

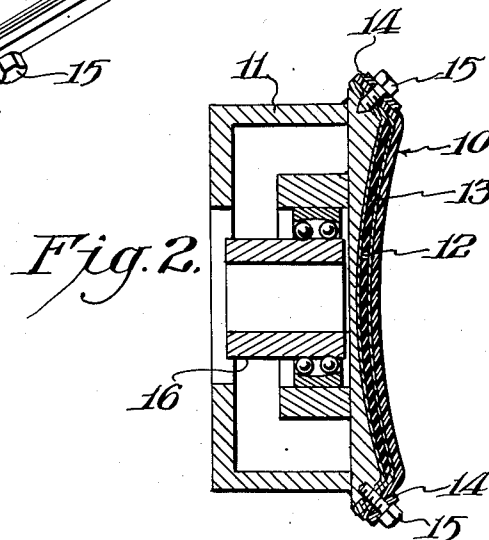
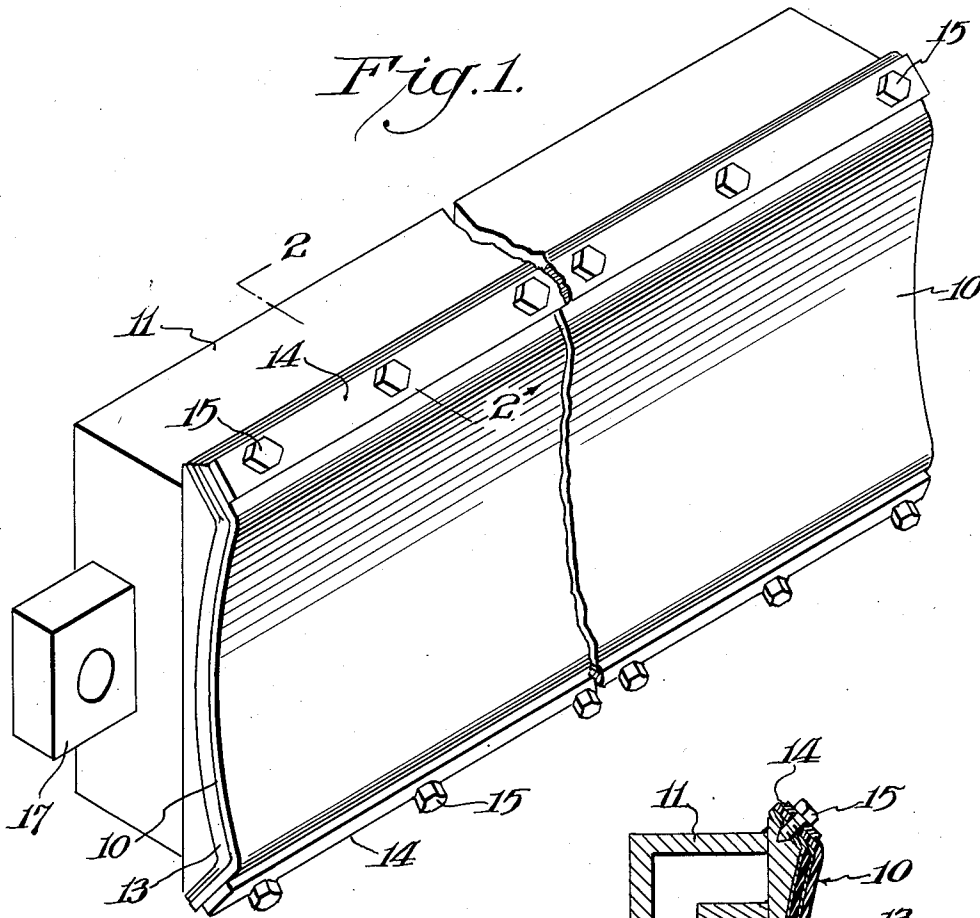
Oct. 20, 1953

T. G. LEWIS

2,655,775

LAPPING METHOD AND TOOL

Filed May 22, 1950



INVENTOR.

THOMAS G. LEWIS

BY

W. S. Leroy

ATTORNEY.

UNITED STATES PATENT OFFICE

2,655,775

LAPPING METHOD AND TOOL

Thomas G. Lewis, Wilmington, Del., assignor to
E. I. du Pont de Nemours & Company, Wil-
mington, Del., a corporation of Delaware

Application May 22, 1950, Serial No. 163,562

4 Claims. (Cl. 51—281)

This invention relates to improvements in methods for lapping metal articles, and also to tools for practicing the new method of lapping hereinafter described.

"Lapping," as the term is used in this specification, comprises working a particulate abrasive material suspended in a liquid vehicle against the surface of a work piece until an exceedingly fine, mirror-like finish is imparted thereto. The objective sought is the attainment of a very smooth surface finish, while retaining a high degree of dimensional control, so that the resulting product will conform to very precise size standards. The lapping of surfaces from their original state to the final finish is a progressive operation, involving the use of a series of abrasives ranging from relatively coarse at the beginning through successively finer sizes to the end. The results secured depend upon a number of factors, such as the properties of the abrasive employed, the pressure with which the abrasive is forced against the work, the pattern of movement preserved in the contact of the work with the abrasive particles, and other considerations.

Hitherto, the theory has been that good lapping action depends upon the retention of abrasive against the work by the lapping tool. Thus, it has been the practice of the prior art to utilize as lapping materials substances which have the property of retaining more abrasive on their working surfaces than the work which it is desired to lap. Where work having a relatively rough initial surface is to be processed, it is advantageous to accomplish the lapping in two stages, the first being a rough lapping operation employing a tool capable of removing material at a high rate when used in conjunction with coarse abrasive, while the second is a fine lapping operation wherein a finer abrasive is utilized for the removal of any scratches or other imperfections remaining from the first stage. To secure high retention of abrasive in the lapping tools used in the rough lapping stage, it has been the practice of the prior art to employ tools fabricated from materials softer than the work being processed, so that at least a substantial proportion of the abrasive particles will embed themselves in the tool surface and will thereupon abrade the surface of the work away in somewhat the same manner as a conventional lathe tool removes material by its cutting action. Customarily, the fine lapping operation has been conducted with materials which are much softer than those employed for rough lapping, but again it has been considered desirable, or at least not disadvan-

tageous, to employ substances which act to retain the abrasive preferentially to the work, and thereby maintain a relatively high concentration of the wearing substance at the tool face.

In both cases, the abrasive particles are bound to a considerable degree to the working tool surface, and the same general portions of the retained particles continue to contact the work during operations, so that wear is largely localized in these areas, while the remainder of the abrasive grains do not carry their share of the burden. It will be understood that many of the abrasive particles are not immediately retained by the lapping tool and may pass through the working area in a relatively free manner a number of times as the tool and the work are moved with respect to one another. The result is that the particles have a widely varying freedom of movement which tends to distribute the abrading burden non-uniformly, causing scratches or other blemishes in the work. The situation is aggravated by the dislodgement of particles from the work surface during the course of lapping, which particles appear to agglomerate into larger masses on the face of the lapping tool, where they eventually mar the surface of the work in the same manner as would an exceptionally large abrasive particle if it entered upon the field currently worked by a finer size of abrasive. The effect of agglomerates is usually not as long-sustained as would be the case with a coarse abrasive particle but, nevertheless, the damage is accomplished whenever a deep scratch results, even though the length of the blemish may not be great. Under these circumstances, some areas of the work require intensive special lapping treatment to remove local defects before they acquire the same quality of surface as the balance of the work, which requires time and the services of specially trained personnel.

I have now found that an improved lapping action is obtained by conducting operations so that the movement of the abrasive particles is primarily one of rolling, as distinguished from the sliding or shearing action which has characterized the prior art.

A primary object of this invention is to provide a method for lapping metal articles which is capable of producing an improved surface quality with the expenditure of less time than required by present practice.

Another object of this invention is to provide a method for lapping metal articles which is capable of yielding a high degree of reproducibility in operation.

Another object of this invention is to provide lapping compositions having a low retentivity for abrasive materials, which give improved results in both rough and fine lapping operations.

These and other objects of this invention are attained by employing a contacting pressure, a random movement of the abrasive with respect to the work and a lapping tool less retentive of abrasive than the work being processed, so that rolling movement of the abrasive particles over the surface of the work being treated is favored.

In order to illustrate one preferred arrangement for applying the invention, reference is made to the accompanying drawing in which—

Figure 1 is a perspective view of one design of a lapping head provided with a backing material embodying this invention, while Figure 2 is a vertical section taken along line 2—2 of Figure 1.

The lap 10 comprises a hard surfacing material which may be tool steel, or glass of equivalent hardness, or a softer material for subsequent surfacing such as tetrafluoroethylene, and 12 designated a backing material having a plasticity subject to cold flow under the conditions of operation, which may be bitumen. The head 11 is adapted to support the lapping surface and may have its forward face arcuately shaped or recessed to conform to the profile of the work, as contemplated and illustrated in companion applications Ser. Nos. 163,560 and 163,561, referred to elsewhere herein. The backing material may be interposed in this recess between the lap 10 and the head 11 as indicated at 12. The backing material may be supported directly, or encased in a fibrous bag as indicated in application Ser. No. 163,560, and may be clamped to head 11 by straps 14, secured by bolts 15. The head 11 may be operated in various ways, but is particularly suitable for operation by the lapping machine of my above application Ser. No. 163,561, in which a powered means is adapted to engage self-aligning sleeve 16, while the head 11 is supported in oscillating position by lugs 17 as shown in said co-pending application.

Since it is desirable to first remove the surface material of the work at a relatively high rate, which is decreased as the finish is improved, I prefer to conduct my lapping in two distinct stages, utilizing different laps in each. In the initial rough lapping operation, a very hard tool, such as one fabricated from tool steel, glass or material of the same or greater hardness is preferred. In the fine lapping operation I prefer to employ a softer lap, such as one fabricated from polymerized tetrafluoroethylene, for example, the surface of which appears to resist attachment of the abrasive thereto to an extraordinary degree. For best results the surfaces of the laps should conform as closely as possible to the surface of the work, so that an even pressure will be transmitted to the abrasive suspension at all points over the full working area. In the case of the flexible polytetrafluoroethylene lap, close conformation to the work may be achieved by backing the lap with a material having a plasticity at room or slightly higher temperatures such that the material will cold flow to an extent sufficient to take a surface the reverse of that of the work under the lapping pressures employed, this backing being described in detail in my co-pending application, Ser. No. 163,560, filed May 22, 1950.

As hereinabove described, lapping is accomplished by the use of abrasives of progressively

decreasing particle size. Any of the commonly used abrasives may be utilized in the methods of this invention, including aluminum oxide, silicon carbide, diamond dust and other materials. The inherent crushing strengths of these abrasives appear to have little effect on the abrading action secured, the particles continuing to remove materials from the work surface uniformly, even after being fractured. The sizes of abrasives employed will depend to some extent upon the surface condition of the work as received and the resistance to abrasion possessed by the work material. In the rough lapping of copper electroplates, case hardened steel, 18-8 type stainless steels and nickel cladding, I have found that good results may be achieved by the employment of the following sizes of aluminum oxide abrasive (e. g. the Norton Company's 38 series material) in sequence, identified by grit number, using a tool steel lap of a Rockwell C hardness of about 60, a lap pressure of about 10 lbs./sq. inch and a sperm oil vehicle, the concentration of the abrasive in the oil being maintained at about 8 oz./gal.: 180, 240, 320, 400, 500, 700, and 1000. The resulting finish has a general quality such that an average surface defect measures about 6 to 8 microinches, as determined by the conventional root-mean-square method with a profilometer. At this point a diamond dust abrasive may be substituted for the aluminum oxide, and operation continued with the same lap, operating pressure and oil vehicle, with a concentration of about 1 carat of abrasive per 50 cc. of oil, through a range of grit sizes from about 3200 to about 6400, when a general surface quality of 2 to 3 microinches R. M. S. is obtained. A polytetrafluoroethylene lap may now be substituted for the tool steel and the fine lapping operation performed using a 1 carat/50 cc. dispersion of 6400 grit diamond dust in olive oil, until a very high quality finish, approximating $\frac{1}{4}$ to $\frac{1}{2}$ microinches R. M. S., is obtained.

The liquid vehicle employed in the method of this invention should be one capable of simultaneously wetting the work, the lap and the abrasive. Animal and vegetable oils of the type represented by sperm oil and olive oil, respectively, have proved entirely satisfactory, uniform dispersion of the abrasive therein being facilitated by the addition of up to about 1% by volume of one of the commercially available dispersing agents, such as, for example, Antarox B190 and B200, manufactured by the General Aniline & Film Corporation. The viscosity of the liquid vehicle should be low enough to preserve the mobility of movement of the abrasive particles therein. In practice, sperm oil of a viscosity below about 100 seconds on the Saybolt scale has given good results as a vehicle for aluminum oxide and silicon carbide abrasives in the particle size range from about 180 through about 1000 grit. Diamond dust suspended in olive oil appeared to have a considerably lower settling rate than when sperm oil was employed as the vehicle, thus olive oil is preferred as the vehicle for fine lapping operations, and the limiting upper viscosity on the Saybolt scale was determined to be about 200 seconds for diamond dust in the size range of about 3200 to 6400 grit. The rate at which the rough lapping abrasive suspension is applied to the work is not particularly critical; however, in the case of fine lapping, using a diamond dust in the fine particle sizes described, best results are obtained by supplying the suspension at such a rate that the film thickness

corresponds to about two-thirds the diametrical dimension of the average particle. The film thickness can be most conveniently regulated by applying the diamond dust-oil suspension to the work sparingly, then observing the extent at which abrading proceeds, and increasing or decreasing the rate of application accordingly.

The surface texture of the polytetrafluoroethylene lap is an important factor in obtaining best results by the method of this invention, particularly when relatively long laps of large surface area are employed at pressures in excess of about 10 lbs./sq. in. It is preferred to break the surface by slitting it to a depth of 0.040" to 0.060" in a uniform square pattern, each unit of which measures about 0.015" to about 0.125" on a side, one diagonal of the squares being parallel to the width dimension of the work when the lap and the work are at rest before relative motion is initiated. In this connection, it will be understood that the depth of the slits is limited so that the lap is not weakened appreciably by the surface roughening imparted by the slitting, and a polytetrafluoroethylene lap 1/4" thick may be treated as described without sacrificing much of its useful strength. The primary purpose of the slit lines is to relieve pressure built up in the oil film, particularly with very fine abrasives such as diamond dust suspended in olive oil, so that the thickness of the film will not exceed a value about two-thirds that of the average abrasive particle diameter, at which point abrading action is considerably reduced or even entirely halted. An additional effect of surface slitting is that the flexibility of the lap is thereby somewhat improved, so that the formation of "hard spots" resulting from non-homogeneities in the lap material is inhibited.

The movement of the lap in contact with the work should be of a random nature such that the pattern described is non-repetitive to a high degree. In the hand lapping of the test pieces described in the following examples the lap was moved in a circular or elliptical manner, with the work being continuously turned with respect to the lap so that the successive paths described by the abrasive particles continually crossed one another. Powered equipment operating to produce a periodic spiral pattern repetitive only at relatively long time intervals has proved equally satisfactory. In both instances best results are obtained at operating pressures below about 18 lbs./sq. in., the highest quality finishes being obtained in the lapping of most materials at pressures in the neighborhood of 10 lbs./sq. in., at which level the free rolling movement of the particles is apparently preserved to the greatest extent.

The following examples illustrate the application of this invention to materials of widely varying physical properties and detail the conditions which have been determined by test to give good results. In all cases the lapping was effected by manual manipulation of the lap with respect to the work in the manner hereinabove described for random movement, the work specimens being flat metal pieces measuring approximately 1 1/4" x 1 1/4" square. A contacting pressure of about 10 lbs./sq. in. was maintained throughout.

Example 1

A tool steel sample having a hardness of 60 Rockwell C was processed with a tool steel lap having a hardness of 60 Rockwell C, using the following successive grit sizes of aluminum oxide

suspended in a sperm oil vehicle: 180, 320, 500, and 1000. The time of treatment ranged from about 30 minutes for the 180 size grit to about 10 minutes for the 1000 size grit, the total time consumed in the rough lapping operation being about 90 minutes. At the end of this period the average quality of the finish measured about 6 microinches R. M. S. An intermediate lapping operation using the same tool steel piece employed for the rough lapping was then conducted with 3000 and 6000 grit sizes of diamond dust in sequence suspended in olive oil as the vehicle, the time required being about 15 minutes for the 3000 grade and 15 minutes for the 6000 grade abrasive. An average finish of quality measuring about 2 microinches R. M. S. was thereby secured. The sample was finished with a surface-slitted polytetrafluoroethylene lap employing 3000 and 6000 grit diamond dust, respectively, suspended in olive oil, for a time of 10 minutes for the 3000 size and 20 minutes for the 6000 size, the final surface quality of the specimen measuring about 1/4 microinch R. M. S.

Example 2

A mild S. A. E. 1020 steel sample having a hardness of 85 Rockwell B was processed with a tool steel lap having a hardness of 60 Rockwell C, using the following successive grit sizes of aluminum oxide suspended in a sperm oil vehicle: 180, 320, 500 and 1000. The time of treatment ranged from about 20 minutes for the 180 size grit to about 10 minutes for the 1000 size grit, the total time consumed in the rough lapping operation being about 60 minutes. At the conclusion of this treatment, the average quality of the finish secured was about 8 microinches R. M. S. The specimen was then fine lapped with a surface-slitted polytetrafluoroethylene tool using 3000 grit size and 6000 grit size diamond dust suspended in an olive oil vehicle in sequence, the time required for each of these operations being about 20 minutes. The quality of the final finish measured about 1/2 microinch R. M. S.

Example 3

A commercial bronze sample having a hardness of about 80 Rockwell B was rough lapped with a piece of tool steel of 60 Rockwell C hardness, employing 320, 500 and 1000 grit sizes of aluminum oxide suspended in sperm oil in sequence, the duration of each step being about 15 minutes and the total time for the rough lapping aggregating 45 minutes. The surface finish quality at the termination measured about 8 microinches R. M. S. The specimen was then fine lapped with a piece of surface-slitted polytetrafluoroethylene using 3000 and 6000 grit sizes of diamond dust suspended in olive oil for periods of 20 minutes each, after which measurement of the final surface quality obtained showed an improvement to 1 microinch R. M. S.

Example 4

An aluminum sample with a hardness of about 70 on the Rockwell B scale was rough lapped with a piece of tool steel having a Rockwell C hardness of 60 for a period of 15 minutes with 500 grit size, and 15 minutes with 1000 grit size, aluminum oxide suspended in sperm oil, to give a surface quality measuring about 10 microinches R. M. S. The sample was then fine lapped with a piece of surface-slitted polytetrafluoroethylene for 15 minutes with 3000 grit and 20 minutes with 6000 grit diamond dust suspended in olive

oil, yielding a final surface quality of about 1 microinch R. M. S.

Example 5

A specimen of electroplated copper having a hardness of about 70 on the Rockwell B scale was rough lapped with a piece of tool steel having a Rockwell C hardness of 60, using 320 and 500 size grits of aluminum oxide abrasive suspended in sperm oil in sequence for periods of 15 minutes each. The surface finish quality obtained measured about 10 microinches R. M. S., after which the work was subjected to a fine lapping treatment employing a surface-slitted polytetrafluoroethylene lap and 3000 and 6000 grit sizes of diamond dust suspended in olive oil in turn. After a treatment of 15 minutes' duration with the 3000 size diamond abrasive and 20 minutes with the 6000 size material, the quality of the surface finish obtained measured about $\frac{3}{4}$ microinch R. M. S.

Example 6

A specimen of electroplated nickel having a hardness of about 85 on the Rockwell B scale was given a preliminary lapping treatment with a piece of tool steel having a Rockwell C hardness of 60, employing 320 and 500 size grits of aluminum oxide suspended in sperm oil as the abrasives for periods of 25 minutes and 15 minutes, respectively. The resulting surface quality measured about 10 microinches R. M. S., whereupon a fine lapping operation was conducted with a piece of surface-slitted polytetrafluoroethylene and 3000 and 6000 grit sizes of diamond dust suspended in olive oil. After 30 minutes' lapping with the 3000 grit size and 30 minutes with the 6000 grit size materials, a surface finish quality measuring about $\frac{1}{4}$ microinch R. M. S. was attained.

Progressive microscopic examination of the specimens prepared according to the procedures described in the foregoing examples indicated that the surface had a uniformly indented appearance, somewhat resembling that obtained by shot blasting, except that the indentations were, of course, much smaller in size. The surface carried few of the straight scratches which characterize work lapped by the abrasive stones or cast iron laps heretofore employed in the art. An additional advantage was the practical elimination of the "graininess" or pigskinlike texture from steel and nickel surfaces displaying microscopic variations in hardness, which has previously not proved amenable to removal by lapping.

The surface appearance of materials treated according to this invention supports the conclusion that the beneficial effects are produced by the rolling movement of the abrasive particles. A high degree of uniformity of finish results after sustained operation with a given size of abrasive, and the quality improves as lapping is continued, indicating that all of the particles are progressively worn away to about the same extent. While all of the factors hereinabove described are important for the maintenance of the abrasive in rolling movement, the low retentivity of the laps is believed especially important to success. The low retentivity properties of hard steel and polytetrafluoroethylene may be demonstrated by employing these materials with one size of abrasive suspended in oil and, after a period of protracted use, substituting a much finer grade of abrasive for the original material and observing the new finish secured. The lapping tools may be freed of the coarse ma-

terial by simply washing thoroughly with a solvent for the oil vehicle, such as a chlorinated hydrocarbon, for example, whereupon no scratches will develop with the fine abrasive which would indicate retention of any of the larger size material previously used. Lapping tools of low retentivity possess an additional advantage in that it has been observed that metal particles from the work do not tend to agglomerate to masses which attain sufficient size to deface the work, either because the tool does not provide a surface for build up, or because the masses are eroded away by the wearing action of the abrasive particles as they come into contact one with another in the course of rolling.

This method of lapping and lap therefor may form an element of my invention disclosed in my copending application Ser. No. 163,561, filed May 22, 1950.

As many apparent and widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments thereof except as defined in the appended patent claims.

I claim as my invention:

1. The method of lapping a metal article comprising applying to said article a particulate abrasive suspended in an oil vehicle, forcing said abrasive against said article with a material having a Rockwell C hardness of 60 or higher at a pressure below about 18 lbs./sq. in. while maintaining relative random movement between said article and said material, and progressively decreasing the size of said suspended abrasive from coarse to fine as the surface finish of said article is improved, then forcing successively smaller sizes of finer abrasive suspended in oil against said article with a mass of polytetrafluoroethylene at a pressure below about 18 lbs./sq. in. while maintaining relative random movement between said article and said mass of polytetrafluoroethylene to produce a high quality final finish.

2. An abrading lap comprising a body of substantially homogeneous polytetrafluoroethylene having on its working surface a parallelogram pattern of intersecting slit lines of a depth of 0.040" to 0.060", but not exceeding about one-half the thickness of said body, with parallel slit lines separated by distances ranging from about 0.015" to about 0.125", and capable of surfacing metal articles with particulate abrasives suspended in liquid vehicles.

3. The method of lapping a casting wheel of substantial diameter and having a metallic surface, with a lapping tool having a concave-curved surface conforming to the surface of and maintained in parallel and horizontal relation with the casting wheel, comprising lapping the cylindrical work piece in two stages, first with a lap of tool steel, and then with a lap of solid tetrafluoroethylene, backed by a material having a plasticity capable of slight cold flow at approximately normal room temperature, and under a pressure not exceeding about 18 pounds per sq. in., repeating the treatment with a suspension of lapping material of decreasing particle sizes, and maintaining random movement of the surfaces with respect to each other to freely roll the abrasive over the opposed surfaces of the work while maintaining the surfaces in substantially parallel, horizontal position, to produce a uniform final surface finish for film casting.

4. The method of lapping a casting wheel of substantial diameter and having a metallic sur-

face, with a lapping tool having a concave-curved surface conforming to the surface of and maintained in parallel and horizontal relation with the casting wheel, comprising lapping the cylindrical work piece in two stages, first with a lap of glass having a hardness equal to tool steel, and then with a lap of solid tetrafluoroethylene, backed by a material capable of slight cold flow at normal room temperature under the conditions of operation and under a pressure not exceeding about 18 pounds per sq. in., repeating the treatment with a suspension of lapping material of decreasing particle sizes, and maintaining random movement of the surfaces with respect to each other to freely roll the abrasive over the opposed surfaces of the work while maintaining the surfaces in substantially parallel, horizontal position, to produce a uniform final surface finish for film casting.

THOMAS G. LEWIS.

20

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
Re. 14,751	Brockbank	Nov. 18, 1919
Re. 22,770	Sjorgren	July 2, 1946
257,612	Renshaw	May 9, 1882
336,582	Morris	Feb. 23, 1886
1,318,300	Robertson et al.	Oct. 7, 1919
1,343,522	Robertson et al.	June 15, 1920
1,356,330	Allen	Oct. 19, 1920
1,682,420	Rolf	Aug. 28, 1928
1,979,689	Hoke	Nov. 6, 1934
2,230,654	Plunkett	Feb. 4, 1941
2,353,171	MacConnell	July 11, 1944
2,412,306	Stoll	Dec. 10, 1946

OTHER REFERENCES

Laps and Lapping, pages 969-972, inclusive, from Machinery's Handbook, 5th edition, 1918, N. Y., Industrial Press.