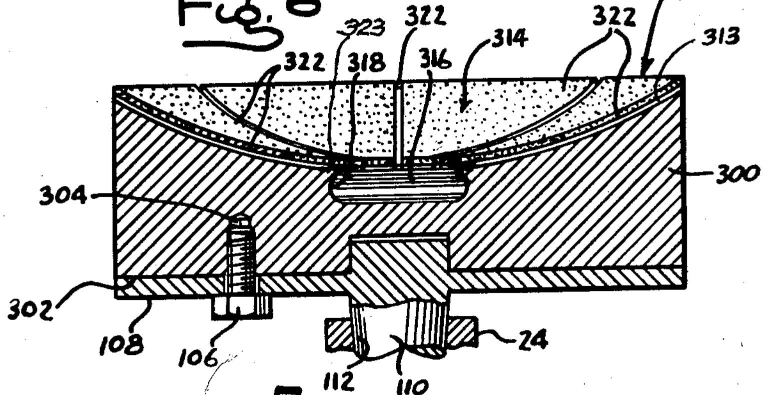

Fig. 7

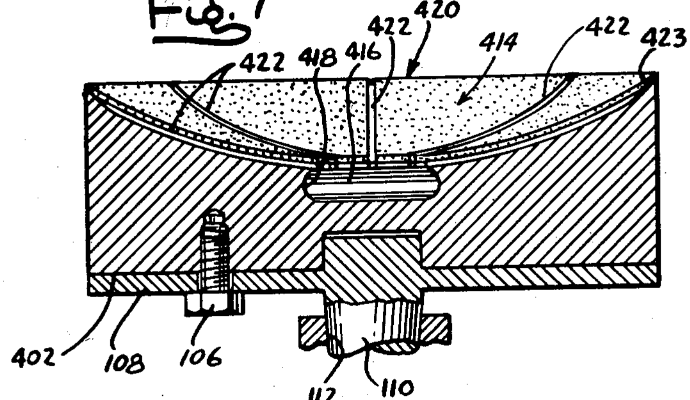

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Fig. 8

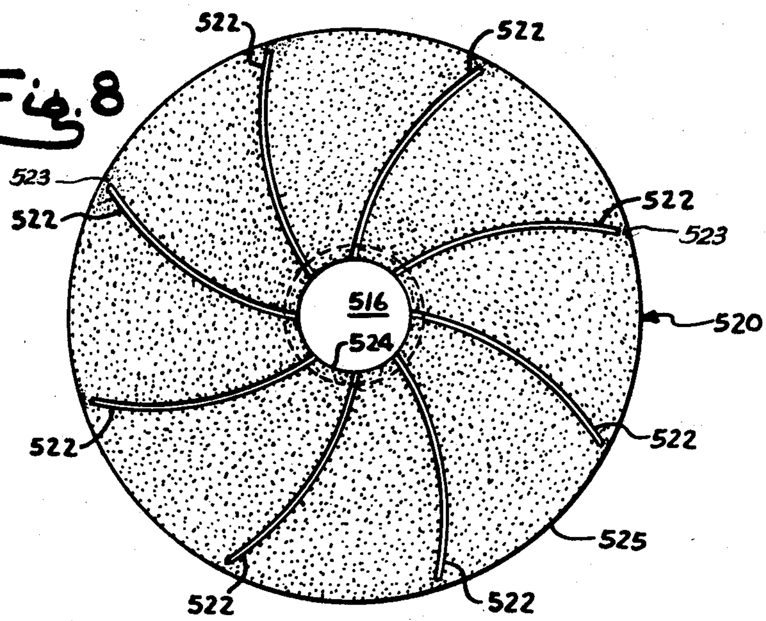
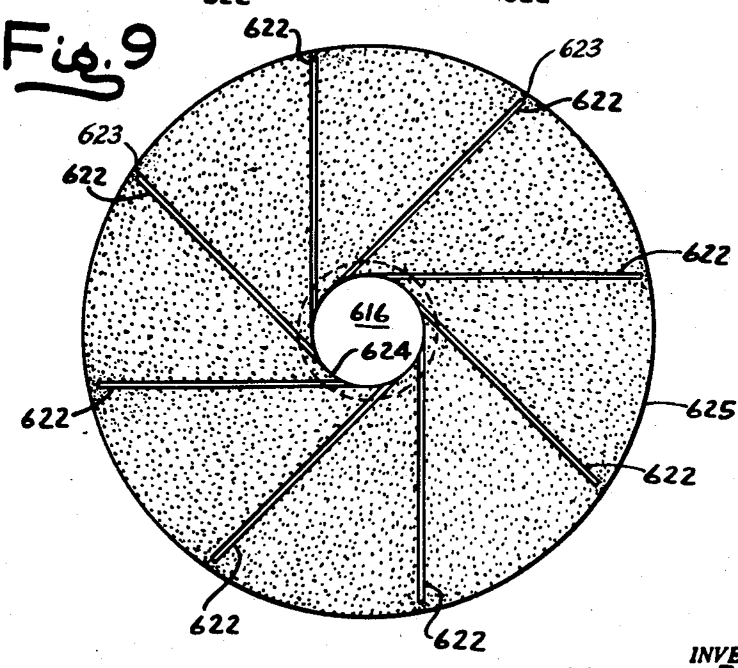


Fig. 9



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COMPOSITE LAP FOR GRINDING AND POLISHING MACHINES

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Fig. 10

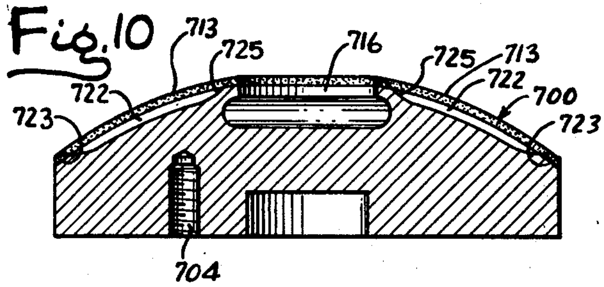


Fig. 11

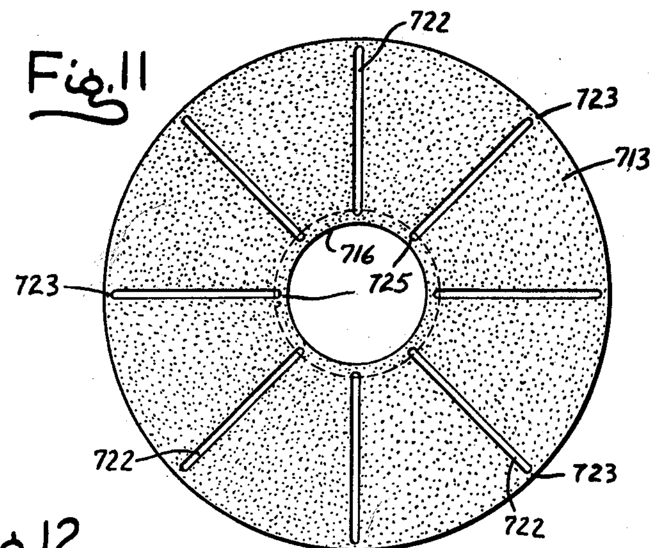
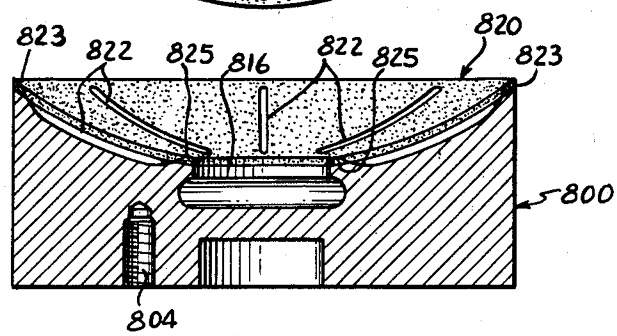


Fig. 12



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Patented Apr. 14, 1964

3,128,580

COMPOSITE LAP FOR GRINDING AND POLISHING MACHINES

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Filed Jan. 30, 1963, Ser. No. 255,054
10 Claims. (Cl. 51—131)

The present invention relates to grinding and polishing machines and has particular reference to a novel form of composite diamond lap wherein the coolant liquid may more effectively be applied to the article or articles undergoing lapping and the resultant sludge more effectively discharged from the surface of the lap.

In United States Patent No. 2,607,174, granted on August 19, 1952, to Ralph Lanius and entitled "Method of Grinding Eyeglass Lenses," there is shown and described a grinding and polishing machine which is suitable for carrying out the particular grinding method of such patent. It is to this general class of machines that the present invention relates and the composite lap of the present invention is applicable to the machine which is shown in the Lanius patent, as well as to various other so-called lapping machines for performing the same function.

Insofar as the abrasive material which performs the actual cutting, grinding or polishing operation is concerned, rotary laps may be divided into two general classes. In one type of lap, the lap body is formed of close grained cast iron and a relatively small quantity of abrasive material, such as finely divided emery, in suspension in a liquid, such as water, is continuously applied to the lap surface for effecting the actual removal of material from the article or articles undergoing lapping, this liquid material being distributed over the surface of the lap by a natural spreading operation. In the other type of lap, as exemplified by the machine which is illustrated in the Lanius patent, the abrasive material is in the form of finely divided crushed or fragmented diamonds which are embedded in a metallic or other matrix with the cutting points of the diamonds protruding outwardly beyond the surface of the matrix and this protruding relationship being maintained throughout the life of the matrix as the embedding material wears away. In the operation of this latter type of lap, a liquid coolant is supplied to the lap surface in relatively large quantity to produce a thin film on which the article undergoing lapping is supported or "floats," so to speak, with the diamond cutting material projecting through and protruding above the film surface a predetermined distance as determined by the particle size. The thickness of the coolant film, as determined by the character of the coolant, and as related to the particles size, determines the nature of the cutting operation, and when these two factors are properly correlated, the rate of removal from the article or articles undergoing lapping is at its maximum consistent with effective lapping, i.e., without producing surface blemishes, such as grooves or striations, burn spots, and the like. Broadly stated, laps of the first mentioned type employ loose or free abrasive particles which may or may not have a diamond content. Laps of the last mentioned type employ diamond particles which are fixed with respect to the lap surface and rotate with the lap about the central axis of rotation. Laps of the first mentioned type are usually designed for slow speed rotation and the liquid material which is applied thereto has but little cooling function, it serving merely to distribute the abrasive particles evenly over the lap surface. Laps of the second mentioned type are usually designed for high-speed rotation and the liquid coolant that is applied thereto is both for cooling purposes and to prevent surface burns, as well as to provide the aforementioned film which properly spaces the surfaces undergoing lapping from the upper face of the diamond-carrying matrix.

The present invention is specifically concerned with laps of the fixed particle type as outlined above and it is to be distinguished from laps which employ loose abrasive particles over the wroking surfaces thereof since to this class of lap the present invention is not applicable. It should be further understood that throughout this specification and in the following claims the terms "lap" and "lapping" relate to working platens and operations respectively by means of which material is actually removed from the surfaces undergoing treatment and is carried away by the liquid coolant.

The improved composite lap comprising the present invention has been designed for use primarily in connection with the grinding and polishing of articles having spherical or arcuate surfaces, especially lenses which are formed of glass or other transparent materials, such as quartz, synthetic plastics and the like, and are used for optical purposes. The invention is, however, capable of other uses and composite laps constructed in accordance with the principles of the present invention may, if desired and with or without modification, be employed in the grinding and polishing of articles having planar surfaces, as, for example, piezo electric or quartz oscillator crystals and small machine parts, such as the running seal faces of mechanical seals. Irrespective, however, of the particular use to which the present invention may be put, the essential features thereof are at all times preserved.

In connection with a lap of the type briefly outlined above, it has been found, particularly where the diamond abrasive is of small mesh or micron size, that there is a tendency for the surface undergoing lapping to run dry due to the inability of the coolant liquid to enter between the article undergoing lapping and the operative lapping surface of the lap. One reason for this resides in the small entrance area leading to the space existing between the article and the operative lap surface. Furthermore, the working pressure which is maintained draws the two running surfaces together with sufficient force to exclude the entrance of the coolant liquid. For these same reasons, it is difficult to discharge the fine silt-like sludge which is created as a result of the lapping operation from beneath the article.

Another limitation that is attendant upon the construction and use of a conventional lap resides in the interference which is offered by resistance of the material undergoing lapping to actual stock removal from the surface thereof. This resistance restricts and sometimes terminates altogether the free movement of the article undergoing lapping. This latter limitation is prevalent in connection with the use of that class of lapping machines in which the work holder is intended to allow freedom of movement of the article on the lap surface under the influence of frictional forces between the lap surface and the articles themselves, while at the same time, the work holder is prevented from revolution about the axis of rotation of the lap. In such machines, the work holder to which the article is affixed is usually mounted for limited universal movement in one sector of the lap area, while at the same time, it is permitted freedom of rotation about its own axis. It is thus held against revolving about the axis of the lap while the surface of the article undergoing lapping is free to seat squarely upon the lap. Due to the higher circumferential speed of the outer regions of the lap than the circumferential speed of the inner regions of the lap, a frictional differential is set up which produces unbalanced forces on the article tending to cause rotation of the work holder. In the case of a single article, the same is caused to rotate on the lap, while in the case of plural articles, the articles are given a localized rotary path of movement over the rotating lap surface. However, when a high degree of stock removal is taking place, this freedom of movement of the work holder is restrained, and since the involved frictional differential is invariably small, amounting to but a few dynes of resultant torque on the work holder, the free movement of the work holder is retarded appreciably, even to the point of its cessation altogether. The net result is the production of arcuate striations on the surfaces undergoing lapping due to repetitious encounter with the same diamond or other grit particles which repeat their paths of movement across the surface being lapped.

The present invention is designed to overcome the above-noted limitations that are attendant upon the construction and use of conventional optical and similar laps and it, therefore, contemplates the provision of a composite diamond lap which physically is so constructed as to receive and evenly distribute over the operative surface thereof the liquid coolant to carry the coolant freely between the opposed running surfaces on the lap and article or articles undergoing lapping without sacrificing the necessary lapping pressure; and to establish and maintain the necessary coolant film between such running surfaces so that there will be no interference with freedom of independent rotation of the work holder, and consequently, of the article or articles that are carried thereby.

The provision of a diamond lap which, as stated above, avoids the limitations of conventional laps constitutes the principal object of the invention, and in carrying out this object, there is provided a lap body which has the desired lap curvature or configuration and in which the operative abrasive or cutting surface of the diamond-embedding matrix is divided into sectors or other segments by a series of intervening radial grooves, or grooves which have a large component of radial direction. The lap surface is essentially annular in that it is provided with a circular central depression therein so that it has both an inner and an outer periphery with the grooves extending between or spanning the distance between such peripheries. The depth of the grooves is preferably, but not necessarily, greater than the thickness of the diamond-embedding matrix so that this matrix is thus divided by the grooves into individual sectors or segments. The grooves which, in the preferred form of the invention, are radially disposed, serve several functions, principally among which are the creation of an entryway for the liquid coolant beneath the face of the article undergoing lapping, as well as for the positive forcing of the liquid coolant between the particle and the lap surface; the equal distribution of the liquid coolant over the operative surface of the lap so that there will be no coolant-starved lap areas; and the bleeding of the space between the article and the lap surface to the atmosphere to prevent the creation of a vacuum therein.

Still further, in carrying out the above-mentioned object, in order more effectively to feed the inner ends of the diverging grooves in the lap surface, the central depression with which the inner ends of the grooves communicate has its wall bowed outwardly or undercut to provide a generally circular peripheral pocket within which the liquid coolant may collect under the influence of centrifugal force and from thence be distributed to the ends of the grooves, while at the same time being prevented from creating a spout or fountain at the rim of the depression, such a phenomenon being prevalent when the wall or the depression is truly cylindrical.

It has been found that in certain instances it may be desirable to restrict the flow of liquid coolant radially outwardly along the grooves by damming up the ends of the latter, so to speak, thereby causing such liquid coolant as may flow outwardly in the grooves to be retained under the article or articles undergoing polishing on the lap surface. Toward this end, in one modified form of the invention, means are provided at the outer ends of the grooves for effectively damming them so that the quantity of liquid coolant flung from the lap by centrifugal force will be restricted. In another modified form of the invention, means are provided at the inner ends of the grooves for effectively restricting the quantity of coolant which may enter these grooves and for thus diverting some of the liquid coolant issuing from the central depression to the inter-groove areas of the lap. By such an expedient, the tendency for too high a concentration of coolant in the grooves with a consequent dearth of coolant on the intergroove areas of the lap is eliminated. It is a further object of the invention to provide novel means for thus restricting the outward flow of coolant and effecting a more even distribution of the coolant over all areas of the lap than has heretofore been possible.

It is an ancillary object of the invention to provide a composite diamond lap which, by reason of the greater groove depth as outlined above, will permit the diamond-carrying matrix which establishes the lap surface proper to be used to completion, while at the same time maintaining throughout its entire useful life the benefits afforded by the radial grooves.

With these and other objects and advantages in view, which will more readily become apparent as the following description ensues, the invention consists in the novel construction, combination and arrangement of parts shown in the accompanying five sheets of drawings forming a part of this specification.

In these drawings:

FIG. 1 is a side elevational view, partly in vertical longitudinal section, of a polishing and grinding machine employing a composite diamond lap constructed in accordance with the principles of the present invention and designed for use in producing spherical concave surfaces on an optical lens or the like;

FIG. 2 is an enlarged vertical section of the lap of FIG. 1;

FIG. 3 is a section similar to FIG. 2, but showing the lap being employed for multiple lens lapping purposes;

FIG. 4 is a top plan view of the lap of FIG. 2;

FIG. 5 is a sectional view similar to FIG. 2 but showing a slightly modified form of the invention;

FIG. 6 is a sectional view similar to FIG. 2 but showing a diamond lap designed for use in producing spherical convex surfaces on an optical lens or the like;

FIG. 7 is a sectional view similar to FIG. 6 but showing another form of diamond lap;

FIG. 8 is a top plan view similar to FIG. 4 but showing a further modified form of the invention;

FIG. 9 is a top plan view similar to FIGS. 4 and 8, but showing another modified form of the invention;

FIG. 10 is a sectional view similar to FIG. 5 but showing a further modified form of lap for producing concave surfaces on an optical lens;

FIG. 11 is a plan view of the lap of FIG. 10; and

FIG. 12 is a sectional view similar to FIG. 10 but showing a modified form of lap for producing convex surfaces on an optical lens.

Referring now to the drawings in detail, and in particular to FIG. 1, a more or less conventional grinding and polishing machine employing a composite diamond lap constructed according to the present invention has been designated in its entirety by the reference numeral 10 and involves in its general organization a base casting 12 of hollow, generally cylindrical design and including a central hub portion 14, an upper horizontal table portion 16, and an outer cylindrical apron portion 18. The hub portion 14 serves rotatably to support a composite diamond lap 20 having an upwardly facing convex lap surface 22. The lap 20 is of novel design and constitutes the subject matter of the present invention. It will be described in detail presently after its environment in the machine 10 has been set forth.

The lap 20 is removably carried on the upper end of a vertically extending rotatable shaft 24 which is telescopically and slidably mounted within a sleeve 26 and is keyed to the sleeve as at 28 for rotation in unison therewith. The sleeve 26 is rotatable in bearings 29 which are supported in the hub 14. The shaft 24 is formed with a depending shank **30** of reduced diameter. The lower end of the shank **30** receives thereover an adjusting collar **32**. A spring **34** has its lower end seated on the collar **32** and has its upper end bearing against a downwardly facing shoulder **36** on the shaft **24** and serves to urge the latter, and consequently, the lap, upwardly so that the desired working pressure between the lap surface **22** and the work may be maintained. A set screw **38** permits the necessary vertical adjustment of the collar **32**. A pulley **40** is mounted on the lower end region of the sleeve **26** and is adapted to be driven by a belt **42** leading from a suitable source of power which may be the drive shaft of an electric motor (not shown).

The article which is to be applied to the upwardly facing convex lap surface **22** is adapted to be positioned in a suitable work holder, such as the holder shown at **50** in FIG. 1. The work holder **50** illustrated herein is purely exemplary as various other types of work holders may be employed. The work holder **50** is designed to accommodate the positioning of a single concavo-convex lens blank **52** with its concave face against the lap surface **22** and, accordingly, the underneath face of the holder is provided with a surface **54** (FIG. 3) to which the complementary convex face **56** of the blank **52** is suitably cemented or otherwise adhered.

The work holder **50** is positioned over the rotating face of the lap and is possessed of a limited degree of universal motion so that it will follow the lap contour. As shown in FIGS. 1 and 2, the work holder is adapted to be positively rotated independently of the rotational movements of the lap while preserving such universal motion. Accordingly, the work holder has a ball and socket connection **60** with the lower end of a spindle **62** and a driving connection in the form of engageable driving pins **64** and **66** on the work holder and spindle, respectively, establish this driving connection.

The spindle **62** is rotatably mounted in upper and lower bearings **68** and **70** and they are carried in a sleeve **72** which is slidable in a yoke **73**. The yoke is longitudinally adjustable in a bracket **74** which is pivoted as at **76** to a foot piece **78**. The latter is adjustably mounted as at **80** on the table portion **16** for movement toward and away from the axis of rotation of the lap **20**. The upper end of the spindle **62** carries a pulley **82** which is adapted to be operatively connected to a belt **84** by means of which the spindle is rotated. The yoke **74** is provided with a threaded bore **86** through which there extends a feed screw **88**, the ends of which are rotatable in the brackets **75**. An operating hand wheel **90** enables the feed screw **88** to be manually rotated to adjust the position of the yoke **74**, and consequently, of the work holder **50** toward and away from the lap surface. The proper working pressure of the work holder **50** against the lap may be regulated by means of an adjusting collar **92** and a cooperating spring **94**.

The arrangement of lapping machine parts thus far described is purely conventional and no claim is made herein to any novelty associated with the same. The work holder **50** may be positioned against the lap **20** by mechanism other than that illustrated in FIG. 1. The illustrated mechanism maintains the work holder against the lap at a fixed radial distance from the center of the lap, but it is contemplated that gyratory or other movements having a radial component of motion may be applied to hte work holder if desired. Under certain circumstances, it may be found desirable manually to move the work holder **50** over the surface of the lap in the manner shown and described in the above-mentioned patent to Lanius. The present invention is independent of any particular lapping machine or any particular form of work holder or work holder operating mechanism and consists rather in the novel form of lap and in the means whereby the lap surface thereof is fed with a liquid coolant, as will now be described in detail.

Referring now additionally to FIG. 2, the composite lap **20** is in the form of a generally cylindrical body **100** which is formed of a suitable metal, such as brass, bronze, or the like. The flat underneath side **102** of the body is provided with a bolt-receiving hole **104** for the reception therein of a fastening bolt **106** by means of which the lap may be secured to a suitable adapter **108** having a shank **110** receivable in a socket **112** in the upper end of the rotary drive shaft **24** (see FIG. 1). The lap body **100** is provided with an upper surface **113** which is commensurate in shape to the configuration of the surface on the lens **52** or other article undergoing lapping. As shown additionally in FIG. 4, the upper surface of the lap body **100** is substantially covered with a matrix **114** having diamond particles distributed throughout the same. The matrix may be formed of any suitable material and the particles are substantially evenly distributed therein, the matrix serving to fix the individual diamond particles on the lap surface for movement with the lap as the latter rotates. The hardness and other physical characteristics of the matrix are such that as the matrix wears, the diamond particles are exposed for approximately one-third of their over-all height, such being the nature of a lap which will produce optimum results and effect maximum removal of material from the lens with a minimum of wear on the lap surface. The upper surface **72** of the matrix constitutes the actual operative lap surface.

The upper surface **113** of the lap **20** is formed with a generally cylindrical coolant-receiving depression or well **116**, the side wall of which is undercut as at **118** so as to provide an inwardly extending lip **120** which constitutes, in effect, a weir over which the liquid coolant that is supplied to the well is adapted to flow in a manner and for a purpose that will be made clear presently. The lip region of the well **116** communicates with a series of radially disposed linear grooves **122** (see particularly FIG. 4) which substantially span the distance between the inner periphery **124** of the annular lap surface **113** and the outer periphery **125** thereof. The depth of the grooves as shown in FIG. 2 is preferably, but not necessarily, slightly greater than the thickness of the matrix so that these grooves cut completely through the matrix and into the metal of the lap body **100**, thus completely dividing the matrix into a series of independent sectors which are separated from one another by the various grooves **122**. The bottoms of the grooves **122** have their external outer regions **123** turned upwardly so as to provide, in effect, dams or restrictions which inhibit the passage of liquid coolant along the grooves. Such an arrangement prevents inordinate centrifugal flinging of the coolant from the outer ends of the grooves and thus conserves the coolant while at the same time serving to hold an adequate supply of coolant on the upper surface **113** of the lap.

In order to supply the liquid coolant to the lap surface **113**, a supply pipe **130** is arranged to discharge such coolant into the well **116** from above the lap. Various types of coolant are suitable for use in connection with the present lap and any coolant which is non-oily, non-slippery, non-toxic and non-rusting does not necessitate cleaning of the lens blank **52** after a grinding operation, will not permit filling of the spaces between the exposed portions of the diamond particles at the lap surface **113**, and is chemically stable, may be used. Extremely desirable results have been obtained by either of the liquid coolant materials which are now being marketed by Super-Cut, Inc. of Chicago, Illinois, under the trade designations S5 and S25.

A cylindrical guard or shield **131** is secured by screws **133** to the marginal regions of the table portion **16** to collect the liquid coolant which is flung from the periphery of the lap **20**. This coolant flows through a series of small holes **135** in the table portion **16** and is collected in a drip pan **137** for re-use if desired.

During the grinding of the lens blank **52**, the blank is mounted on the underneath surface **54** of the work holder

50, pitch or other suitable adhesive being applied to the lens and surface to hold the lens in position. The feed screw 88 is manipulated to bring the lens into operative grinding relation with respect to the lap 20, after which the driving belts 42 and 84 are set into motion to drive both the lap and the work holder in the manner previously described. At the same time, the liquid coolant is fed from the pipe 130 to the interior of the well 116.

It is to be noted that the working pressure which is maintained by reason of the springs 34 and 94 maintains the surface 54 of the lens 52 undergoing grinding in close proximity to the lap surface 113, the surface of the lens being maintained slightly spaced from the body of the matrix by a thin film of the coolant. Only extremely limited portions of the upper ends of the diamond particles project through this film and operate upon the lens for cutting purposes. If the surface tension of the film is insufficient to maintain the lens properly supported, the diamond particles will cut too deeply into the lens and provide scratches on the latter. If the surface tension is too great, insufficient cutting action will take place. The character of the liquid coolant is thus important. With diamond exposure of the magnitude set forth above and with the proper liquid coolant, a long wearing and effective lap will be obtained.

The various grooves serve several functions when employed in connection with diamond laps of the general character herein described. Principal among these functions is the carrying of the liquid coolant beneath the surface of the lens undergoing grinding. Due to the pressure which is exerted by the springs 34 and 94 as described above, especially where diamonds of small particle size are concerned, for example, particles of 270 mesh size, or smaller, the surface 54 undergoing lapping and the lap surface 113 are relatively close together so that there is not sufficient entrance-way for the liquid coolant to move into the space between the lap and the lens in the absence of the grooves 122. These grooves serve to carry the coolant beneath the lens surface 54 and thus establish the necessary supporting film for effective grinding operations, and for prevention of scratches on the lens surface and prevention of surface burns. The radial grooves also constitute conduction channels for proper radial distribution of the liquid coolant over the entire lap surface 113. Since the inner ends of the grooves communicate through the lip 120 with the wall 116, an equal supply of liquid coolant will be distributed to each radial groove. The undercut portion 118 of the well 116 provides an annular retaining pocket for the coolant which is forced therein by the centrifugal force initiated by the high speed of the lap rotation, and as more liquid is supplied to the well 116, the coolant passes directly from the well around the lip 120 and into the inner ends of the various grooves 122 from whence it is carried outwardly radially of the lap and distributed evenly over the lap surface as previously described.

Although in FIG. 4 eight of the grooves 122 have been shown with the grooves extending truly radially of the lap, it will be understood that a greater or lesser number of such grooves may be employed if desired. Furthermore, it is not essential, but only preferable, that the grooves extend truly radially since good results may be obtained where the grooves extend between the inner and outer peripheries of the lap surface 113 in secant fashion. These grooves 122 may be formed by cutting completely through a continuous matrix and into the metal of the lap body 100, or they may be formed by making the matrix in individual segments and then applying them to the surface of the lap body in slightly spaced relationship, in which case the grooves will be of a depth only equal to the thickness of the matrix. In either event, the grooves will remain in evidence and be effective until such time as the matrix has been completely used up.

In FIG. 3 the composite lap 20 of FIG. 1 is shown as being operatively associated with the lapping of surfaces

on plural lens blanks 152. The lens holder 150 is similar in its construction to the lens holder 50 of FIGS. 1 and 2 and to avoid needless repetition of description, reference numerals of a higher order, but similar in character, have been applied to the corresponding parts as between the two lens holders. The holder 150 is of larger over-all size than the holder 50 and its underneath surface 154 is designed to have adhered thereto a plurality of the lens blanks 152 which may be spaced about the longitudinal axis of the holder. The surface 154 overhangs both the inner and outer peripheries of the lap surface 113 of such an extent that the lens blanks 152, during the gyratory motion that is imparted thereto under the influence of the driving pins 164 and 166, are caused to sweep over these peripheries during the course of their movements. If the driving pins 164 and 166 are omitted, a similar gyratory motion will be applied to the lens blanks 220 under the influence of the frictional differential which exists between the faster moving outer peripheral regions of the lap and the slower moving inner peripheral regions thereof. It is to be noted in connection with FIG. 3 that although the holder 150 overhangs the inner periphery of the lap surface 113 and overlies the well 116, there still is adequate space for introduction of the liquid coolant into the well from the pipe 130.

In FIG. 5, the composite diamond lap is similar in many respects to the lap 20 of FIGS. 1 to 5, inclusive. Thus, again to avoid needless repetition of description, reference numerals of a still higher order have been employed as between the corresponding parts. In this latter form of the invention, the bottoms of the radial grooves 222 terminate short of the outer periphery of the lap body so that the matrix is not completely divided into individual sectors. The sectors which are created by reason of the grooves 222 remain joined together at the outer periphery of the lap body by narrow circumferentially extending webs 223, these webs constituting restrictions against the free flow of liquid coolant in a manner similar to the restrictions 123 at the outer ends of the grooves 122 of the lap 20.

In FIG. 6, the principles involved by the provisions of the radial grooves 122 in connection with the lap 20 are applied to a composite diamond lap 320 in which the upper surface 313 thereof is of concave configuration and is provided with grooves 322. The bottoms of these grooves 322 have their extreme inner end regions turned upwardly at 323 to provide, in effect, dams or restrictions at the inner ends of the grooves 322, the restrictions inhibiting but not completely preventing the entry of liquid coolant into the groove from the well 316. Such damming of the inner ends of the grooves prevents overflooding of the lap with the liquid coolant and, in effect, serves a function similar to the restrictions 123. In this form of the invention, the matrix 314 is divided into individual and separate sectors. The lap 320 is designed for use in the lapping of convex surfaces on concavo-convex, plano-convex or double convex lenses.

The composite diamond lap 420 of FIG. 7 is substantially the same as the diamond lap of FIG. 6 with the single exception that the radial grooves 422 have the bottoms of their outer ends turned upwardly as at 423 to provide fluid restrictions to inhibit coolant discharge as described in connection with the diamond lap of FIG. 5. In this form of the invention, the grooves 422 divide the matrix 414 into individual sectors.

In FIG. 8, a further modified form of the invention is illustrated wherein the radially diverging grooves 522 are of arcuate extent, while in FIG. 9, another modified form of the invention reveals that the grooves 622, instead of extending truly radially as in the case of the laps of FIGS. 1 to 7, inclusive, extend in secant fashion between the inner and outer peripheries of the lap. In each of these two views, reference numerals of a progressively higher order are employed to designate corresponding parts as between the laps of the preceding views and those of FIGS.

8 and 9, thus again avoiding needless repetition of description. In both of these views, the grooves involved terminate short of the outer periphery of the lap, leaving interconnecting webs between the matrix sectors.

In FIGS. 10 and 11, the invention is illustrated in connection with a grooved convex lap for producing concave surfaces on a lens blank or similar article, and in which the radial grooves **722** have not only their outer ends blocked by restrictions **723**, but also their inner end regions blocked by restrictions **725**, while in FIG. 12, similar restrictions **825** are provided at the inner ends of the radial grooves **822** in a concave lap for producing convex surfaces on a lens blank. In these two forms of the invention, the grooves terminate short of the inner and outer peripheries of the laps so as to leave narrow webs between the adjacent matrix sectors. Repetitious description has again been avoided in connection with each of these forms of the invention by the use of reference numerals of a higher order to designate corresponding parts as heretofore explained in connection with the other modified forms of the invention.

Where any of the forms of the invention employing radial grooves having restrictions at either their inner or outer ends or at both ends are concerned, these restrictions may conveniently be made by commencing the grooves a slight distance away, on the annular lap surface, from the adjacent periphery of the lap, whether it be the outer periphery thereof or the inner periphery or both. The thus restricted ends of the grooves may have their bottom regions flared upwardly so as to intersect the lap surface at the extreme ends of the grooves. The illustration of FIG. 11 is typical of the other instances where restricted grooves are employed and the illustration has not been repeated for all such instances.

Restricting the inner ends of the grooves **722** or **822**, as the case may be, is particularly effective in attaining an even distribution of the coolant over the entire surface of the lap. It is to be noted that by reason of the restrictions **725** and **825**, the upper rims **720** and **820**, respectively, of the wells **716** and **718** are truly circular and unbroken. These restricted inner ends form, in effect, weirs which establish an even flow of the coolant thereover in a radially outward direction so that in each instance, a horizontally directed unbroken curtain of the coolant flows radially outwardly from the well and into the grooves, as well as onto the inner-groove areas of the lap, thus insuring uniformity of distribution of the coolant over the entire lap area. The grooves will receive some of the coolant and conduct the same radially outwards. However, the function of the grooves is primarily one of scavenging the lap of the products of abrasion. Such coolant as does find its way into the grooves serves to flush the sludge or products of abrasion along the grooves under the influence of centrifugal force while the inter-groove surfaces of the lap are supplied with coolant directly from the weirs at the rim of the well.

The invention is not to be limited to the exact arrangement of parts shown in the accompanying drawings or described in this specification since various changes in the details of construction may be resorted to without departing from the spirit of the invention. For example, the laps **20**, **320**, **420**, **520**, **620**, **720** and **820** shown herein are capable of use in connection with various lapping machines other than the machine herein disclosed. Similarly, the work holders **50** and **150** are useable with other work-manipulating means, the use of the driving pins being optional. Therefore, only insofar as the invention has particularly been pointed out in the accompanying claims is the same to be limited.

This application is a continuation-in-part of copending patent application Serial No. 113,589, filed by me on May 4, 1961, and entitled "Composite Lap for Grinding and Polishing Machines" (now abandoned).

Having thus described the invention what I claim as new and desire to secure by Letters Patent is:

1. In a lapping machine for producing a spherical surface in a lens or the like, in combination, a rotary diamond lap body having an upwardly presented annular surface of frusto-spherical contour and shaped conformably to the spherical surface to be produced on the lens, a thin sheet-like matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an annular upper lap surface from which fixed diamond particles project in part outwardly for cutting purposes as the lap surface becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central well having a circular rim which defines the inner periphery of the lap surface, said lap surface being formed with a series of equally spaced diverging grooves which are of substantially equal depth throughout and extend from the inner peripheral region of the lap surface to the outer peripheral region thereof so that they substantially divide the matrix into a series of circumferentially spaced segments, the extreme ends of the bottoms of said grooves adjacent to one of the lap peripheries being provided with fluid restrictions therein, and means for supplying a liquid coolant to said central well.

2. In a lapping machine, the combination set forth in claim 1 and wherein the fluid restrictions are provided at the ends of the grooves which are adjacent to the inner periphery of the lap.

3. In a lapping machine, the combination set forth in claim 1 and wherein the fluid restrictions are provided at the ends of the grooves which are adjacent to the outer periphery of the lap.

4. In a lapping machine, the combination set forth in claim 1 and wherein the grooves are of a depth greater than the thickness of the matrix.

5. In a lapping machine for producing a spherical surface in a lens or the like, in combination, a rotary diamond lap body having an upwardly presented annular surface of frusto-spherical contour and shaped conformably to the spherical surface to be produced on the lens, a thin sheet-like matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an annular upper lap surface from which fixed diamond particles project in part outwardly for cutting purposes as the lap surface becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central well having a circular rim which defines the inner periphery of the lap surface, said well being provided with a cylindrical wall surface, the bottom region of which is undercut to provide an annular pocket and an overlying inwardly extending circular lip which terminates in said circular rim, said lap surface being formed with a series of equally spaced diverging grooves which are of substantially equal depth throughout and extend from the inner peripheral region of the lap surface to the outer peripheral region thereof so that they substantially divide the matrix into a series of circumferentially spaced segments, the extreme ends of the bottoms of said grooves adjacent to one of the lap peripheries being provided with fluid restrictions therein, and means for supplying a liquid coolant to said central well.

6. In a lapping machine for producing a spherical surface on a lens or the like, in combination, a rotary diamond lap body having an upwardly presented annular surface of frusto-spherical contour and shaped conformably to the spherical surface to be produced on the lens, a thin sheet-like matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an annular lap surface from which fixed diamond particles project in part out-

wardly for cutting purposes as the lap surface becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central well having a circular rim which defines the inner periphery of the lap surface, said well being provided with a cylindrical wall surface, the bottom region of which is undercut to provide an annular pocket and an overlying inwardly extending circular lip which terminates in said circular rim, said lap surface being formed with a series of equally spaced diverging grooves which are of substantially equal depth throughout and extend from the inner peripheral region thereof and thus substantially divide the matrix into a series of circumferentially spaced segments, the extreme ends of the bottoms of said grooves adjacent to both of the lap peripheries being provided with fluid restrictions therein, and means for supplying a liquid coolant to said central well.

7. In a lapping machine, a rotary diamond lap comprising a lap body having an upwardly presented annular surface shaped conformably to the contour of a surface on an article to be lapped, a matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an upper annular lap surface from which fixed diamond particles project in part outwardly for cutting purposes as the lap becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central coolant-receiving well having a circular rim which defines the inner periphery of the lap surface, said lap surface having formed therein a series of outwardly diverging grooves which extend from respective points spaced a slight distance radially outwards of the inner periphery of the lap surface and terminating adjacent to the outer periphery of the lap surface, said grooves serving to divided the lap surface into a series of substantially equal and circumferentially spaced matrix sectors, adjacent sectors being connected together at the inner periphery of the lap by narrow webs which constitute restrictions to the radial flow of coolant entering said grooves, and means for supplying a liquid coolant to said central well.

8. In a lapping machine, a rotary diamond lap comprising a lap body having an upwardly presented annular surface shaped conformably to the contour of a surface on an article to be lapped, a matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an upper annular lap surface from which fixed diamond particles project in part outwardly for cutting purposes as the lap becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central coolant-receiving well having a circular rim which defines the inner periphery of the lap surface, said lap surface having formed therein a series of outwardly diverging grooves which extend from points adjacent to the inner periphery of the lap surface to respective points spaced a slight distance radially inwards of the outer periphery of the lap surface, said grooves serving to divide the lap surface into a series of substantially equal and circumferentially spaced matrix sectors, adjacent sectors being connected together at the outer periphery of the lap surface by narrow webs which constitute restrictions to the radial flow of coolant leaving said grooves, and means for supplying a liquid coolant to said central well.

9. In a lapping machine, a rotary diamond lap comprising a lap body having an upwardly presented annular surface shaped conformably to the contour of a surface on an article to be lapped, a matrix of uniform thickness throughout bonded to said surface and coextensive therewith, said matrix having diamond particles distributed throughout the same, said matrix presenting an upper annular lap surface from which fixed diamond particles project in part outwardly for cutting purposes as the lap becomes progressively worn, said lap body and matrix, considered as a whole, being formed with a central coolant-receiving well having a circular rim which defines the inner periphery of the lap surface, said lap surface having formed therein a series of outwardly diverging grooves which extend from respective points spaced a slight distance radially outwards of the inner periphery of the lap surface to respective points spaced a slight distance radially inwards of the outer periphery of the lap surface, said grooves serving to divide the lap surface into a series of substantially equal and circumferentially spaced matrix sectors, adjacent sectors being connected together at the inner and outer peripheries of the lap by narrow webs which constitute restrictions to the radial flow of coolant entering and leaving said grooves, and means for supplying a liquid coolant to said central well.

10. In a lapping machine, the combination set forth in claim 9 and wherein the grooves are of a depth greater than the thickness of the matrix.

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