Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

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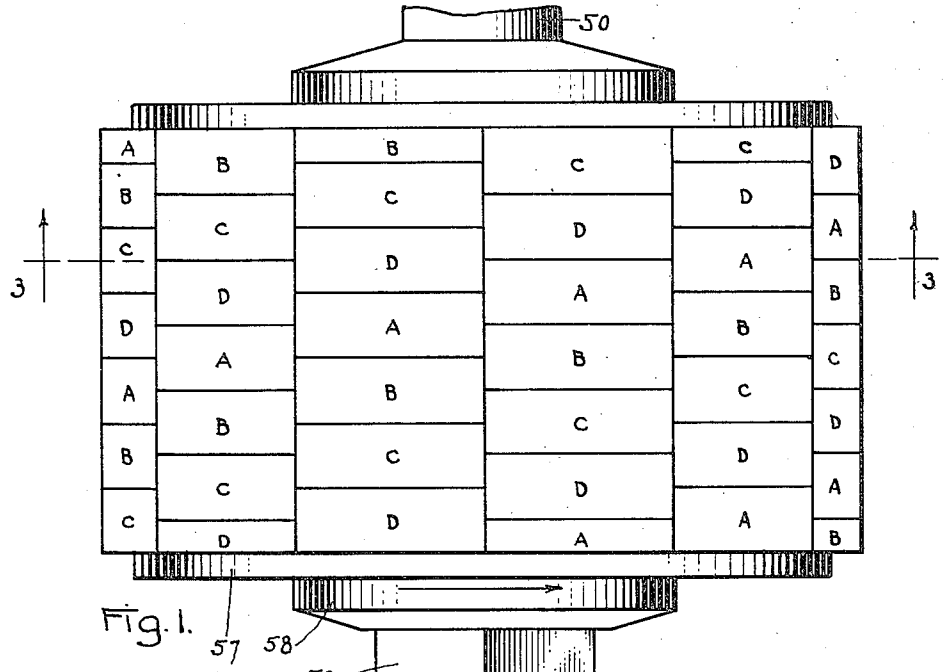


Fig. 1.

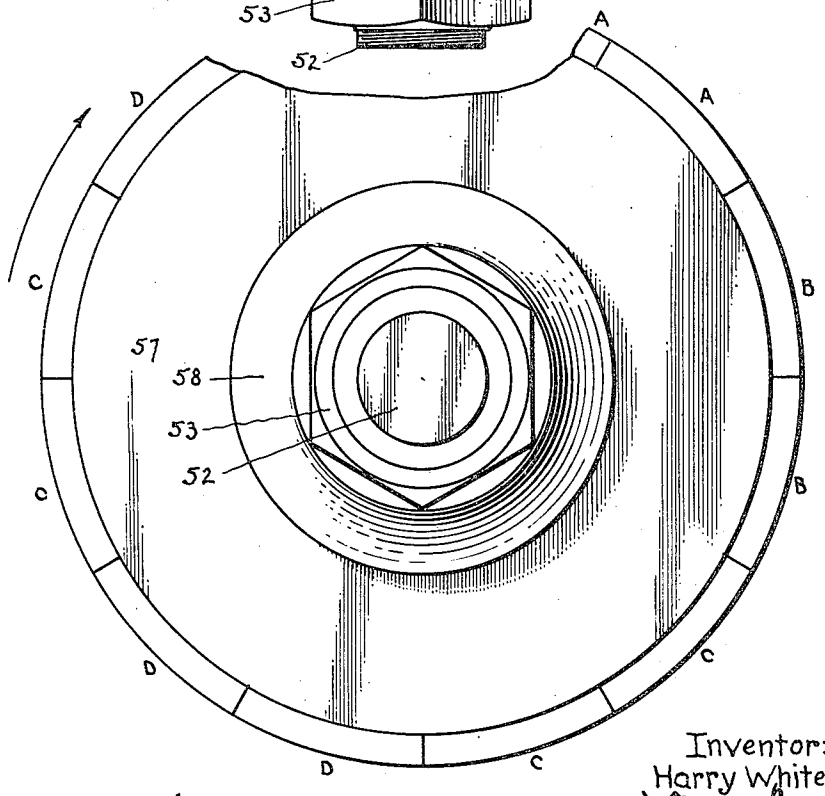


Fig. 2.

Inventor:
Harry Whitesell,
by Thos. Hamilton & Co.
Atty.

GRINDING AND POLISHING AND THE LIKE

Filed Aug. 31, 1953 8 Sheets-Sheet 2

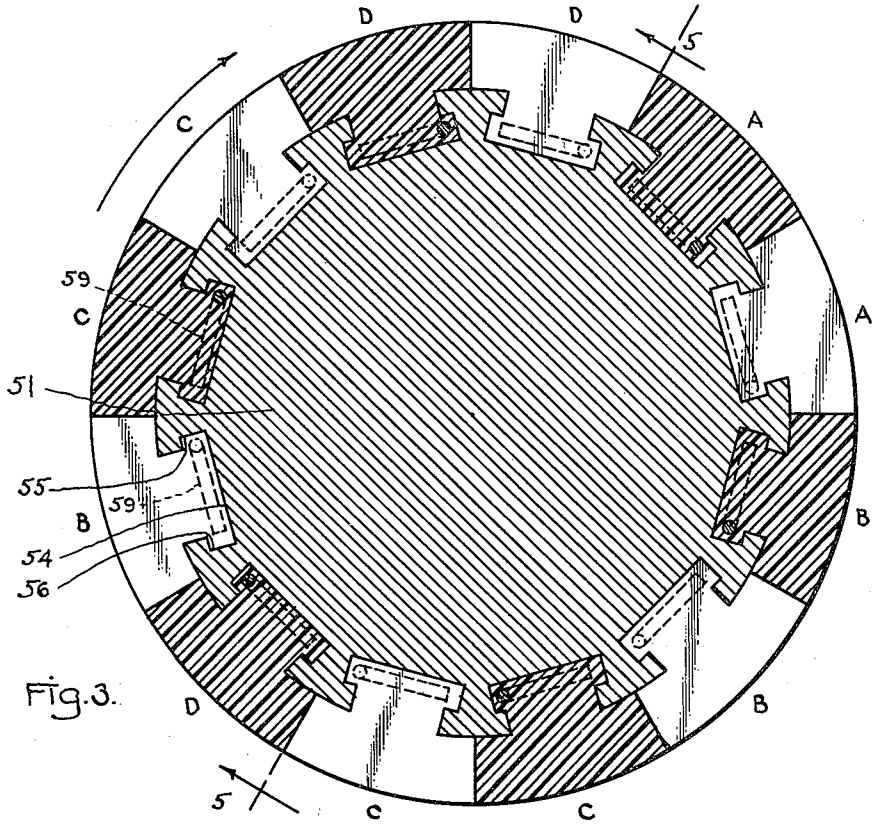


Fig.3.

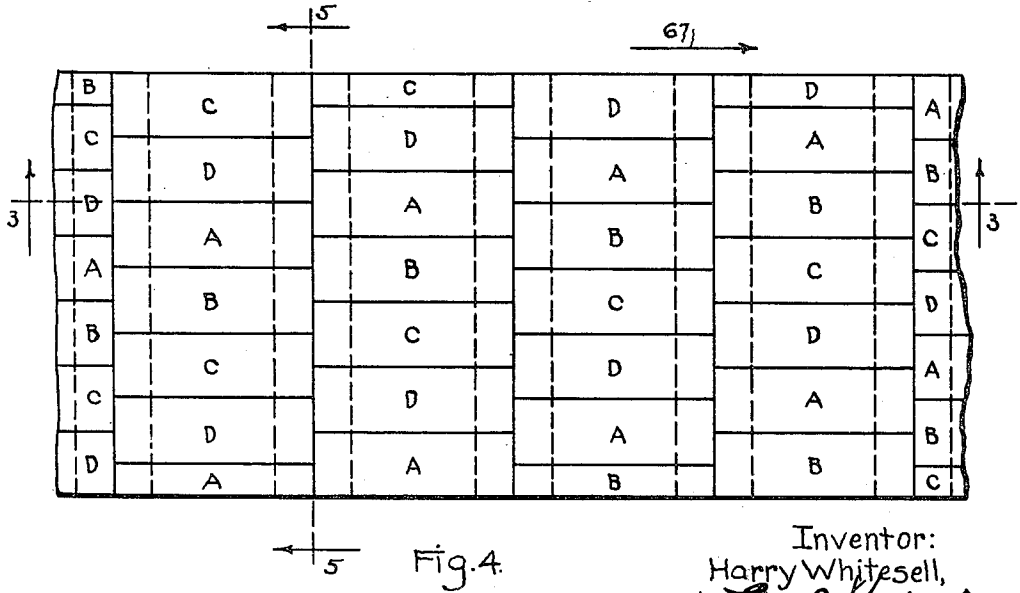


Fig.4.

Inventor:
Harry Whitesell,
by Thos. A. Kennedy
Atty.

Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

Filed Aug. 31, 1953 8 Sheets-Sheet 3

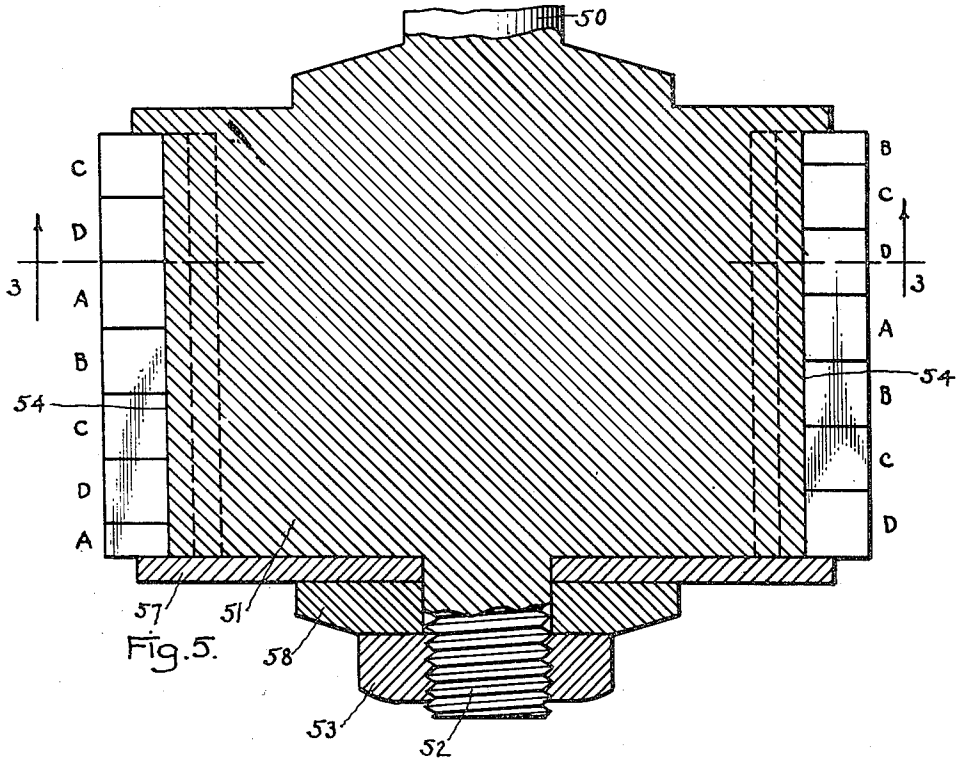


Fig.5.

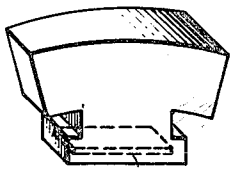


Fig.8.

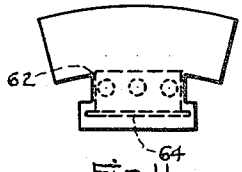


Fig.11.

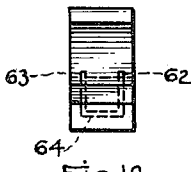


Fig.12.

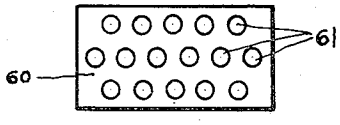


Fig.9.

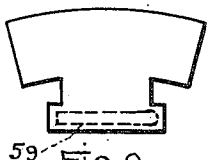


Fig.6.

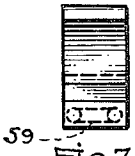


Fig.7.

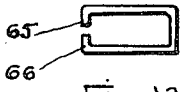


Fig.13.



Fig.10.

Inventor:
Harry Whitesell.
by Theo. A. Lavine & Co.
Atty.

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GRINDING AND POLISHING AND THE LIKE

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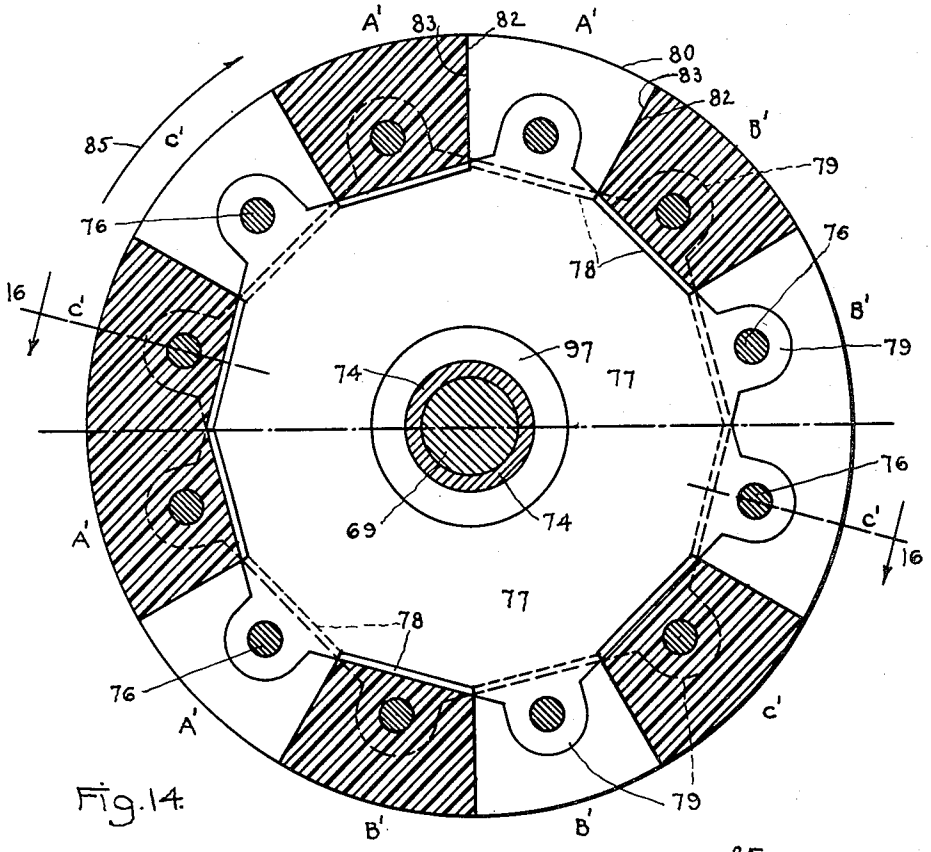


Fig. 14.

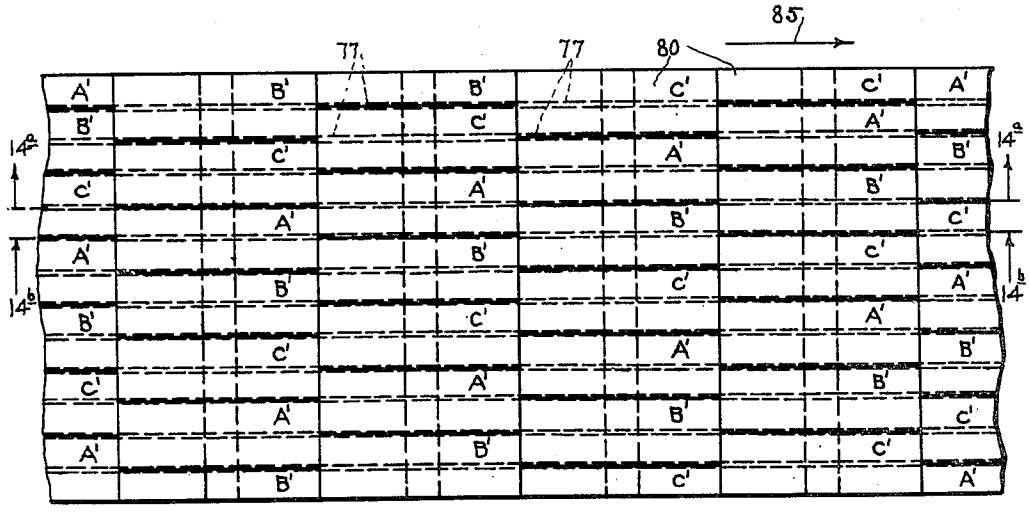


Fig. 15.

Inventor:
Harry Whitesell,
by Thos. A. Banning Jr.
Atty.

Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

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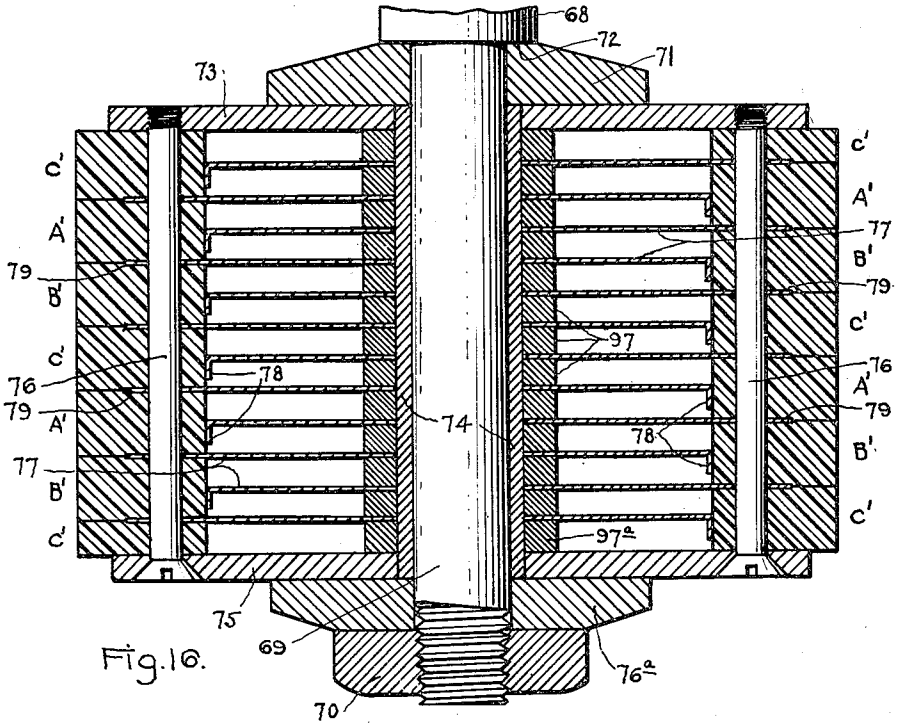


Fig.16.

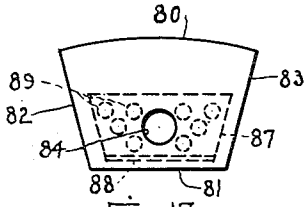


Fig.17.

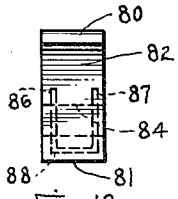


Fig.18.

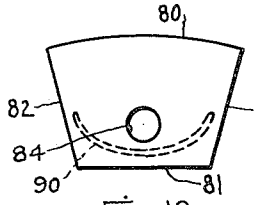


Fig.19.

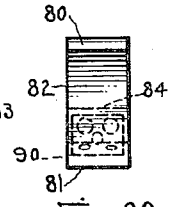


Fig.20.

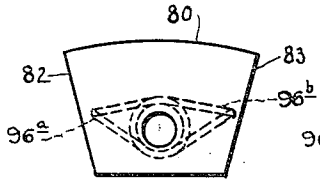


Fig.23.

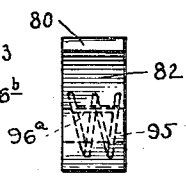


Fig.24.

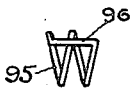


Fig.22.

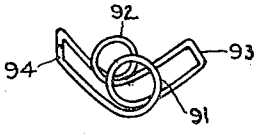


Fig.21.

Inventor:
Harry Whitesell,
by Thos. A. Brady Jr.
Atty.

Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

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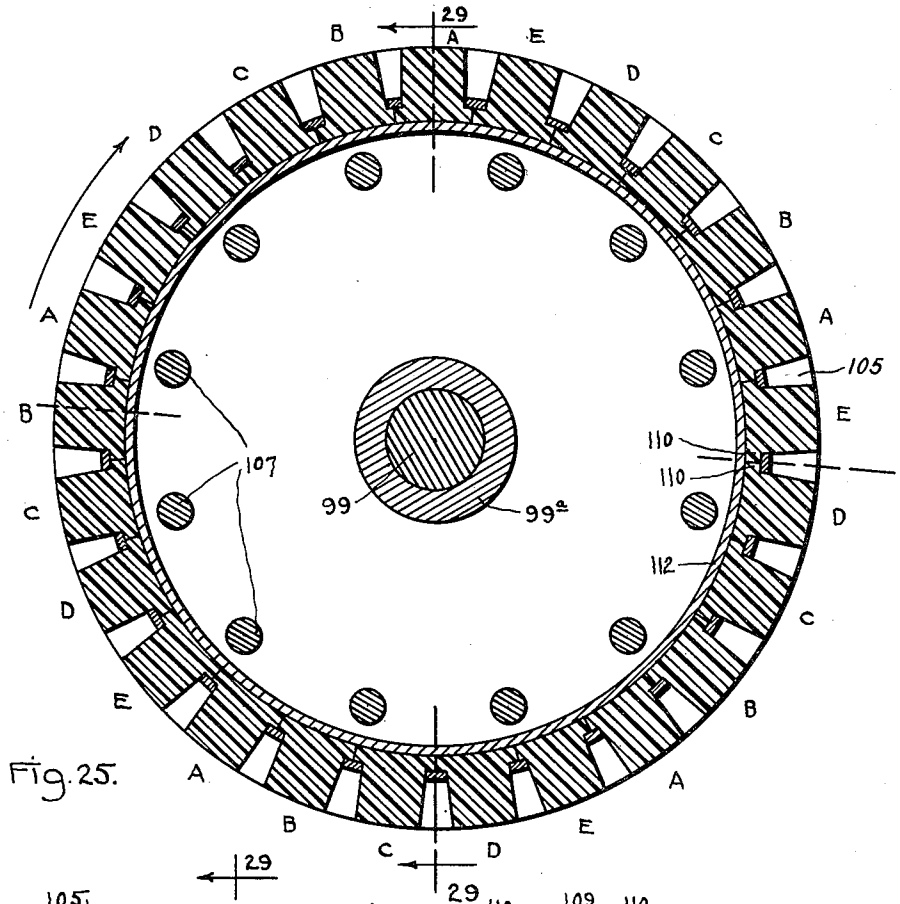


Fig. 25.

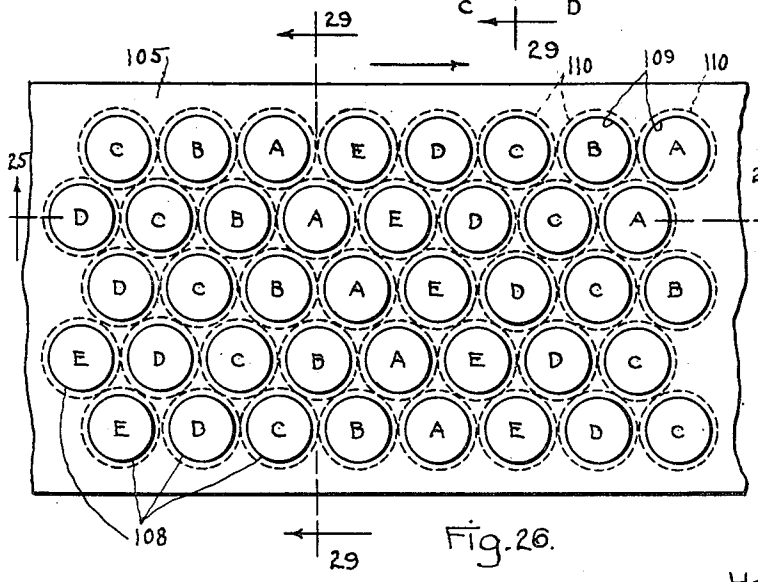


Fig. 26.

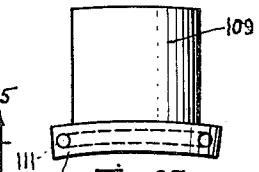


Fig. 27.

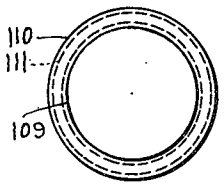


Fig. 28.

Inventor:
Harry Whitesell,
by Thos. A. Fleming Jr.
Atty.

Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

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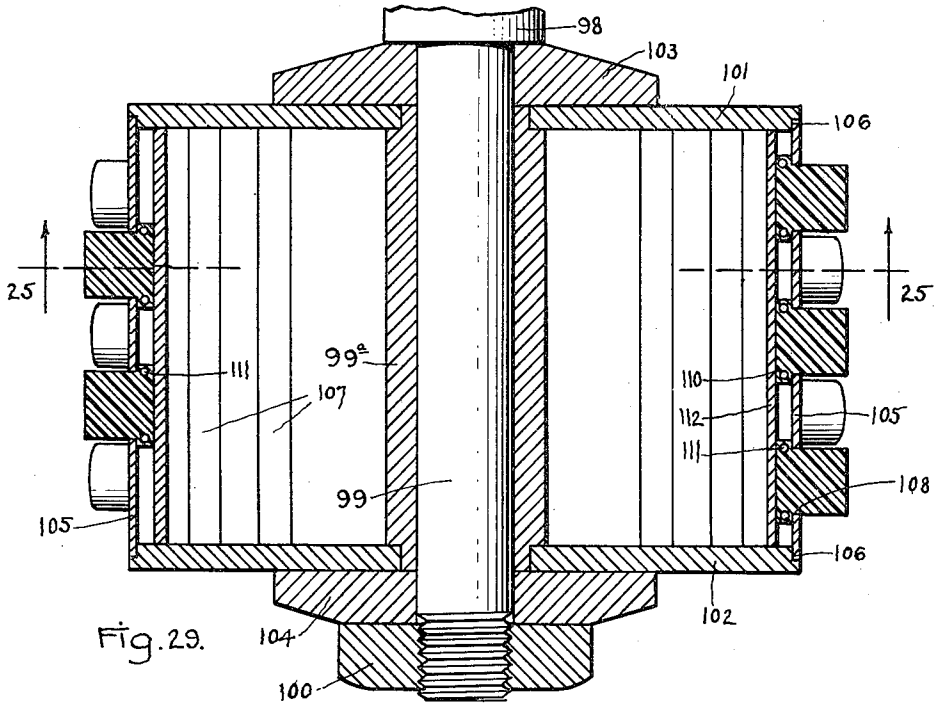


Fig. 29.

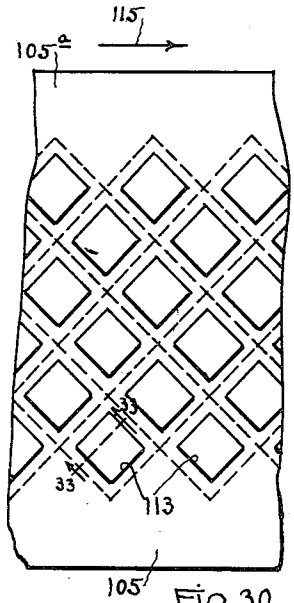


Fig. 30.

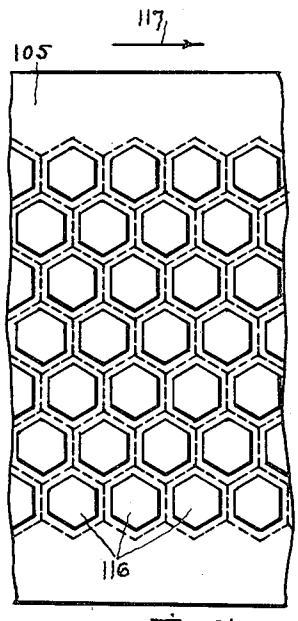


Fig. 31.

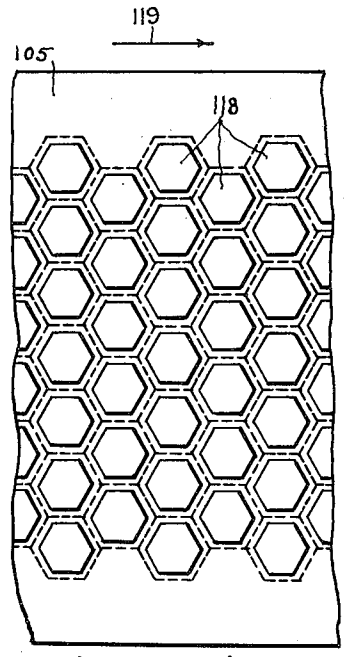


Fig. 32.

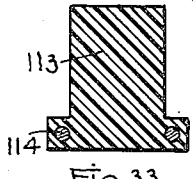


Fig. 33.

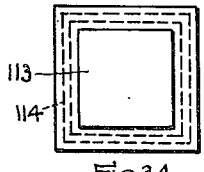


Fig. 34.

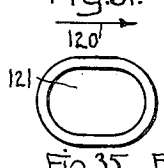


Fig. 35.

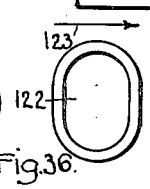


Fig. 36.

Inventor:
Harry Whitesell,
by [illegible]
Atty.

Nov. 13, 1956 H. WHITESELL 2,770,082

GRINDING AND POLISHING AND THE LIKE

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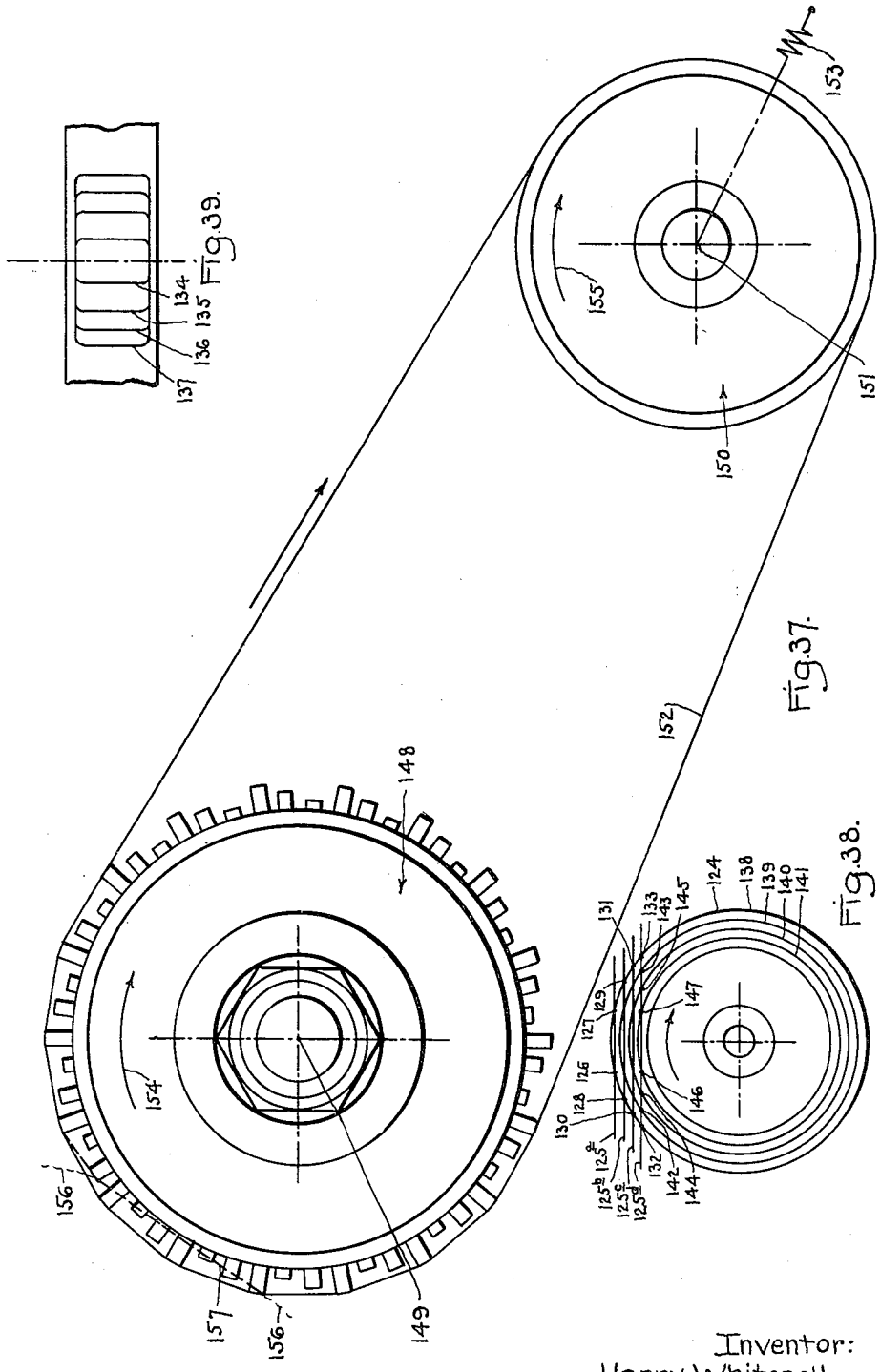


Fig. 37.

Fig. 39.

Fig. 38.

Inventor:
Harry Whitesell,
By Thos. A. Kennedy Jr.
Atty.

United States Patent Office 2,770,082 Patented Nov. 13, 1956

2,770,082

GRINDING AND POLISHING AND THE LIKE

Harry Whitesell, Chicago, Ill.

Application August 31, 1953, Serial No. 377,521

17 Claims. (Cl. 51—141)

This invention relates to improvements in grinding and polishing, and the like. The invention relates to both the improvements in grinding and polishing operations and the process or method of conducting the same, and also to the means which I have devised for conducting such improved operations. The following introductory statement will facilitate an understanding of the present improvements and assist in differentiating said improved operations from previously known and practised grinding and polishing operations:

Grinding and polishing operations are closely related to each other—each involves the removal of material from the stock or work article by an abrasive action, and the difference between the two operations as generally known resides rather in degree than in kind. That is to say, in each case the removal of material is effected by abrasion, but in the case of grinding operations such removal is generally at a higher rate than the rate used in the polishing operation which usually follows such grinding operation. This difference in degree or rate of material removal imposes substantial differences in the operational conditions under which the abrasion is effected. These operational differences may include both the abrasive material used, and the pressure which is applied between such abrasive material and the work or object being treated.

Usually a lighter contact pressure is used between the work and the abrasive surface when conducting a polishing operation than is used when the operation is one of grinding. However, it is generally desirable to so conduct the polishing operation that the scratches created on the work surface are longer and lighter than the scratches created during the grinding operation. That is to say, in polishing the scratch strokes are usually produced under a lighter pressure than is used when grinding, and conversely, the scratches produced in the polishing operation represent longer work strokes. Such longer work strokes and scratches of the polishing operation serve to eliminate the irregularities of surface produced during the grinding operation, in which grinding operation the material is generally removed more rapidly and with a deeper abrasive cut, being somewhat in the nature of a gouging out of the surface of the work being treated. The lighter the pressure used in the polishing operation, and the longer the polishing scratches (which are very minute in themselves) the finer the polishing and finishing operation which may be produced.

Generally in the past it has been customary to conduct grinding and polishing operations on a given object or piece of work by use of abrasive surfaces of different degrees of coarseness. Thus it has been customary to use a coarser abrasive surface when grinding than when polishing, and vice versa. However, since the difference between polishing and grinding is largely a matter of degree, and since the polishing operation is performed by use of a lighter contact pressure and longer scratches than are used in the performance of a grinding operation on that same object, it is possible to effect both grinding and

polishing operations on a given object by use of the same abrasive surface, provided that said surface be not too coarse. It is also possible to conduct both the grinding and polishing operations simultaneously—that is, as a single properly co-ordinated operation—by use of the equipment or means hereinafter described, and when conducted according to my improved method or operation.

My improved operations and the means to practise the same, are primarily intended for use in connection with belt type operations and machines—that is, operations wherein the work is held against a rapidly travelling belt or tape, which belt is provided with an abrasive surface against which the work is held and pressed. Usually such operations include two pulleys or wheels over which the belt loop travels, the belt being retained under desired tension by suitable means to draw one or both of the pulleys away from the other. Usually, also, spring means is provided in connection with such tension arrangements so that slight back and forth movements of one or both of the pulleys may occur during the conduct of the operations.

When using such an arrangement as that just referred to it is customary to hold and press the work against such belt abrasive surface at the location of one of the pulleys or wheels, which is referred to as the "contact wheel." By providing the belt surface of such wheel with a slightly yieldable surface, such as a layer or rubber or the like, smooth running of the abrasive surface during contact of the work therewith is ensured, and slight yield of such wheel surface is possible during the conduct of the operation. However, it is nevertheless true that all portions of the wheel's peripheral surface, with such an arrangement, are of the same softness or yieldability, both peripherally or around the wheel, and axially or across the wheel surface.

Usually the abrasive belt used in such operations is rather thin and sufficiently pliable to permit such belt to closely accommodate itself to slight variations in the wheel's peripheral contour during running, and during the abrading contact of the work against such belt surface at the location where the work presses against the belt which is running on the wheel. Due to this circumstance a working pressure of the work body against the abrasive belt (while said belt is travelling over the wheel, such abrasive pressure being exerted against the belt at a location where the belt is travelling on the wheel surface) acts to slightly depress the belt by compression of the yieldable surface of the wheel. If the work surface which is pressed against the abrasive belt is flat, then there will be produced a slight depression and deformity of the belt at the location of such pressure, and such deformity and its area of contact with the abrasive belt will be determined by the length of the chord which intersects the original or true circular form of the abrasive belt surface prior to such deforming action. At the middle of such chord the deformity will be a maximum, and the amount of deformity will increase from one end of the chord to such maximum and then decrease from such maximum to zero at the trailing end of such chord. Thus, the abrasive action will commence at the near end of such chord, rise to a maximum, and then decrease to zero at the trailing end of the chord. Such deformity will be transmitted through the thin belt to the elastic peripheral surface of the wheel on which the belt rides.

It is now to be noted that under the foregoing operating conditions, however, in which the wheel surface is of a uniform degree of softness, a given length of chord of contact of the work against the abrasive belt will always represent the same amount of pressure of such work body against the abrasive belt surface. Thus the ratio between length of chord and amount of pressure of the work body

against the abrasive surface must remain constant in the case of such previously known and used arrangements.

The length of chord referred to in the foregoing statement is also a measure of the length of scratch produced on the work body surface. Therefore in order to increase the length of that scratch (as for the production of a "polishing" operation), under the pressure of the work against the abrasive surface, under the conditions assumed, it is necessary to increase the pressure of the work against such abrasive surface. This is undesirable, beyond a certain pressure condition, if a good "polishing" operation is to be secured. Therefore, when the yieldable wheel surface is homogeneous in character, and of substantially uniform softness over the entire peripheral or belt sustaining surface of the wheel, it is evident that a limitation is imposed on the abrasive operations which may be conducted with such arrangement, since the pressure of the work against the abrasive surface must not exceed an amount which is consistent with production of the desired finish on the work surface. Also, that "finish" which can be produced will be determined largely by the coarseness of the abrasive surface of the belt used in the operation. Thus, such an arrangement, which is customary in the art at the present time, must be practically limited in its use, to one particular operation, such as "grinding" or "polishing," and even to sub-divisions of these two, and it becomes necessary to conduct the "grinding" and "polishing" operations on belts of different degrees of coarseness, or contact wheels whose homogeneous surfaces are of different degrees of softness as required for the specific operations to be conducted on them.

Thus it is true that under present and conventional operations as conducted by the use of such equipment (wherein the surface of the contact wheel is substantially homogeneous and of substantially uniform softness over its entire area) it is necessary to conduct the different operations of grinding and polishing (and sometimes, intermediate operations) by use of different abrasive belts and/or different contact wheels, making it necessary to either change the wheel and belt of an installation when another operation is to be conducted, or to provide different complete grinding equipments for the different operations. In any case it is evident that severe limitations are imposed on the use of such equipment, when the contact wheels are provided with homogeneous contact surfaces of substantially uniform softness over their entire working areas.

According to my present improvements I provide the contact wheel with a belt carrying working surface which is composed of numerous areas or sections of different degrees of softness so that under the pressure exerted by abrasive contact of the work with the abrasive belt riding on such wheel said belt will be deformed by varying amounts as these various areas of different degrees of softness come into registry with the area of engagement of the belt with the work element being abrasively treated. Under this operation, as a relatively soft area of the wheel surface comes into operation the deformation will be larger than that produced when a relatively less soft wheel area is in operative relation to the belt and the work. These areas of different or varying degrees of softness are interspersed over the peripheral belt contacting surface of the wheel in such manner that as the wheel rotates with belt travel, the work location being substantially unchanged, the different softness areas are successively brought into play, thus producing a combined effect on the operation. Thus the abrasive effect is one produced by a rapidly changing softness effect, and a corresponding rapidly changing amount of deformation of the belt at the location of contact of the belt with the work.

It has been pointed out that the lengths of the abrasive scratches produced on the work, for a given pressure of that work against the belt, depend on the lengths of the chords of abrasive contact at the location of the operation; and when the successive wheel surface areas are thus

of varying degrees of softness it is evident that varying lengths of scratches will be produced on the work section being treated, some long when the wheel surface is relatively soft, others shorter when the wheel surface is relatively hard. Thus a combined grinding and polishing action is produced on the work section being treated, and in fact varying degrees of grinding and polishing action will be produced in rapid succession on the work section, as a more or less continuous and uninterrupted operation.

The different areas of varying degrees of softness are relatively small as compared to the entire wheel perimeter. Thus, on any narrow band around the wheel surface there may be as many as fifty or a hundred or more successive areas which are of different degrees of softness, interspersed in such manner that as the wheel makes each revolution these different incremental areas come successively into play. Also, there may be few or many degrees of softness included in these successive incremental areas. As a simple example, use may be made of four or five distinct degrees of softness in the areas, but the exact number used will be a matter of choice on the part of the operator as will presently appear. Usually these areas of different degrees of softness will be interspersed according to a regular pattern, such pattern including the various degrees of softness, and the entire wheel perimeter area being covered by such patterns which are repeated frequently over such wheel surface. Each incremental area may be of selected form, such as circular, rectangular, hexagonal, square, oval, or of any selected form. Sometimes the entire perimeter surface of the wheel, over which the abrasive belt travels, may be occupied by such incremental areas, without interstices between the successive incremental areas; sometimes said incremental areas will not come into direct perimeter contact with each other, but will be spaced apart to a greater or less extent as decided by the designer of the equipment. When such interstices are included between the adjoining incremental areas it is evident that, when each such incremental area is subjected to pressure, due to the forcing of the work object against the belt travelling on such incremental area the material of such area may be forced laterally into such interstices by the compressive action produced by such work and belt pressure. When such interstices are not provided between the successive incremental areas it is evident that the deformations of such incremental areas will be accompanied by lateral compressive forces exerted against the adjoining incremental area elements of different degrees of softness.

I have herein disclosed several embodiments of device including the features of my present invention, and disclosing various forms including both the interstice arrangement and other arrangements in which such interstices are not included.

It is evident that when the contact wheel is at rest no centrifugal action is produced on the incremental areas of different degrees of softness. However, when the wheel is at speed very considerable centrifugal forces are developed in these areas. These areas are formed of material such as rubber of varying degrees of softness, or of other suitable elastic material. These various softness areas are, however, of more or less the same specific gravity so the centrifugal forces developed in the various incremental areas are substantially equal in amount at any given wheel running speed. Any radial enlargement of an area due to its elasticity and the centrifugal force being developed during running will somewhat exaggerate the centrifugal force so developed, but for the present discussion we shall momentarily disregard such radial enlargement effect on the centrifugal force developed at a given running speed. Under this assumption it is evident that each incremental area will expand radially under wheel running, and also that the amount of such radial expansion of each area will be more or less dependent on the degree of softness of such area's

material. That this is true will be seen from an application of the theory of elasticity and use of Young's modulus of elasticity to the problem. It is to be assumed that all of the incremental areas are composed of materials having substantially the same specific gravity so that the centrifugal forces developed in said areas are of substantially the same value (the sizes of the areas being substantially equal), and if it be assumed that Young's modulus is smaller in the case of the relatively softer materials than it is in the case of the relatively less soft materials, then

$$e=Fl/MA$$

for each incremental area, where; e equals the elongation, F equals the total force exerted to produce the elongation (being the centrifugal force developed in each of the incremental areas), l equals the length of the body of the incremental area in the direction of its stretch (being its length radially), M equals Young's modulus for the material of such incremental area, and A equals the cross-sectional area of such incremental area. Under the assumed conditions, if all of the bodies of the incremental areas are of the same radial length, initially, and are of substantially the same cross-sectional area, then each such body will suffer stretch radially by an amount substantially inversely proportional to its Young's modulus, and therefore substantially proportional to its softness degree. This means that the areas of greater softness will extend radially to a greater amount than those areas of less softness, it being assumed that they were all of substantially the same radial dimension to begin with. If they were not all of the same radial dimension to begin with (when the wheel is at rest) each of them will suffer a radial elongation modified from that previously stated from the elongations of other area bodies in the same proportion which such body bears in original length to the original lengths of the other bodies. In each case, however, the elongation of each body under centrifugal force during running (and when not affected by other modifying influences, such as the pull of the belt, and the applied pressure of the work object), will be greater for the softer materials areas, per inch of original radial dimension, than for the less soft materials.

In practice, the incremental area bodies are applied to or built into the wheel periphery surface by an assembling operation. When this has been done the exposed or perimeter surfaces of these bodies should be ground to proper dimensions and finishes. Such grinding may be effected when the wheel is at rest or may be effected while the wheel is running at a predetermined or specified speed, generally much less than its normal running speed when grinding and polishing operations are being effected. Or such grinding may be effected while the wheel is rotating slowly so that substantially no centrifugal effect is being produced on the various incremental area bodies. In any case, however, such grinding operation will bring the exposed or peripheral surface areas of the various bodies to a common cylindrical surface at the speed and under the conditions under which the grinding is performed. If the grinding is performed with the wheel at rest or rotating so slowly as to produce substantially no centrifugal effect, then, when the wheel is at rest all of the working surfaces of the bodies will lie within that cylindrical surface to which said bodies were ground. If the grinding is performed with the wheel rotating under a speed sufficient to produce a material amount of centrifugal force in the bodies so that they are under strain at the time of such grinding, then when the wheel is at rest the softer bodies will contract radially more than the less soft bodies, and will thus lie beneath that cylindrical surface to which less soft bodies have withdrawn. However, in any case, either the grinding while the wheel is at rest, or the grinding while the wheel is rotating fast enough to produce some centrifugal force, when the wheel is brought up to normal working speed the softer body areas will expand under centrifugal force sufficiently to carry their working surface areas out beyond the working surface areas of the less soft bodies, so that the softer material bodies will project beyond the bodies formed of the less soft materials. Accordingly, the abrasive belt will travel principally on the incremental areas of the softer materials, when the work body is not pressed against the abrasive belt. When such work body is pressed against the abrasive belt said softer material body areas will be compressed radially inwardly, the belt of course also being correspondingly deformed, the extent of such inward deformation depending on the amount of force exerted against the belt by the work body at such time.

If the pressure of the work body against the abrasive belt be light so that the radial inward movement is not sufficient to bring the belt into good engagement with the less soft bodies, then the abrasive effect will be due solely to pressure resistive effects produced by the softer material bodies. If, on the other hand, the pressure of the work body against the belt be increased sufficiently said softer material bodies will be compressed sufficiently to allow the belt to also run on other bodies of less soft materials, which have not been centrifugally projected as far as the softer material bodies. Under this new assumption of an increased pressure of the work body against the belt it is evident that the resistive effects of at least two sets of bodies have come into play—the softer material bodies originally in effective operation, and now the additional less soft material bodies thus brought into play. Further, it is evident that the radially inward deformations of the original soft bodies are always greater than the radially inward deformations of the less soft bodies which have only afterwards come into play. Further, it is evident that, once the pressure of the work against the abrasive belt has been raised sufficiently to bring the less soft bodies into operation, not only has the effective pressure exerted by the softer bodies been increased, but additionally thereto a further pressure has been developed by the less soft bodies as they come into play; and, since these less soft bodies have a greater value for Young's modulus than the softer bodies it is evident that a given amount of further deformation of the belt by the pressure of the work body against such belt must be accompanied by a greater proportionate increase in abrasive pressure exerted on the belt at the locations of the less soft bodies than at the locations of the original softest bodies.

By providing a number of groups of bodies of different degrees of softness, it is possible to produce operations involving a corresponding number of effects from a truly "polishing" effect to one which is truly a grinding effect.

As an example of a contact wheel construction which includes elemental areas of six degrees of softness the following may be cited:

The wheel diameter is substantially 14 inches at the surfaces of the elemental areas when the wheel is at rest. With a wheel speed of 1750 R. P. M. the diameters of the several groups of elemental areas will be expanded to the following:

Areas of bodies rated at 40 Durometer, expanded to 17 inches diameter.

Areas of bodies rated at 50 Durometer, expanded to 16 inches diameter.

Areas of bodies rated at 60 Durometer, expanded to 15½ inches diameter.

Areas of bodies rated at 70 Durometer, expanded to 15 inches diameter.

Areas of bodies rated at 80 Durometer, expanded to 14½ inches diameter.

Areas of bodies rated at 90 Durometer, expanded to 14¼ inches diameter.

The foregoing shows clearly the relationship between the degree of softness and the effect of the centrifugal action on the various groups of bodies. It will be understood that the expanded diameters stated above are the diameters to which the bodies may be expected to expand when the belt is not in contact with the bodies on the wheel so that they are free to expand naturally under centrifugal action. Since the abrasive belt is in contact with substantially one-half of the periphery of the wheel or with the elemental areas of those bodies lying over substantially one half of the wheel circumference it follows that the effect of the contact of the belt with such elemental areas of such bodies must be explored as follows:

The amount of expansion of the softer bodies will be reduced by the engagement of the belt with them. The amount of such reduction of centrifugal force expansion will depend largely on the belt tension. I have already referred to the provision of spring means to enable maintaining the desired tension in the belt and to allow for slight back and forth movements of the tensioning wheel so as to maintain the desired tension of the belt on the contact wheel as now being discussed. By properly adjusting the tension in the belt it is possible to predetermine the differential between the centrifugally expanded softest material bodies and those bodies of less softness to thus vary the overall effects produced during a given running of the wheel, and the effects produced on the work object corresponding to such operation.

It is also to be seen that the pressing of the work object against the abrasive belt of itself modifies the extent of expansion of the various bodies and correspondingly affects the compressions of those bodies at the location of such work object. This has already been referred to herein. As the wheel rotates and the belt travels to and in contact with the work object (and thereafter away from such work object) each of the compressed bodies exerts a pressure urging the belt into contact with the work object under a corresponding pressure. Since the successive bodies are of different degrees of softness and are under different amounts of pressure against the belt it follows that the pressure being exerted to urge the abrasive surface into contact with the surface of the work object suffers rapid variations and is not a uniform pressure. These variations of pressure may be large in amount, and they may be sudden or of a graduated nature of change in amount. In any case these variations in pressure are of great rapidity and continue during the entire operation. For example, in the case of a wheel presenting a working surface of substantially 15 inches diameter when running, and which wheel is provided with fifty bodies around its circumference at any given plane normal to the axis of rotation, at a rotative speed of 1750 R. P. M. there will be 87,500 bodies passing the work object per minute. Each of these bodies will cause an increase of pressure during approach and a decrease of pressure during recession of the body away from the work object. Corresponding variations in the abrasive pressure being exerted on the work body by the abrasive belt will occur. These variations in the working pressure of the abrasive surface against the work object will greatly improve the abrading action, and will also greatly increase the "cutting" action so that much more rapid operations will be produced under a given set of conditions of work object and rate of belt travel.

A prime object of the present invention is to provide a method or mode of operation for conducting the grinding and/or polishing which method includes the features hereinbefore disclosed.

It is a further object of the invention to provide the means to perform the grinding and/or polishing operations according to such method. Accordingly I have illustrated and shall describe several constructions of contact wheels or the like embodying in each case numerous bodies of elastic material and wherein these bodies are of various degrees of softness or the like. In this connection it is a further object to disclose arrangements in which these bodies of various degrees of softness are interspersed over the peripheral surface of the wheel, so that the effects of the various degrees of softness shall be intermingled or interlaced during the running of the wheel. Specifically, I have provided arrangements wherein such intermingling or interlacing may be produced according to any preselected pattern, and whereby such pattern may be changed from time to time very conveniently by the operator to meet varying operations, and according to varying needs imposed by the grinding and/or polishing to be effected, and the specifications of finish desired to be secured.

Other objects and uses of the invention will appear from a detailed description of the same, which consists in the features of construction and combinations of parts hereinafter described and claimed.

In the drawings:

Figure 1 shows a plan view of a typical contact wheel including one embodiment of the present invention wherein the elastic bodies comprise blocks of uniform design, and wherein said blocks are retained in place and locked to the body of the wheel by tongue and groove arrangements; said blocks being formed of elastic material, and several degrees of softness being used, the blocks of each degree of softness comprising a group, and the blocks of the several groups being interspersed over the peripheral surface of the wheel;

Figure 2 shows a front end view of the wheel of Figure 1, a portion of the periphery of such wheel being broken away for convenience in illustration;

Figure 3 shows a cross-section taken on the line 3—3 of Figures 1, 4 and 5, looking in the directions of the arrows; and in this figure I have shown one form of reinforcing element in the base portions of the various elastic blocks, which element serves to prevent radial withdrawal of such block from the wheel under centrifugal action;

Figure 4 shows a development of a portion of the peripheral portion of the wheel of Figures 1, 2 and 3, and it shows one pattern of interspersing of the bodies of the several degrees of softness so that desired effects are produced;

Figure 5 shows a longitudinal section through the wheel of Figures 1, 2 and 3, being taken on the line 5—5 of Figure 3, looking in the direction of the arrows; and this figure is also a section taken on the line 5—5 of Figure 4, looking in the direction of the arrows;

Figures 6 and 7 are face and edge views, respectively, of one of the bodies of elastic material used in the type of construction shown in Figures 1, 2, 3 and 5; and these Figures 6 and 7 show a reinforcing element comprising a U-shaped unit of stiff wire, embedded and moulded in the base of each of the elastic bodies, and of size such that said body may not be displaced nor withdrawn from its locking engagement with the wheel under centrifugal or other action;

Figure 8 shows a perspective view of a modfied form of elastic body or block for use in the construction of Figures 1, 2, 3 and 5, in which modification the reinforcing element for each elastic block comprises a plate of metal, preferably foraminated, embedded and moulded in the base of the elastic block, and of size to prevent withdrawal of the block from the locking engagement with the wheel body;

Figures 9 and 10 show, on enlarged scale as compared to Figure 8, a face view and an edge view of the foraminated reinforcing plate used in the arrangement of Figure 8;

Figures 11 and 12 show a face view and an edge view, respectively, of another modified form of elastic block

for use in connection with the construction shown in Figures 1, 2, 3 and 5; and in this case of Figures 11 and 12 the reinforcing comprises a U-shaped plate of sheet metal, foraminated, and embedded and moulded into the material of the elastic block, and of form to prevent radial withdrawal of the elastic block from the wheel body; and the reinforcing shown in Figures 11 and 12 is also designed to produce a desired control of the radial expansion of the elastic block under centrifugal force to be developed during the running of the wheel in service, to thus ensure a desired and proper contour of the outer or working surface of the elastic block under working conditions;

Figure 13 shows a detail view of another form of the reinforcing element for embedding in the base portion of the elastic blocks, being a stiff wire element formed into almost a closed rectangle, instead of being of U-shape as in the case of the reinforcing elements shown in Figures 6 and 7;

Figure 14 shows a cross-section through a modified form of contact wheel construction embodying the features of my present invention; and in the present case the wheel body is provided with numerous longitudinally or axially extending rods having their ends properly supported in rigid relationship to each other, and the elastic bodies or blocks are strung on these rods in overlapping relationship so as to cause said bodies to "break joints" with each other; and in the present construction I have provided radial supporting plates strung on the wheel shaft and also strung on the aforesaid rods at locations intermediate between the circularly aligned bodies or blocks and serving to give support to the rods against radial displacement under centrifugal forces developed during running, and also giving support to the elastic blocks to retain them against rocking movement on the rods whereon such blocks are strung; and this figure shows a broken cross-section wherein the circular semi-portion above the horizontal medial line is taken on the line **14***a*—**14***a* of Figure 15, looking in the direction of the arrows, and wherein the circular semi-portion below the horizontal medial line is taken on the line **14***b*—**14***b* of Figure 15, looking in the direction of the arrows;

Figure 15 shows a development of a portion of the peripheral surface of the wheel shown in Figure 14, the locations of the radially extending plates being shown by dotted lines;

Figure 16 shows a longitudinal section taken on the line **16—16** of Figure 14, looking in the direction of the arrows;

Figures 17 and 18 show face and edge views, respectively, of one form of body or block of elastic material for use with the wheel construction shown in Figures 14 and 16; and in this block construction I have provided a reinforcement embedded and moulded in the base of the block, and comprising a U-shaped plate of sheet metal which is foraminated, and with the arms of such U-shaped element perforated to receive the rod on which the block is strung; the reinforcement element being designed and formed to control the radial expansion of the block under centrifugal force effect to ensure production of the desired contour of the outer working surface of the block when the wheel is running;

Figures 19 and 20 show face and edge views, respectively of another form of reinforcing element for the blocks to be used in the wheel construction shown in Figures 14 and 16; and in this case the reinforcing element comprises a curved plate of foraminated sheet metal embedded and moulded into the base portion of the elastic block;

Figure 21 shows a perspective view of another form of reinforcing element for use in the elastic blocks of the wheel construction of Figures 14 and 16; and in this case such reinforcing element comprises a length of stiff wire formed to provided spiral spring sections to surround and receive the rod on which the elastic block is strung, and also to provide laterally projecting wings at the two sides of such spiral spring sections, so as to ensure better adhering connection to the lateral portions of the elastic block and better control of the radial expansion effects produced on the block under centrifugal force effects;

Figure 22 shows a face view of another form of stiff wire reinforcing element for embedding and moulding into the base of the elastic block, and it comprises a spiral spring section to receive the rod on which the elastic block is strung, together with a single laterally extending wing element;

Figure 23 shows a face view of an elastic block having embedded and moulded therein two of the reinforcing elements of the form shown in Figure 22, such elements being set together with their wings extending laterally in opposite directions;

Figure 24 shows an edge view corresponding to Figure 23;

Figure 25 shows a cross-section through another modified form of wheel embodying the features of the present invention; and in the construction shown in this figure I have provided the wheel body with a cylindrical sheet which is provided with numerous openings through which the elastic blocks may be radially extended from the inside of such cylindrical sheet, the bases of such blocks being so formed that said blocks are retained against outthrow under centrifugal force developed during the running of the wheel; and the bases of these elastic blocks are provided with suitable reinforcing elements (not shown in Figure 25, but shown elsewhere), which are so formed as to prevent the bases of the blocks from pulling through the openings of the cylindrical wheel sheet; and Figure 25 is a section taken on the lines **25—25** of Figures 26 and 29, looking in the directions of the arrows;

Figure 26 is a development of a portion of the peripheral surface of the wheel shown in Figures 25 and 29;

Figures 27 and 28 are a face view and a bottom or inside view, respectively, of the elastic block incorporated into the wheel construction shown in Figures 25 and 29; and this elastic block is provided with a ring of stiff wire embedded and moulded into the base portion of such block, and of size to retain the elastic block against pulling through the opening of the cylindrical wheel sheet;

Figure 29 shows a longitudinal or axial section taken on the lines **29—29** of Figures 25 and 26, looking in the directions of the arrows;

Figure 30 shows a fragmentary development of a portion of the peripheral surface of the wheel of Figures 25 and 29, but with such wheel provided with square bodies or blocks of elastic material set into diamond position in the wheel surface, when considering the direction of surface movement;

Figure 31 shows another modified form of body or elastic block for use with the wheel construction of Figures 25 and 29, the blocks in this case being hexagonal in cross section, and set with their faces normal to the direction of wheel surface travel;

Figure 32 shows another view similar to that of Figure 31, but with the hexagonal cross-section blocks set with their edges facing in the direction of wheel surface travel;

Figure 33 shows a longitudinal section through one of the blocks of the type shown in Figure 30, being a detail section taken on the line **33—33** of Figure 30, looking in the direction of the arrows;

Figure 34 shows a top plan view of the block shown in Figure 33;

Figure 35 shows a top plan view of another modified form of block which may be used in connection with the type of wheel construction shown in Figures 25 and 29, the block in this case being oval or elliptical in cross-section, and set with its major axis parallel to the direction of wheel surface movement;

Figure 36 shows a view similar to that of Figure 35, but with the oval block set into the wheel periphery with its major axis normal to the direction of wheel surface movement;

Figure 37 shows schematically a typical installation of grinding and/or polishing equipment incorporating the features of the present invention; and in this case I have shown a contact wheel of the general form shown in Figures 25 and 29, but only for convenience of illustration; and in this figure I have shown the elastic blocks as being fully extended radially due to centrifugal action, but have not shown modifications of the block extensions caused by belt pressure over the arc of belt contact with the wheel surface; and in this figure I have shown but three groups of the elastic material blocks, being of three degrees of softness, the blocks of these three groups being interspersed around the wheel surface; and in this figure I have shown the effect caused by the pressing of a work body surface against the abrasive belt at a given location of the contact wheel;

Figure 38 shows diagrammatically the centrifugally produced radial extensions of elastic bodies of four degrees of softness, and the manner in which the chords of contact of the work body against such an arrangement depend both on the softnesses of the respective materials of which the elastic bodies are made, as well as the deformation pressure of the work body against the wheel surface; and

Figure 39 shows diagrammatically a development of the deformation surfaces of the various elastic bodies shown in Figure 38.

Referring to Figures 1 to 13, inclusive, I have therein shown a contact wheel construction embodying the features of my present invention in simple form, but consistently with widely accepted conventional practice in the general arrangements of such wheels as used in connection with abrasive belts travelling over them. In the case of these figures I have shown the end portion of a spindle **50** which is suitably journalled by journals not shown in the figures, so that said spindle extends horizontally towards the observer in Figures 1, 2, 3 and 5. This spindle is shown as provided with a rather large body **51** of generally cylindrical form, and beyond such enlarged body **51** the spindle terminates in a threaded stem **52** on which the locking nut **53** is threaded.

The body portion **51** is provided with a series of axially extending grooves **54** (12 being shown in Figure 3). These grooves are laterally undercut as shown at **55** and **56** so that the elastic blocks presently to be described may be set axially or endwise into the several grooves in number sufficient to fill the axial dimensions of the grooves. These blocks are provided with laterally extending tongues to enter into and lock with the undercuts **55** and **56** as is clearly evident from examination of Figure 3. Thus the blocks are locked into the grooves to prevent radial outward movement of the bases of the blocks during wheel running.

The number of grooves which will be provided around the wheel's perimeter lies within the choice of the designer, and likewise the axial lengths of the body portion **51** and thus of the grooves is a matter of choice of the designer; but it should be noted that such axial length should be sufficient to accommodate the maximum size of work body to be treated by the machine in question. In Figures 1, 3, 4 and 5 I have shown provision for only six full sized blocks and additionally a half-size block in each groove, but evidently the spindle body **51** may be made of sufficient axial length to accommodate many more blocks than indicated; and conversely, the number of blocks which may be accommodated within a groove of determined axial dimension will depend on the widths of the blocks (their dimension axially).

In the figures just referred to, and Figure 2, I have shown 12 grooves around the wheel circumference. The number of these grooves will likewise be a matter of choice on the part of the designer, and will also be affected by the desired diameter of the wheel. In determining the number of such grooves account may also be taken of the number of groups of blocks to be used, assuming that each group includes blocks of a specified softness. When the number of grooves is a full multiple of the number of groups of blocks it is possible to set the blocks into the wheel body under a pattern of block distribution which is uniform over the entire wheel perimeter.

A front end plate **57** is set onto the projecting stem **52**, and a block **58** is conveniently set between this end plate **57** and the nut **53** as well shown in several of the figures. By this arrangement it is possible to secure all of the blocks in place on the wheel, and by proper proportions of the parts, to ensure slight endwise pressure against the sets of blocks occupying the various grooves.

Since the blocks are formed of rubber or other suitable elastic material, and since considerable centrifugal forces are developed during running of the wheel at speed, it is evident that ample provision must be made to ensure against out-throw of the blocks even against the tongue and groove provision shown in these figures. Accordingly, I have made provision for reinforcing the bases of the blocks, and for amply preventing any such out-throw. Thus, each of the blocks shown in Figure 3 is provided with a U-shaped stiff wire element **59** embedded and moulded into its base portion, and of size and placement such that portions of such reinforcements extend well into the overhangs of the grooves **54** when the blocks are set into place. Such fact is well apparent from examination of Figure 3. With this arrangement it is evident that no block can be thrown centrifugally out from the groove without tearing the base portion of the block apart.

Various modified forms of reinforcing elements for the blocks to be used in the embodiment of the invention now being described, are also shown in Figures 8 to 13, inclusive. Thus, in Figures 8, 9 and 10 there is shown a form of reinforcement comprising a flat plate **60** of length such that the ends of said plate reach into the undercuts of the grooves **54**. Such plate is foraminated to include the numerous openings **61** through which the elastic material extends and within which such material is moulded to bond the base of the block into a well integrated body. In the arrangement of Figures 11 and 12 the reinforcement comprises a sheet metal element of U-shape, set into the base portion of the block, and with its flanges **62** and **63** lying parallel to the faces of the block, and with its connecting or central portion **64** set into the lower portion of the block's base. This portion **64** is also shown as being of length sufficient to reach into the undercut portions **55** and **56** of the groove, for the reason already explained in connection with the descriptions of other blocks. Preferably, also, this reinforcing element is foraminated, at least in its side flange portions **62** and **63**, as shown in Figure 11. In Figure 13 I have shown another form of reinforcing element similar to that shown in Figures 6 and 7; but in the case of Figure 13 the reinforcing element is formed into almost a closed rectangular element, and, for that matter, the end portions **65** and **66** might be brought together to close the gap between them.

Various other forms of reinforcing element will suggest themselves to the designer or student of this specification, and I do not intend to limit myself to the forms shown in the drawings, except as I may do so in the claims to follow.

At this point I wish to call attention to the fact that under the centrifugal forces developed during wheel running the radial expansions of the blocks will be determined by the resistive forces developed within the blocks themselves, and which resist such radial expansions. Included in such resistive forces is the effect of the reinforcing element embedded into and bonded to the base portion of each of the blocks. Evidently such reinforcing element has a far higher tensile strength and modulus of

elasticity than the elastic material of which the body of the block is formed. Accordingly, it is seen that those portions of the elastic body which are in radial alignment with portions of the reinforcing element, which portions of such reinforcing element are capable of effectively receiving and retaining expansive forces and resisting them, will have their expansions under centrifugal action greatly modified by the reinforcing element. By proper design and placement of the reinforcing element within the elastic block it is possible to ensure a desired contour of the outer perimeter surface of the elastic block when under running speed. It is not deemed necessary to here explore the exact relationships between reinforcing element and design of the elastic block to secure the desired result, but if need be such design might be based on empirical tests and reformations of design from a calculated design.

In the embodiment shown in Figures 1 to 13, inclusive, I have shown, by way of illustration only, four groups of the elastic blocks, of four different degrees of elasticity. These are conveniently designated as "A," "B," "C" and "D" blocks. Assuming that there are the same number of blocks in each of these groups, it is generally desirable to distribute the blocks of the several groups over the perimeter of the wheel according to a selected pattern. Preferably, also, such pattern is so selected that any elemental area of the work object which is being held in contact with the abrasive belt will be subjected to the influence of the blocks of the several degrees of softness in regular succession, and according to a pattern of softnesses. To accomplish this result the user of the contact wheel will set the elastic blocks into the various grooves in such order or progression around the wheel, and in such succession axially of the wheel, as to produce on the perimeter of the wheel that pattern which he desires to use. It will also usually be desirable to be able to "break joints" in the pattern thus finally produced so that no elemental area of the work object may continue in contact with a circumferential joint around the wheel for more than the length of one block continuously. The number of possible patterns which may be produced on the surface of a wheel of conventional size, for example, 14–15 inches diameter, is very large, even when using only three or four degrees of softness.

Since it is desirable to set the blocks into place in such pattern as to break joints, as already referred to, it is needful to make use of some blocks which are of less than the normal full width assigned to the blocks. Conveniently these partial width blocks are made of half width, in which case the joints between blocks may be brought to align with the central portions of preceding and following blocks. Likewise, a more regular and orderly pattern may be produced when using such half size blocks than when using blocks of either greater or lesser widths than half width for production of the joint breaks.

In Figure 4 I have, by way of illustration, shown one pattern which may be produced on the wheel now being described, when use is made of four groups of blocks, of four degrees of softness. The direction of wheel surface travel is shown by the arrow **67** in this figure. It will be seen that any elemental area of the work object held in contact with the belt at a given point will be subjected to the blocks of the several groups in the order progressing from "A" backwardly through "D," "C" and "B" back to "A." That order might have been reversed by setting the blocks into the wheel grooves in reverse order fashion. It will also be seen that actually such elemental area of the work object will be influenced by the blocks in the order "A," "A," "D," "D," "C," "C," and "B," "B," and back to another block of the "A" groups.

Examination of Figure 4 will also show the use of the half width blocks to enable the breaking of joints as referred to.

The radial dimensions of the blocks when originally installed into the wheel should be somewhat greater than will be required for the wheel specifications to be complied with. Such excess need not be large. Then, when the assembly of all of the blocks into place has been completed, and the wheel end plate has been locked into position, the outer perimeter of the wheel may be somewhat uneven, and in any case slightly oversize, it being understood that the wheel is then at rest. The outer wheel perimeter may then be subjected to a grinding operation to bring all of the outer faces of the blocks to a common cylindrical surface of specified size, within the allowed tolerance. Such grinding may be effected with the wheel rotating slowly so that substantially no centrifugal effect is produced on the various blocks, or under a speed sufficient to bring about some centrifugal enlargement during the grinding operation. This has already been referred to in the preamble, and need not be further repeated here. Reference will be made to this matter hereinafter.

The operation of the wheel shown in Figures 1 to 13 under belt running conditions will be considered hereinafter.

In the construction shown in Figures 14 to 24, inclusive, the spindle **68** is provided with an extension **69** of reduced size and has its front end threaded to receive the locking nut **70**. The block **71** is set against a shoulder **72** at the junction of the extension **69** with the spindle, and the wheel end plate **73** sets against the said shoulder. A spacer sleeve **74** is set onto the extension **69** and reaches forwardly to the front end of the wheel. There the front plate **75** is set onto the extension **69** or onto the sleeve as shown; and a block **76a** is set onto the extension **69** and is clamped towards the end of the sleeve **74** by the nut **70**. The front end plate of the wheel, **75**, is set just inside of the block **74**.

A series of rods **76** extend between the front and back end plates **73** and **75**, all of said rods being located at the same radial distance from the axis of rotation of the wheel. Conveniently these rods are extended through the front end plate **75** and are threaded into the back end plate **73**, as shown, so that by pulling these rods up tightly a clamping action may be developed between the end plates **73** and **75**.

A series of plates **77** are built into the body of the wheel. These plates are of the general form shown in Figure 14, from examination of which figure it will be seen that each such plate has its periphery formed to present flattened outwardly facing edges or supports **78** which are preferably formed as chords normal to the radii which touch said chords centrally; and between these chords each plate is provided with outwardly extending ears **79**. In the embodiment now being described there are preferably provided an even number of the rods **76**. Thus, each of the plates **77** is provided with a number of the ears **79** equal to one-half the number of rods **76**, and is provided with a like number of the supports **78**. Also, each of the plates is formed with its ears **79** and its supports **78** coming in alternation as well shown in Figure 14. The ears are perforated to receive the rods **76** registering with such ears, so that each rod is thus supported by the ears through which it passes, being the ears of one-half of the plates. Examination of Figures 14, 15 and 16 shows that in assembling the present wheel construction the plates **77** are angularly staggered in alternation, so that the ears of alternate plates come into registry, with their supports **78** also in registry; and so that the ears of the intermediate plates also come into registry, with their supports **78** also in registry; and also shows that each of the rods is thus registered with and extended through the ears of alternate plates, and that successive rods pass through the ears of alternate plates. In studying Figure 14 it must be remembered that the upper and lower halves of this figure are sections taken at the locations of successive plates, as is evident from examination of Figure 15.

The elastic blocks illustrated for use in connection with the embodiment of wheel now being described are shown in detail in Figures 17, 19 and 23 in face elevation. From

these figures it is seen that such blocks are of generally quadri-lateral form, each including a circular arcuate outer perimeter **80**, a chordal inner perimeter **81**, and two radially extending sides **82** and **83**, connecting the outer and inner perimeters. Each such block is provided with a transverse opening **84** of size to nicely pass or ride on the rod **76** on which such block is strung; and such opening **84** is so placed with respect to the chordal perimeter **81** of such block that when the block is strung on a rod at a location between the ears of two plates which are separated by an intermediate plate, the chordal perimeter **81** of such block will contact with and be supported by the support **78** of the plate which lies intermediate between the two whose ears have been just referred to. When so strung onto the rod such block is thus retained against out-throw under centrifugal action by such rod, and also the block is supported against rocking movement on the rod, in part at least, by engagement of its chordal perimeter **81** with the support **78** of the intermediate plate. Conveniently these supports **77** are enlarged axially by forming the sheet metal from which the plate is formed, at right angles—that is, axially, as well shown in Figure 16. In such case it is noted that such right-angularly formed portion or support must not extend beyond the limits of the chordal perimeter **81** as such further extension would interfere with the chordal perimeters of the two angularly adjacent blocks.

It is intended that the blocks used in the embodiment now being described shall break joints. This fact is apparent from examination of Figure 15. In that figure the plate locations where the ears **79** are found are shown by the double dotted lines with the unbroken line between them, such unbroken line representing the surface of engagement of one of the blocks with the axially adjacent block. It is here to be noted that due the elastic nature of the blocks themselves it is possible to assemble them on the rods whereon they are carried, with the ears **79** between the faces of the successive blocks; and then, when the blocks are compressed slightly together their proximate faces will compress at the locations of the ears sufficiently to permit the outer peripheral surfaces of adjacent blocks to come into substantial continuity. For this reason there is shown in Figure 15 no actual space between the adjacent blocks of each axial row. However, the blocks are so sized that when they are assembled on the successive rods their sides **82** and **83** come successively into contact as well shown in Figures 14 and 15. Thus when the blocks have been assembled and drawn into position a substantially continuous outer perimeter surface is provided for the wheel.

In Figures 14, 15 and 16 I have indicated the presence of three groups of blocks of three degress of softness, the blocks of these three groups being designated as "A'," "B'," and "C'," respectively. Examination of Figure 15 will show one typical pattern of distribution of the blocks of these three groups over the wheel surface to ensure a good distribution of the several softnesses over the entire wheel surface. The direction of surface travel is shown by the arrow **85**.

It is now noted that in the arrangement of blocks schematically shown in Figures 1 to 13, there are shown twelve blocks around the wheel at any given section, and there are shown six full blocks and one half size block axially of the wheel, together with four groups of blocks of four corresponding degrees of softness. These various figures are more or less schematic in form, and accordingly, in practice there might be, for example, twice as many blocks axially of the wheel, as are shown. In such a case, or by using other ratios of numbers of groups of blocks as compared to the number of blocks around the wheel, and also as compared to the number of blocks axially of the wheel, perfect distribution patterns of the blocks of the several degrees of softness, over the wheel surface, may be secured.

By comparison, examination of Figures 14, 15 and 16, showing the modified embodiment, will reveal that in this case there are shown only three groups of blocks, of three corresponding degrees of softness, twelve blocks around the wheel, and six full blocks and a half block axially of the wheel. It will be seen that this relation between the various factors enables production of a perfectly uniform pattern over the entire wheel surface, both circumferentially and axially.

Each of the elastic blocks used in the embodiment of Figures 14, 15 and 16 is provided with a reinforcing element in its base portion. Several such reinforcing element forms are shown in Figures 17 to 24, inclusive. Such reinforcements are not shown in the section of Figure 14 but any one of the block forms shown in Figures 17 to 24, or other block and reinforcement forms, may be used with the wheel construction now being described.

In the arrangement of Figures 17 and 18 the reinforcement element comprises a U-shaped sheet metal unit having the side plates **86** and **87** connected by the bottom connecting piece **88**, the side plates preferably being foraminated to permit the material of the elastic block to extend through the reinforcing element and be thus well moulded together. These foraminations are shown at **89**. These side plates **86** and **87** are also provided with openings registering with the block opening **84**, so that when the block is assembled onto the wheel rod the reinforcing element will be directly sustained by such rod against out-throw under centrifugal action. Thus a very perfect support for the block will be ensured.

In the arrangement of Figures 19 and 20 I have shown the reinforcement plate as comprising a curved sheet metal element **90** set between the rod opening **84** and the chordal perimeter surface **81**, and with the concave surface of such reinforcing element facing outwardly of the block. Under centrifugal force action this reinforcing element may bend or yield slightly in its extremities, if so designed.

In the arrangement of Figure 21 the reinforcing element comprises a single length of stiff wire formed to provide the two laterally adjacent spirals **91** and **92**, together with the wing **93** reaching outwardly at one side of the element, and another wing **94** reaching outwardly at the other side of the element. Usually the wing **94** will comprise the end portions of the wire length, bent to approach each other, but not actually integrated together, although such integration might be provided if desired. The spirals **91** and **92** are of size and are so placed as to register with the through opening **84** of the block in which such reinforcement element is embedded and moulded, so that when the block is in place on the rod such reinforcement element will secure direct support by engagement with the rod. Such engagement will enable a slight rocking movement of the reinforcement element to occur if need be, but usually this will not occur. However, it is noted that with this type of reinforcement there will be some springiness in the reinforcement itself, so that the wings **93** and **94** may deflect outwardly to a slight extent under centrifugal force effects, thus enabling the block, when under strain, to have its enlarged outer perimeter surface of the exact desired contour.

In Figure 22 I have shown another modified form of stiff wire reinforcing element for use with the type of elastic block now being considered. In this case the wire is bent into form to provide the spring spiral **95**, together with the wing **96** at one side, only, of such spiral. As shown in Figures 23 and 24 it is intended that two of these elements shall be interlaced within the elastic material block, so that one of the wings **96a** shall reach outwardly at one side of the block, and the other wing, **96b** shall reach outwardly at the other side of the block; and so that the wheel rod shall pass through the spirals of both of these elements.

Reference to Figure 16 in particular shows the presence of the washers or collars **97** at the central portions of the plates **77** of the embodiment now being described.

These are riveted or spot welded or otherwise secured to the several plates, and their central openings are of size to fit nicely on the sleeve 74. These washers or collars are also of thickness such that when the plates are assembled together their central portions will come into engagement with the washers or collars of the adjacent plates, thus ensuring correct spacing of the plates within the wheel body, taking account of the thicknesses of the several elastic blocks which have been strung on the rods. An extra washer or collar, 97a is provided at the end of the wheel last assembled, to ensure correct spacing at that end.

By forming these washers or collars of proper thicknesses, so that when the plates and washers or collars have been completely assembled their total axial length is slightly greater than the length of the sleeve 74, upon pulling the nut 70 up tight the various plates 77, the washers or collars, and the wheel end plates 73 and 75 will be drawn solidly together, thus ensuring driving from the spindle 68 (and the block 71) to the plates 77, and thus also to the rods 76. Thereby drive will be ensured directly from the rods to the several elastic blocks which provide the wheel surface.

In Figures 25 to 36, inclusive I have shown another modified embodiment of my present invention. In this case the spindle 98 is provided with the extension 99 whose front end is threaded to receive the locking nut 100. The wheel body includes the back and front plates 101 and 102, respectively with the blocks 103 and 104 set onto the extension against the outer faces of these plates. The cylindrical element 105 is supported by the peripheral portions of the plates 101 and 102, for which purpose said plates are conveniently shouldered as shown at 106 so that the cylindrical element 105 will seat nicely onto the peripheral portions of the plates 101 and 102 and against the shoulder when the plates are drawn towards each other. A number of through bolts 107 extend between the plates 101 and 102 and serve to draw said plates towards each other.

The cylindrical element 105 is provided with numerous openings to receive the elastic blocks, said openings being of form according to the block form intended to be used. In the showing of Figures 25, 26 and 29 said openings are circular in form, but as will presently appear, other forms of openings and blocks are also illustrated herein. These circular openings are designated 108 for the circular form blocks. They are distributed over the cylindrical element 105 in regular fashion, and according to a pattern which is a consolidation of the patterns adopted for the blocks of the several groups of softnesses used in the wheel. In the arrangement shown in Figures 25, 26 and 29 this pattern of the openings is one in which said openings are located at the apexes of equilateral triangles, so that the openings lie in straight lines extending around the element 105 at the lines of intersection of planes which lie normal to the axis of wheel rotation; and the openings are then set at positions on said straight lines such that the openings "break joints" from line to line, as clearly evident in Figure 26.

A typical form of elastic block for use in such an opening and wheel arrangement as just described is shown in Figures 27 and 28. This block is of cylindrical form, as shown at 109 and is of size to extend nicely through the openings 108. To this end said cylindrical block portions are of substantially uniform size or diameter. Each block is then provided with an enlarged base portion 110 which will engage the inner cylindrical surface of the element 105 when the blocks are set through the openings 108 so as to retain the block against radial out-throw under centrifugal force, it being understood that the blocks are set through said openings from the inside of the cylindrical element 105. These enlarged base portions 110 are of size such that the bases of adjacent blocks do not interfere with each other, although in some cases said base portions may be of form such as to interlock for prevention of rotation of the various blocks on axes radial to the axis of wheel rotation.

In order to prevent possible out-throw of the blocks through the openings 108 by dragging the base elements 110 through said openings, I have provided reinforcements in said base portions of the elastic blocks. In the form shown in Figures 27 and 28 such reinforcement comprises a ring of stiff wire 111 embedded and moulded into the enlarged base portion 110, such ring being of size to underlie the inner surface of the cylindrical element 105 when the block is set through the opening.

The elastic blocks are set through the openings 108 prior to complete assembly of the element 105 to the plates 101 and 102, etc. When the blocks have been set through the openings an inner retaining cylindrical element 112 may be inserted into the wheel body, being of a size to slip nicely within the generally cylindrical surface which defines the inner surfaces of the blocks thus in place. Such inner retaining cylindrical element 112 will then prevent shift of the blocks inwardly and will retain them in proper projected positions irrespective of centrifugal forces, and prior to wheel running. Such cylindrical element will also prevent forcing of the blocks inwardly under tension of the belt which is afterwards run over the wheel. The engagement of the inner surfaces of the base portions of the blocks with the outer cylindrical surface of the element 112 will also prevent tilting of the blocks although the blocks may be deflected by bending or like deformation, since they are formed of elastic material.

After the blocks have been assembled into the wheel, and the assembling of the wheel has been completed, the outer surfaces of the blocks may be finished by a grinding operation, according to the principles already disclosed herein.

The number of degrees of softness of the blocks used in this embodiment of the invention will be determined by the designer and according to the intended uses and specifications of use of the wheel, and need not be further explained beyond calling attention to the face that in the arrangement shown I have indicated five groups of blocks, designated as "A," "B," "C," "D" and "E" blocks, respectively; and in Figures 25 and 26 I have shown a simple form of pattern of distribution of these blocks over the wheel surface.

In Figures 30 to 36, inclusive, I have shown several modified forms of the elastic blocks intended for use in connection with the embodiment of Figures 25, 26 and 29, and I have also therein shown other details of pattern formation than that shown in Figure 26. In Figure 30 I have shown a fragmentary development of the wheel surface provided with square openings through which are extended square blocks, 113. The bases of these blocks are also square and are of such size that the bases of the adjoining blocks come together edge to edge, thus locking the various blocks against rotation on their own axes. In Figures 33 and 34 I have shown details of a square block intended for use with the arrangement of Figure 30, and I have shown the reinforcement element 114 in the base of such block. This element 114 is of size such that it cannot be pulled through the square opening of the wheel element 105a (corresponding to 105 of Figures 25 and 29). As shown in Figure 34 this reinforcement element 114 may be square and placed with its sides parallel to the sides of the square block, but evidently other arrangements of reinforcement might also be used.

It is also noted that in the pattern of Figure 30 the openings through which the blocks are set are rocked to an angle of 45 degrees with respect to the direction of wheel surface travel, which direction of travel is shown by the arrow 115 in Figure 30.

In Figure 31 I have shown a fragment of a development of a wheel surface which is provided with blocks of hexagonal form extended through corresponding hex-

agonally formed openings. These blocks **116** of Figure 31 are set into a pattern in which the flat faces of the blocks lie normal to the direction of wheel surface travel, shown by the arrow **117**. In Figure 32 I have shown a fragment of a development similar to that shown in Figure 31; but in the case of Figure 32 the hexagonal blocks **118** are set into the wheel with their apexes facing in the direction of wheel travel shown by the line or arrow **119**.

In Figure 35 I have shown an elliptical or oval form of block, set with its major axis parallel to the line of wheel surface travel, **120**, such block being shown at **121**; and in Figure 36 I have also shown an elliptical or oval form of block **122**, but set with its major axis normal to the direction of wheel surface travel as shown by the arrow **123**.

Various other forms of blocks, and various other patterns of distribution of the blocks over the wheel surface will suggest themselves to the user or student of this invention.

In Figures 37, 38 and 39 I have shown schematically various of the operations which occur when using my improvements in grinding and polishing, and when using equipment of the general type previously described in detail herein. The showings of these figures are exaggerated as to amounts of elastic extensions or radial enlargements of the blocks of different degrees of softness, this being done for better illustration of the nature of the operations and the effects produced.

In Figure 38 I have shown by the circle **124** the working size of the surface of the abrasive belt to which the work object is to be presented, prior to contact of such object with such belt surface, it being assumed that the wheel is at speed. It is also assumed for simplicity of explanation that the work surface to be presented to the belt is flat. The flat work surface is shown in several successive positions as 125^a, 125^b, 125^c, etc. Upon pressing such surface slightly against the belt surface so as to produce a slight deformation of the elastic wheel surface, to bring the work surface to the line 125^a the length of the chord over which scratching engagement will occur is shown between the points **126** and **127**, and is relatively small. Furthermore, the pressure which must be exerted between the work surface and the abrasive belt is light. Thus a light cutting or scratching action is produced, in the nature of a polishing operation.

It will now be assumed that the wheel surface is formed of elastic material, but is homogeneous in character and composition. Under these conditions, increase of pressure of the work surface against the wheel surface will cause deformation to the line 125^b. Corresponding to this new condition the length of the scratch has been increased to the distance between the points **128** and **129**, and the pressure has also been increased as already stated.

Upon further increase of the work pressure against the belt surface a further increase of deformation will be produced, bringing the work surface to the line 125^c. Then the lengths of the scratches will become that distance between the points **130** and **131**. Finally, a further increase of work pressure will shift the deformation to the line 125^d with increase of the lengths of the scratches to that distance between the points **132** and **133**.

It is thus apparent that when the elastic surface of the contact wheel is of uniform softness or yieldability over its entire surface, the lengths of the scratches will increase with increase of pressure of the work against the abrasive belt. Also, the entire operation which will be produced for any given pressure of the work body against the belt surface will be that due to the abrading engagement of the work body surface against the abrading belt under the condition that at all times, from one end of the area of deformation to the other end of such area, the abrading pressure exerted between the work object and the abrading surface is that pressure which causes deformation of elastic material on the wheel surface, of one and only one degree of softness over the entire extent of the deformation which is momentarily produced by the working pressure then in force. For any value of the working pressure of the object against the abrading belt surface there will be produced a corresponding total deformation, accompanied by a corresponding total length of scratch. Also, the pressure per unit area, of contact of the work object against the belt surface will rise from zero to a maximum, and then decrease back to zero. Also, the integrated sum of all incremental area pressures must total to the actual pressure of the work object against the belt. Therefore, the material removing effect of such a total operation is limited to that which will be produced by the softness of the elastic material on the wheel surface, which elastic material has been assumed to be homogeneous in character.

In Figure 39 I have shown schematically the "work areas" produced corresponding to the increasing pressures of the work object against the belt, for the several pressures referred to in Figure 38, and which produce deformations to the lines 125^a, 125^b, 125^c and 125^d, respectively, such work areas being designated as **134**, **135**, **136** and **137**, respectively. These showings are of course diagrammatic only.

Now let it be assumed that the surface of the contact wheel is provided with elemental areas of various degrees of elasticity, such areas being grouped into four groups "A," "B," "C" and "D," according to the principles previously disclosed herein. Then let such wheel be brought to speed with the abrasive belt in working contact with the wheel. Under these conditions let it be also assumed that the centrifugal forces developed in these incremental areas cause expansions of the various areas of different degrees of softness. Such expansions will be according to the softnesses of the bodies, the softer bodies suffering greater expansions than the less soft bodies. Let the circles **138**, **139**, **140** and **141** represent the increased diameter paths of travel of the outer working surfaces of the several groups of incremental area bodies. The circle **138** then corresponds to the softest bodies ("A," for example), and the circle **141** corresponds to the least soft bodies ("D," for example). If, now, the work object be pressed against the belt travelling on such contact wheel, to produce a deformation to the line 125^d in Figure 38, the following conditions will obtain: The softest bodies "A" will be forced inwardly from the circle **138** to said line 125^d, the least soft bodies "D" will be forced inwardly from the circle **141** to said line 125^d, and the bodies of intermediate degrees of softness will be forced inwardly from the circles **139** and **140** to said line 125^d. The scratches produced by the softest bodies "A" will extend between the points **132** and **133** already referred to; but the scratches produced by the least soft bodies and the bodies of intermediate degrees of softness will be of different lengths as follows: For the bodies "B," between the points **142** and **143**, for the bodies "C," between the points **144** and **145**, and for the bodies "D" (least soft bodies), between the points **146** and **147**. Thus the lengths of the scratches produced by the various groups of bodies will vary somewhat inversely as the softnesses of the bodies comprising said groups.

It must, however, be further noted that the contact pressures which will be developed at the various incremental areas of these various bodies will differ from each other in a special manner, as follows: The softer bodies have the smaller moduli of elasticity, as has already been pointed out. Thus the rates of increase of pressures which must be applied to the various groups of bodies in order to produce deformations in them will differ from each other, the rate of pressure increase for a body "D," for example, being much greater than for a body "A." That is, for a given increment of deformation produced in each of these bodies, the pressure applied to the body

"D" will be increased as compared to the pressure applied to the body "A" somewhat inversely as the respective moduli of elasticity of these bodies. The net results of this is that, although the actual amount of deformation produced in the body "D" as indicated in Figure 38 is much less than the actual amount of deformation produced in the body "A," nevertheless the final pressure to which the body "D" may be subjected may actually be as great as or even greater than the final pressure to which the body "A" is simultaneously subjected, notwithstanding the differences in the amounts of deformations suffered by said bodies.

Thus, too, it is evident that with this arrangement, the actual pressures to which the several bodies are subjected do not vary directly with the lengths of the scratches, but the relation of scratch length to pressure is much different in the several groups of bodies. It will also be evident that it is possible to select bodies of such relative softnesses and other characteristics that desired lengths of scratches may be secured in combination with desired pressures against the incremental area bodies in order to produce a specified grinding and/or polishing operation on the work object.

Reference may now be had to Figure 37 for a further showing of the nature of these operations. In that figure the contact wheel is designated **148**, rotating on the axis **149**, an idler wheel is shown at **150** rotating on its axis **151**, and the abrasive belt is shown as **152**. This belt travels over both wheels, and generally the contact wheel **149** is also the driver. The shaft of the idler wheel **150** is conveniently carried by journals which can shift back and forth with respect to the axis of the contact wheel, so as to produce a desired tension in the belt; and I have shown a spring **153** drawing the idler wheel away from the contact wheel to produce the belt tension. The effect of this spring may be adjusted by the operator to meet his requirements. Devices of this type are known and used in this art, and therefore I do not herein illustrate or describe such a device with particularity. The directions of wheel rotations are shown by the arrows **154** and **155**.

The contact wheel **148** is provided with three groups of elastic bodies of three degrees of softnesses. These are designated as "A," "B," and "C," respectively, the bodies "A" being the softest ones. In Figure 37 the system is shown as operating with the contact wheel at speed, so the various elastic bodies are shown as being fully expanded by centrifugal action. Thus the bodies "A" are shown most expanded, and the bodies "C" are shown as least expanded, and the bodies "B" are shown under an intermediate amount of expansion. The belt is shown as running on the outer surfaces of the bodies "A," since said bodies project the greatest amount; and in this figure I have, for purposes of illustration, shown a sufficient difference between the expansion of the bodies "A" and "B" so that the belt is shown as passing tangentially between adjacent bodies "A" without contact with the intermediate bodies "B" and "C." In actual practice this condition would probably never occur, but the belt would actually ride in contact with all of the bodies. This condition would be caused by the following further fact:

In Figure 37 I have not shown any deformation of the bodies lying to the left side of the contact wheel **148**, which deformation is actually caused by the belt pull. With the belt under tension those elastic bodies which are in engagement with the belt will actually be deformed inwardly in amounts dictated by the various factors of the problems of elasticity affecting such distribution, so that actually the belt will probably be travelling in contact with all of the bodies at the left side of the wheel. But due to the fact that these bodies are of various degrees of softness, and the various factors which have heretofore been discussed, the abrading operations produced will still be according to the principles hereinbefore explained.

In Figure 37 I have also shown the effect of application of a work body **156** to the belt under sufficient pressure to deform the belt and the elastic bodies to such an extent that all of the elastic bodies of groups "A," "B" and "C" are brought into operation. The work body illustrated is shown as presenting the flat surface **157** to the abrasive belt under the foregoing conditions of operation.

I claim:

1. A contact wheel having a peripheral cylindrical running surface for arcuate travel of an abrasive surface, said contact wheel including a body section and a plurality of elastic bodies lying in a cylindrical zone at the exterior radial portion of the wheel, each body being of substantially uniform degree of softness throughout its outer peripheral portion, said elastic bodies being of different degrees of softness and including a plurality of groups of bodies, the bodies of each group being of substantially the same preselected degree of softness, and the bodies of the different groups being of different degrees of softness and being located in said cylindrical zone, together with means to retain the elastic bodies within said zone.

2. Means as defined in claim 1, wherein said means to retain the elastic bodies to the body section of the wheel includes disconnectable means constituted to permit attachment and detachment of the elastic bodies to and from the body section of the wheel.

3. A wheel as defined in claim 2, wherein the means to connect the elastic bodies to the body section of the wheel comprises companion tongue and groove portions on the body section of the wheel and on the elastic bodies.

4. A wheel as defined in claim 3, wherein said companion tongue and groove portions extend longitudinally of the wheel and substantially parallel to the wheel axis.

5. A wheel as defined in claim 4 wherein the groove portions of said connecting means comprise portions of the wheel body section and wherein the tongue portions of said connecting means comprise portions of the elastic bodies.

6. A wheel as defined in claim 5, together with stiff reinforcing elements embedded in the tongue portions of the elastic bodies and of size to retain the tongues of the elastic bodies against removal from the companion grooves in a direction substantially radial of the wheel.

7. A wheel as defined in claim 2, wherein the means to disconnectably connect the elastic bodies to the wheel section of the wheel comprises a plurality of substantially parallel rods and means to connect said rods to the wheel body section, and wherein the elastic bodies are provided with through openings to receive said rods, and wherein the elastic bodies are strung on the rods.

8. A wheel as defined in claim 7, wherein said rods extend longitudinally of the wheel and substantially parallel to the wheel axis.

9. A wheel as defined in claim 8, together with reinforcing elements embedded in the elastic bodies and including portions of said reinforcing elements which lie between the axis of wheel rotation and the rods on which said elastic bodies are strung.

10. A wheel as defined in claim 9, wherein said reinforcing elements are formed of spring material and include portions extending within the elastic bodies to positions laterally displaced from the plane which includes the wheel axis and the rod on which the elastic body is strung.

11. A contact wheel having a perpiheral cylindrical running surface for arcuate travel of an abrasive surface, said contact wheel including a body section and a plurality of elastic bodies lying in a cylindrical zone at the exterior radial portion of the wheel, each body being of substantially uniform degree of softness throughout its outer peripheral portion, said elastic bodies being of different degrees of softness and including a plurality of groups of bodies, the bodies of each group being of substantially the same preselected degree of softness, and the bodies of the different groups being located in said cylindrical zone, together with means to retain the elastic bodies within said zone comprising a cylindrical element portion of

the body section of the wheel, and provided with radially extending through openings, and wherein the elastic bodies extend through said radially extending through openings and project radially beyond the outer surface of said cylindrical element, and wherein each elastic body includes a base portion of larger size than the through opening through which such elastic body extends, said base portion being located adjacent to the inner surface of the cylindrical element aforesaid.

12. A wheel as defined in claim 11, together with a second cylindrical element coaxial with the first mentioned cylindrical element and of size to underlie the base portions of the elastic bodies and retain said elastic bodies against movement radially inwardly through the openings of the first mentioned cylindrical body.

13. A wheel as defined in claim 11, together with a reinforcing element embedded in the base portion of each elastic body at a location within the cylindrical element, and comprising a stiff element having a dimension in a surface parallel to the cylindrical element which dimension is greater than the size of the opening in the cylindrical element which opening accommodates such elastic body.

14. A contact wheel having a peripheral cylindrical running surface, a pliable belt having an abrasive surface and travelling on said contact wheel surface, said contact wheel including a body section and a plurality of elastic bodies lying in a cylindrical zone at the exterior radial portion of the wheel, each body being of substantially uniform degree of softness throughout its outer peripheral portion, said elastic bodies being of different degrees of softness and including a plurality of groups of bodies, the bodies of each group being of substantially the same preselected degree of softness, and the bodies of the different groups being of different degrees of softness and being located in said cylindrical zone and adapted to present outwardly facing incremental areas of belt supporting surface, said elastic bodies being located at positions within the cylindrical zone to present at said belt supporting surface a pattern of said incremental areas of the different degrees of softness which pattern is of pre-determined specification, together with means to retain said elastic bodies in said cylindrical zone.

15. A wheel as defined in claim 14, wherein said elastic body retaining means includes means to removably retain the elastic bodies in said zone, and wherein the elastic bodies are interchangeable in said cylindrical zone.

16. A wheel as defined in claim 14, wherein the outwardly facing belt supporting incremental areas all lie in substantially the same cylindrical surface co-axial with the axis of wheel rotation when said wheel rotates at a predetermined rotative speed.

17. A method of treating an object to the abrading effect of a pliable belt having an abrading surface, which method consists in causing said belt to travel in contact with an elastic body member which includes a plurality of elastic bodies of different predetermined degrees of softness and wherein the bodies of the different predetermined degrees of softness comprise a series of groups of said bodies and wherein the bodies of each group are of substantially the same degree of softness, and wherein the bodies of the different groups are interspaced in the surface of the elastic body member according to a preselected pattern of the bodies of the several groups and wherein the bodies of the different groups are of different degrees of softness and which elastic body member travels at the same speed as the belt to thereby produce an elastic backing for said pliable belt which backing is of different degrees of softness corresponding to said elastic bodies, and which method consists in supporting the object to be treated in contact with said abrading surface of said belt under pressure, whereby the yieldability of the belt while in abrading contact with the object being treated is determined by the degree of softness of the backing body at the location of belt engagement with the object being treated at each instant.

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