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2,170,328

ART OF LAPPING OR GRINDING

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2 Sheets-Sheet 1

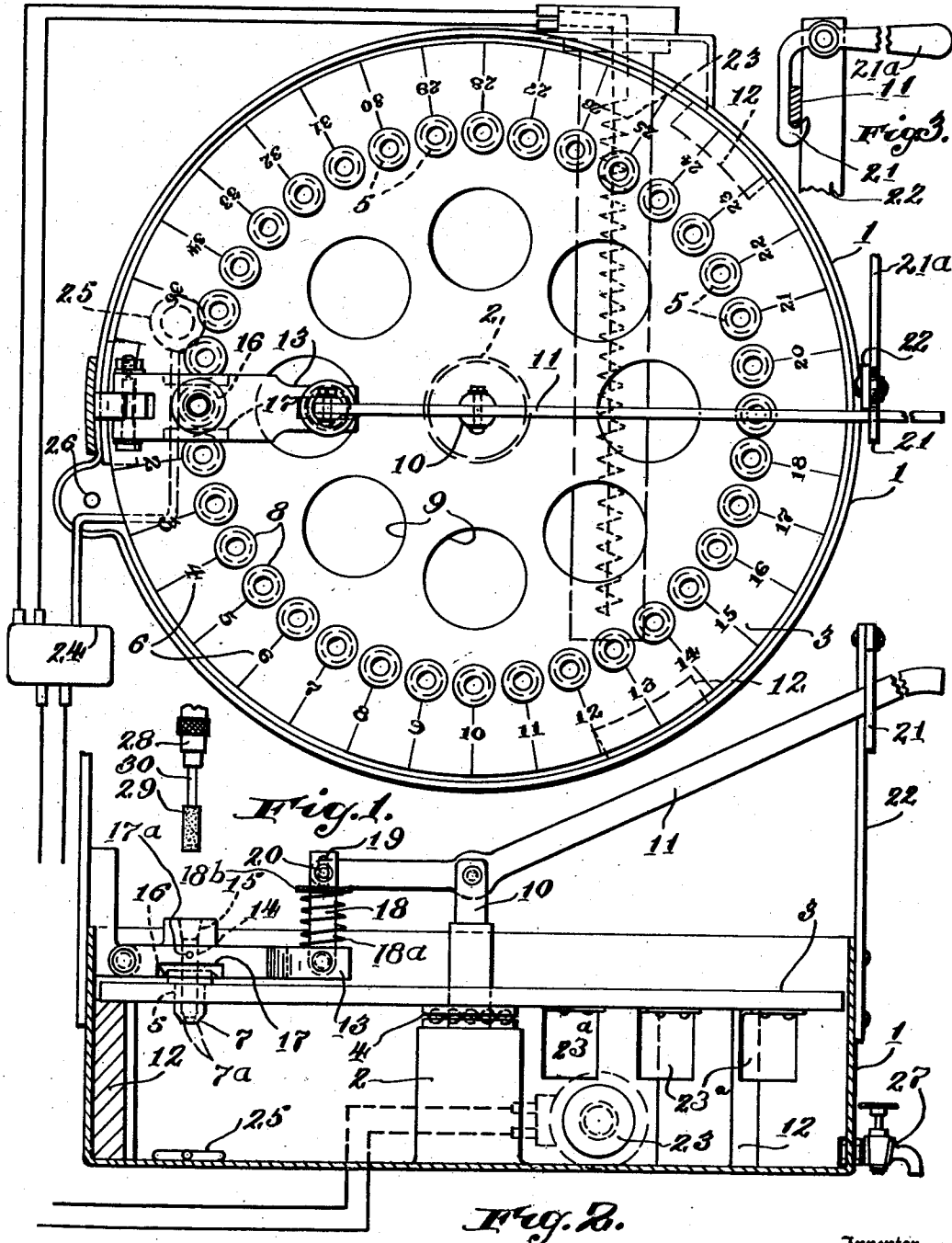


Fig. 2.

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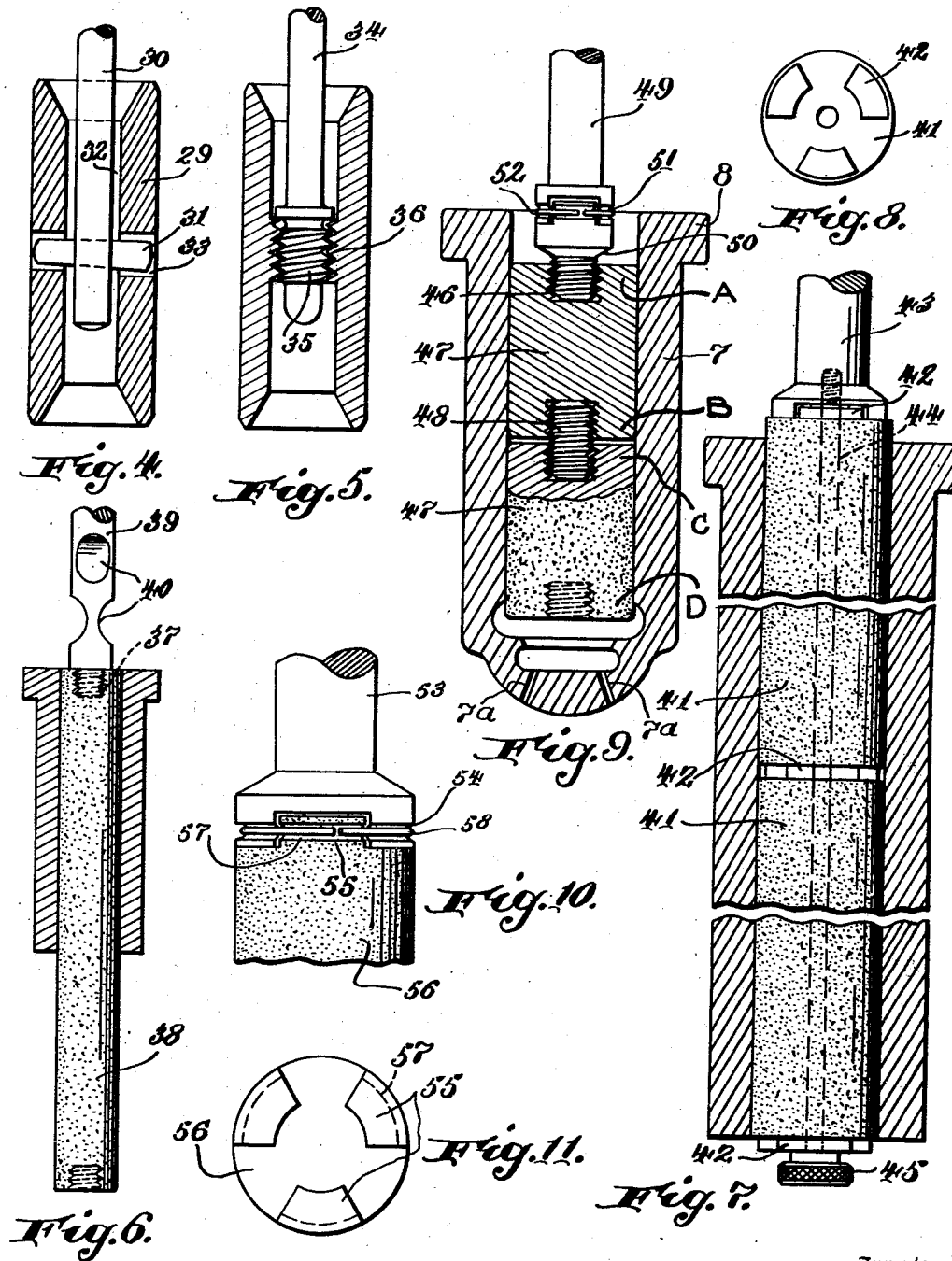
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2 Sheets-Sheet 2



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ART OF LAPPING OR GRINDING

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10 Claims. (Cl. 51—278)

The invention relates to a method of lapping or grinding. This application is a continuation in part of my copending application Serial No. 155,845 filed July 27, 1937. In another application filed of even date herewith I claim the apparatus herein disclosed.

One object of the invention is to provide a method of lapping or grinding in accordance with which extremely accurate results may be achieved. Another object of the invention is to provide a method for the lapping of internal bores to a high polish and extremely accurate limits. Another object of the invention is to provide a method of grinding or lapping according to which the cutting feed is obtained from thermal expansion and/or contraction of the lapping element. Another object of the invention is to provide a method of grinding or lapping according to which thermal expansion or contraction of a tool of known dimensions causes the cutting feed.

Another object of the invention is to provide a method of grinding or lapping wherein the tool has a different thermal coefficient of expansion from the work piece and the diameter of the work piece and the tool is changed, resulting in grinding or lapping pressure between the tool and the work piece. Another object of the invention is to provide a method of lapping or grinding of a plurality of objects such that duplication of results can be successfully achieved. Another object of the invention is to distribute errors equally over different parts of the work piece being ground, thus avoiding excess thereof at any one point. Another object of the invention is to provide a method of grinding or lapping the bore of a work piece which avoids bell mouthing.

Another object of the invention is to grind the bores of a plurality of articles so that they are all interchangeable with a given piston or set of pistons and vary in diameter only by very minute amounts. Another object of the invention is to provide an effective method for removing metal in amounts under one ten-thousandth of an inch. Another object of the invention is to provide an effective method for the grinding or lapping of small bores to high precision limits. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the several steps and relation and order of each of said steps to one or more of the others thereof, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawings in which is illustrated one of many types of apparatus which may be used to practice the method of this invention,

Figure 1 is a plan view of the apparatus;

Figure 2 is an elevation of the same with the container wall shown in section;

Figure 3 is a detailed view of a catch to hold the clamp for the article in place;

Figure 4 is an axial sectional view of a lap having a flexible connection with its arbor;

Figure 5 is a sectional view similar to Figure 4, showing a modified form of lap and connection;

Figure 6 illustrates still another form of lap, lapping an article having a bore open at each end;

Figure 7 is a sectional view illustrating still another modification in which the lap is in two parts;

Figure 8 is a view of the top of the lap shown in Figure 7 with the arbor removed;

Figure 9 is a sectional view of still another modification in which the lap is in two parts, as in the case of the lap of Figure 7, showing, however, a different type of connection;

Figure 10 is a side elevation of still another modification of the lap, showing another manner of connecting the lap to the arbor;

Figure 11 is a plan view of the lap shown in Figure 10 with the arbor removed.

Referring first to Figures 1 and 2, I provide a container 1 having therein a liquid for the transfer of heat. Because of the fact that it also acts as a lubricant, kerosene has certain definite advantages in this connection, but other liquids may be used depending upon the exact conditions in any particular grinding or lapping operation. The invention makes use of differences in the thermal expansion of the article to be lapped or ground and the lapping tool or wheel and therefore with a given set of coefficients of expansion, the greater the temperature difference the more material can be removed. I may therefore in some cases wish to use a liquid which can be successfully raised to a higher temperature than kerosene, but excellent results in actual practice have been achieved with kerosene, it being a good lubricant as aforesaid.

In the center of the container 1 is a standard 2 which supports a rotatable plate 3 by means of ball bearings 4. This plate 3 has a plurality of openings 5 arranged symmetrically therein and each opening 5 has an index number 6. In the illustrative embodiment of this invention there are thirty-six openings numbered from 1

to 36 as clearly shown in Figure 1. In each opening 5 there is placed an article 7 to be lapped. The specific articles to be lapped in this illustrative embodiment of the invention are injection nozzles for Diesel engines. As better shown in Figure 9, these nozzles 7 have one closed or blind end and one open end with an annular flange 8 which rests upon the plate 3.

Fuel pumps and injection nozzles of small size high speed Diesel engines must function with a high degree of accuracy, in view of the very small quantities of fuel injected for each working stroke of the engine. In the case of an engine running at 2000 R. P. M., injection may have to be completed in about .002 of a second and if the engine is of a four cycle type, each fuel pump and injection nozzle must go through the injection process one thousand times per minute. If the engine is of the two cycle type, at 2000 R. P. M., injection must occur two thousand times per minute for each cylinder. The sizes of the fuel pump and injection nozzle of such an engine are so small that it is not practical to use piston rings or other means to insure accurate fitting. The plungers and cylinders must be lapped with a clearance not to exceed .0001 of an inch and to obtain such accuracy has been a very difficult problem in this art heretofore. The outer cylindrical members of the injection nozzle and fuel pump are not only hardened but nitrided before being lapped for final use. The hardening process, if done after the lapping, would so warp the surfaces that they would lose their accuracy of fit, and cause leakage.

The container 1 is filled with kerosene or other liquid to above the level of the tops of the flanges 8 so that it will reach the lapping tool and heat the lapping tool while lapping takes place. To permit free circulation of the liquid in order to facilitate the transfer of heat, I provide holes 9 in the plate 3, as clearly shown in Figure 1.

Referring again to Figures 1 and 2, the standard 2 has projecting from its center a standard 10 on which is pivotally mounted a hand lever 11. The container 1 has preferably equally distributed around its circumference three supports 12 which serve to maintain the plate 3 in a horizontal position. Over one of these supports 12 and hinged to the side of the container 1 is a clamp 13 which has in its center, when horizontal, a vertical opening 14 substantially the finished size of the bore of the article to be lapped. This opening has a slightly flared top portion 15 to form a lead for the lap. The lower portion of the clamp 13 has a seat 16 concentric with the opening 14 and of the same diameter as the flanges 8 of the articles 7 whereby to clamp an article against the plate 3 with its bore in alignment with the opening or bore 14. The clamp 13 has cut-outs 17 to avoid striking adjacent articles and a hole 17a extending right through the clamp intersecting the bore 14. The hole 17a, which has two portions one on each side of the clamp, admits the heated fluid to the opening or bore 14 and also to the bore in the article 7. Thereby the heated fluid is brought in contact with the lapping tool to heat it. The article 7 has holes 7a in the bottom thereof which are the discharge openings for fluid in the article when it is used as a Diesel fuel pump and injection nozzle, and these openings serve to permit the oil to be discharged downwardly, thus avoiding a hydraulic lock when the lapping tool enters.

The free end of the clamp 13 is forked and a link 18 is pivotally fastened to the clamp 13 in

this forked portion. The upper end of the link 18 is forked and in the sides of the fork are elongated slots 19 receiving a pin 20 extending through the end of the lever 11. A spring 18a surrounds the link 18 extending between the forked portion of the clamp 13 and a washer 18b which abuts the end of the lever 11. When the lever 11 is in the position shown in Figure 1 the spring 18a holds the clamp 13 resiliently against the flange 8 of one of the articles 7. By lowering the outer end of the lever 11, thus raising the link 18, the clamp 13 is raised to permit the plate 3 to be indexed to bring another article 7 into position to be clamped in place for lapping. As shown in Figures 1, 2 and 3, the outer end of the lever 11 is held in the resilient holding position of Figure 1 by a catch 21 which is pivoted to a standard 22 attached to the container wall. This catch has a handle portion 21a by means of which it may readily be released in order to lower the outer end of the lever 11 and thus raise the clamp 13. Raising the clamp 13 releases a particular work piece 7 and allows the operator to index the plate 3 to bring another work piece into line with the clamp 13, whereupon he may clamp such work piece in position to be lapped. The plate 3, when the clamp 13 is released, is freely rotatable and a stick or the like may be used to index it into a new position.

I provide an electric coil 23 in the bottom of the container 1 to heat the liquid to a given amount and to maintain the temperature that is desired. Preferably I provide baffles or paddle plates 23a on the under side of the plate 3 to agitate the liquid whenever the plate 3 is indexed, thereby to distribute the heat more effectively. The electric coil 23 may be energized through a thermostatically operated switch 24 which is controlled by a thermostat bulb 25 placed in the bottom of the container preferably near the lapping station. As a guide to the operator a thermometer 26 may also be placed in the liquid. I provide a discharge valve 27 for withdrawing the liquid from the container. The liquid may be discharged from the container when it is desired to start a new series of lapping operations with cool liquid, or any other desired manner of cooling the liquid may be adopted.

Practically any form of drill press may be used having a chuck to hold the lap and to rotate it and to allow it to be raised and lowered at the will of the operator. In Figure 2 a chuck 28 is shown containing a lap 29 held by its arbor 30 in the chuck.

While I have herein illustrated a work piece which is held practically rigidly by a clamp having a seat 16 exactly fitting the flanges 8, and a lapping tool 29 which floats on its spindle 30, it must be understood that I may use a rigidly mounted tool and a floating work piece. This can be achieved simply by making the seat slightly over sized and the spring 18a somewhat weak and providing a lap rigidly fastened to its spindle. However in this present embodiment of the invention I have more particularly shown on sheet #2 of the drawings various types of floating laps and the apparatus of Figures 1 and 2 is adapted to hold the work piece fairly rigidly so that the method involves, in this present embodiment, a rigidly held work piece and a floating lap, it being understood that a lap which is mounted on a fixed axis may be used in lapping a work piece which is allowed to float according to the method of the invention.

Referring now to Figure 4, an arbor 30 is

shown having a key 31 which may be driven tightly therein and removed at will. The lap 29 shown in this view has a slightly enlarged central bore 32 to allow free play of the lap on the arbor.

5 The opening 33 transversely of the lap is larger than the ends of the key 31 to allow comparatively free play of the lap on the key, although rotary motion is transferred to the lap by means of the key. This lap and the others herein
10 described may be made of aluminum, brass, or bronze metals and alloys. Assuming the material to be ground to be a ferrous metal, either cast iron or steel or some other type, as most work pieces are, the coefficient of thermal expansion is of the order of 9 to 13 times 10^{-6} at moderate temperatures, for example from the freezing point of water to the boiling point of water. Brass has a corresponding coefficient of about 18. Aluminum has a corresponding coefficient of around 20 and higher. Bronze has a corresponding coefficient of about 18 and higher depending upon the particular bronze, and an aluminum copper alloy has a coefficient as high as 27. These metals aluminum, brass and bronze
25 are preferred and give excellent results in actual practice. Each of them will readily receive abrasive material into its surface. The abrasive material which is preferably used is diamond dust, for example very fine diamond dust of the order of four hundred mesh grit size or even finer. For certain lapping operations I may use such abrasives as emery, corundum, fused alumina, or silicon carbide. The uncharged piece of aluminum, brass, or bronze is placed on a steel plate which has been sprinkled with the abrasive material and by means of the narrow edge of another steel plate (both being rectangular parallelepipeds), the lap is rolled into the abrasive dust upon the plate and this serves to charge it with
40 abrasive. It should be understood that the materials mentioned are given by way of example and other materials might be used.

While in the specific embodiment of the invention described liquid is used to heat the work
45 piece and the lap, it must be understood that other methods of heating them may be employed, such as the use of a blast of hot air, or on the other hand, so far as certain features of the invention are concerned, the lap alone may be heated and this may be done in any suitable or convenient manner.

Continuing now with the detailed disclosure of the lapping tools and referring again to Figure 4, it will be seen that the key 31 may be removed
55 and the lap may be changed end for end at will and the key reinserted. Thus distribution of possible errors is to this extent achieved. As the lap is free to wobble on the spindle 30 it will readily adjust itself to the bore of the work piece.

Referring now to Figure 5 an alternative structure for accomplishing the same purpose is shown and in this view an arbor 34 has thereon screw threads 35 which fit loosely in screw threads 36 on the lap. These loose screw threads allow the lap
65 to have a floating movement on the arbor thus accomplishing substantially the same result as the construction shown in Figure 4.

A further means of accomplishing substantially this result for a lap intended to operate on an open ended article is shown in Figure 6. In this view not only do the screw threads 37 fit loosely in the lap 38 but the arbor 39 is pressed in on both sides in two places at right angles to each
75 other as shown at 40, which makes practically a

universal joint so far as the amount of play required is concerned.

In Figure 7 a sectioned lap is shown for operating on an open ended article. In this construction the lap is made in two identical transverse
5 sections 41, each section being a small cylinder and each section having three clutch faces 42 projecting from each end. These clutch faces and the spaces allowed therebetween allow a loose connection while imparting rotary movement between the sections of the lap. The arbor 43 has similar clutch faces at its lower end and a rod 44 is threaded into the arbor 43 and has at its lower end a nut 45 to hold the sectioned lap resiliently on the arbor while maintaining its rotation with
15 the arbor.

Instead of using these clutch faces, loose screw threads 46 in the sections 47 of the lap, as shown in Figure 9, may be used and these sections may be fastened together by a bolt 48 loosely attaching them and they may be attached to the arbor 49 by means of the threaded member 50 having thereon a clutch face similar to that shown in Figure 8 and the circumference of which has a groove 51 therein, around which is a spring wire ring 52. This clutch member also fits loosely to allow for play laterally between the lap and the arbor.

In Figure 10 a clutch form of connection between arbor and lap is shown which might be used instead of the connection shown in Figure 6. In this view the clutch portions 54 on the arbor 53 and the clutch portions 55 on the lap 56 are circumferentially grooved at 57 and in this groove is placed a spring ring 58.

Because of the reversible feature of the lap, uniformity of wear on the lap is produced and that uniformity promotes uniformity of lapping in the article. By making the lap in two sections, eight variations of arrangement of the lap on its arbor are available. If the lap shown in Figure 9 be considered and the respective ends of the sections be lettered as shown, the following arrangements (reading down) are possible:

A B A B C C D D
B A B A D D C C
C C D D B A A B
D D C C A B B A

By this means both barrelling and spooling of both lap and bore are avoided and the errors which creep in due to wear on the lap are symmetrically distributed.

This result is also furthered by the use of a lap slightly shorter than a blind bore, in which, after the lap is completely inserted in the bore, it is reciprocated a few times near the blind end of the bore and without abrading the entrance and exit portion at the same time. However, for articles with a bore open at both ends, good results may be obtained with a lap longer than the bore as shown in Figure 6. In all embodiments of the invention it is preferable both to reciprocate and rotate the lap relatively to the object being lapped.

It will now be understood that in the use of the invention, with each vertical movement of the lap into the bore and the withdrawal therefrom only a very small amount of metal is removed and the invention contemplates lapping each of the articles a number of times in any predetermined sequence this small amount. If the sequence were always the same, due to the infinitesimal wear on the lap the articles finally lapped would be lapped less than those initially lapped, and

therefore this sequence should be varied. If, for example, the temperature is to be raised in ten stages, with each work piece lapped a certain amount at each temperature stage, the order of lapping of the work pieces should preferably be different for each of the ten different stages and the order of lapping should be such that each work piece will be lapped the same number of times early in each stage, the same number of times late in each stage, and the same number of times near the middle of each stage. Various numerical arrangements for the order of lapping may be devised and for examples of such numerical variations of lapping reference may be made to my prior Patents No. 1,491,101 and No. 1,486,342. By this process of lapping in a varied sequence the errors which would creep in due to the wear on the lap may be made infinitesimally small and by varying the change of temperature between any sequences a larger or less amount of abrading may be accomplished by the corresponding movements of the lap. Likewise by varying the positions of the lap on its arbor further errors that creep in due to lap wear are eliminated and thus a multiplicity of uniform bores is produced which have the precise size originally desired.

It should be understood that so far as certain features of the invention are concerned I may utilize the special lapping rod shown in Figure 10 of my Patent No. 1,486,338, or other similar mechanically expanded laps.

So far as certain features of the invention are concerned, the method may be operated in reverse. For example the kerosene or other liquid may first be heated to a temperature of around one hundred thirty degrees Fahrenheit with the articles 7 immersed therein. A lapping tool according to any one of the drawings on sheet 2 hereof, or any other suitable form, may be provided which has a very low coefficient of thermal expansion and which is of a size substantially to fit the bore of the unlapped article 7 after it has been expanded by heat. Then the liquid is gradually cooled and the lapping carried out in stages as hereinbefore specified. The result will be a gradual contraction of the article against the lap which will remove metal. As a good example of a material for the lapping tool according to this embodiment of the invention I may use "Invar", which is nickel steel containing thirty per cent of nickel. At a temperature of twenty degrees centigrade this has a calculated coefficient of thermal expansion of .9 times 10^{-6} . The "Invar" tool is charged with diamond dust or other abrasive exactly as previously specified hereinbefore. This "Invar" tool charged with abrasive may have a diameter substantially that of the desired finished size of the bore of the article at seventy degrees Fahrenheit. By this manner of proceeding the article is brought to finished size when the liquid is cool and the article may be immediately measured to find out if the lapping operation was successfully completed.

It should be understood that whereas so far as certain features are concerned the method involves the lapping of a plurality of objects and the distribution of errors, so far as other features of the invention are concerned the steps can be carried out on a single article to completion of that article without reference to any others.

In cases where a liquid is used I prefer to use a liquid which is a good lubricant. Although under certain conditions water might be used, I prefer hydrocarbon liquids such as light spindle

oil or fuel oil, and the liquid which is best suited of all so far as I am now aware is kerosene. I select a kerosene which has a high flash point. For example I have found a kerosene which has a flash point of approximately one hundred thirty-eight degrees Fahrenheit. My upper limit of temperature under such conditions is one hundred forty degrees Fahrenheit as it is perfectly feasible to go slightly above the flash point although care should be taken to keep open flames away from the kerosene. Any of these liquids can be used at room temperatures at around seventy degrees Fahrenheit or, if desired, can be refrigerated almost to their freezing points.

It will thus be seen that there has been provided by this invention a method in which the various objects hereinbefore set forth together with many thoroughly practical advantages are successfully achieved. As various possible embodiments might be made of the mechanical features of the above invention and as the art herein described might be varied in various parts, all without departing from the scope of the invention, it is to be understood that all matter hereinbefore set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim:

1. The method of lapping inner cylindrical surfaces of articles comprising arranging the articles in order, subjecting said surfaces to the abrading action of a lap rotated about its own axis and moved axially the length of said surfaces, in a selected sequence of the surfaces lapped, and then varying the sequence in accordance with a predetermined order, a single lap acting successively on a plurality of said surfaces.

2. The method of lapping inner cylindrical surfaces of articles comprising arranging the articles in order, subjecting said surfaces to a lengthwise lapping action by a lap, while relatively rotating the lap and surface in a selected sequence, and then varying the sequence in accordance with a predetermined order and repeating said lapping operations, the lap simultaneously bearing against and lapping opposite sections of the surface, and repeating said lapping and sequence variation alternately until identical diameters are obtained in all of said articles, a single lap acting successively on a plurality of said surfaces.

3. The method of lapping inner cylindrical surfaces of articles comprising arranging the articles in order on a support, subjecting said surfaces to the axial and rotative abrading of a lap of different ratio of size change with like temperature change than the article in a selected sequence and varying the temperature of the article and lap to maintain the abrading pressure of the lap on the surfaces of the articles.

4. The method of lapping an article with a tool, while the same are surrounded with a fluid, one of said article and tool having a bore and the other being a cylinder having a close fit with said bore and of different ratio of size change with like temperature change than the article, varying the temperature of the fluid to change the relative size of the article and tool to maintain abrading pressure of the tool on the surface of the article.

5. The method of lapping inner cylindrical surfaces of articles comprising subjecting said surfaces to the abrading action of a lap of different ratio of size change with like temperature change than the article by relatively rotating the lap

and surfaces in contact and moving the same longitudinally relatively one to the other, and varying the temperature of the article and lap to maintain the abrading pressure of the lap on the surfaces of the articles.

5 6. The method of lapping or abrading the bore of an object which consists in introducing into the bore an abrasive tool which is a close fit with said bore and which has a coefficient of expansion greater than said object and then changing
10 the temperature of said tool and said object to give an abrading pressure between said tool and object, and moving them relatively one to the other.

15 7. The method of lapping or abrading the bore of an object which consists in introducing into said object an abrasive tool having a close fit with said bore and heating said tool to give an abrading pressure between said tool and object,
20 and moving them relatively one to the other.

8. The method of lapping or abrading an object with a tool, one of said object and tool having a

bore and the other being a cylinder having a close fit with said bore and which have different thermal coefficients of expansion and then changing the temperature of said object and said tool while relatively moving them to effect an abrading action, the cutting advance being caused by the different expansions of said tool and object respectively.

9. The method of abrading an object with a tool one of said object and tool having a bore and the other being a cylinder having a close fit with said bore and relatively moving said tool and said object while changing the temperature of one of said parts to cause pressure between them.

10. The method of lapping the bore of an object which consists in introducing into said bore a tool closely fitting said bore and having a coefficient of expansion less than that of said object and then cooling said tool and said object while relatively moving them to produce a lapping action.

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