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(54) Printing apparatus and method.

(57) A printing apparatus is disclosed which includes a rotatably driven turret (60) carrying one or more collectors (C) at selected radial and angular positions, and transfer means (75) synchronously driven with the turret (60) for depositing on each of the collectors (C) a design configuration. The turret (60) and each of the transfer means (75) share a common point of rotation along respective central axes thereof.

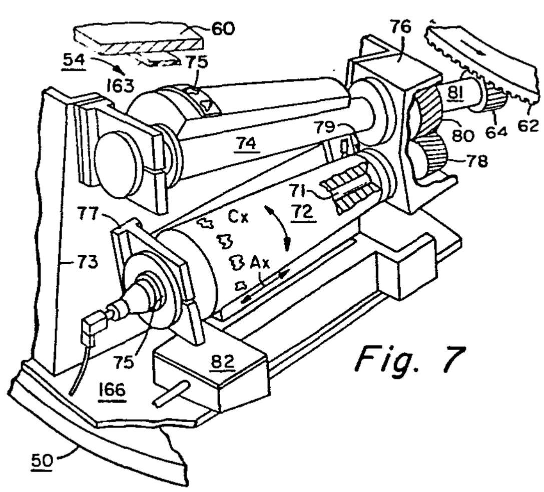

Fig. 7

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PRINTING APPARATUS AND METHOD

The present invention relates to a printing apparatus and a method of carrying out various printing functions. Although many applications for the invention may be possible, the disclosure herein emphasizes the application to ware decoration. It should be understood however, that articles of many types may be printed or decorated using the apparatus and method of the present invention, and such applications are part of the invention herein.

In multicolour ware decoration, speed, versatility, ease of set up, quality of reproduction, accuracy of registration, and cost effectiveness are important factors to consider. State of the art decorating devices approach some, but not all, of the above factors satisfactorily. The present invention was developed for various reasons including a desire to take advantage of the latest ink and elastomer technology, and to maximize printing rates without sacrifice of registration.

The machine configuration of the present invention makes use of two geometric relationships. First, a cone when placed on a flat surface and rolled, will trace an arc centred at the same point as the apex of the cone. The cone will travel along this path freely with no slipping between the surfaces. Second, two cones, sharing the same apex and placed side by side, will roll one on the other without slipping along the line of contact. As will be shown below, by choosing the proper ratio of circumferences between the first mentioned cone and the arc traced in the plane of the flat surface, the cone will roll an integral number of revolutions as it travels one revolution about the traced arc. Similarly the proper choice of circumference ratios of cones will produce integral rotations with each other and the arc. Therefore, discrete locations of the cone will always match up with discrete locations along the arc in the flat surface. Accordingly, a special case of synchronous motion may be defined.

The two cones and the flat surface may be driven in synchronism by a proper gearing arrangement, from which a device may be produced which will establish pattern registration from one set of cones to another and the surface as hereinafter illustrated.

It should be further understood that the device of the present invention may be operated in various ways to establish a degree of versatility not heretofore available in the prior art. The device herein described may be adapted for printing multicolour designs on flat, hollow, and other odd shaped ware inside or out, with high quality, speed, and simplified set up for each of the various types of ware to be decorated.

In an embodiment thereof the apparatus of the present invention includes a rotatably driven turret carrying one or more collector means at selected radial and angular positions, and transfer means synchronously driven with said turret for depositing on each of said collector means a design configuration. The turret and each of the transfer means share a common point of rotation along respective central axes thereof. The invention also provides a method of printing from collectors about a central location.

In the accompanying drawings:

Figures 1-3 (A)-(C) show the geometric relations between the various components and illustrate the operating principle of the apparatus of the present invention;

Figure 4 is a schematic transparency of the apparatus components of the invention;

Figures 5 and 6 are detailed cut-away prespective views of the apparatus showing print, print transfer, load and clean stations of the invention;

Figures 7 and 8 are illustrative specific details of the printing station and inking apparatus;

Figure 9 is a schematic drawing of a floating bearing feature which may be used in the present invention;

Figures 10A-10C illustrate schematic alternative embodiments of the doctoring feature;

Figures 11-14 illustrate the concept and application of a cam-following print transfer feature which may be used in the present invention;

Figures 15A-15B illustrate details of the print transfer apparatus in respective perspective and side section views;

Figure 16 is a fragmented side section of an alternative embodiment of the print transfer apparatus;

Figures 17A-17B are fragmented side section and top views of a hollow ware printing head;

Figure 18 is a schematic showing a flexible membrane printing head and ware throughput relative thereto;

Figures 19A and 19B are side sections of the flexible membrane printing head and ware in two positions;

Figure 20 is a side section elevation of a backing member for supporting the flexible membrane;

Figure 20A is a fragmented detail of an alternative embodiment adapted from Figure 20;

Figure 21 is a cross section of a printing head for a special case of a convoluted saucer;

Figures 22A-C illustrate a method of determining ware head shape; and

Figures 23A-D are schematic drawings illustrating alternative embodiments of print transfer mechanisms.

The machine configuration of this invention makes use, as mentioned above, of two geometric relationships. First, referring to Figure 1, a cone 10 (truncated as shown), having an apex point A, when placed on a flat surface 12 and rolled, will trace a circular arc or disc 14 about a centre line CL and have its apex A located thereon. The cone 10 will travel along this path freely with no slipping. Second, referring to Figure 2, two cones, the first mentioned 10 above and another 16 (both shown in transparency), having the same apex A and placed side by side, roll one on the other with no slipping along the line of contact or ray 18.

Figures 3A to 3C show that by combining the principles of Figures 1 and 2, and by choosing the proper ratio of circumferences between the arc 14 and cone 10, the latter will roll an integral number of revolutions as it travels one revolution around arc 14. This means that discrete locations 20 on the cone 10 will always match up with the discrete locations 22 on the arc 14. Likewise, by choosing the proper ratios of circumferences between the two cones 10 and 16, one will rotate an integral number of times for each revolution of the other. Thus, discrete locations 24 on the cone 16 will always match those discrete locations 20 on cone 10 as the cones are continuously rotated.

Figure 4 shows that the cones 10 and 16 (in transparency) can be geared one to the other and positively driven at the no slip via respective mounting shafts 26 and 28 carrying spiral bevel gears 30 and 32. The same is true of the flat surface 12 and cone 10. Figure 4 shows rotating flat annular surface 12, in transparency, with an associated ring gear 34 carried by webs 36. The ring gear 34 drives a plurality of sets of the exemplary cones 10 and 12 via spiral bevel pinion gears

38 mating with ring gear 34. The cones 10 and 16 are themselves geared to one another as described above. Gears 30, 32, 34 and 38, flat annular surface 12 and cones 10 and 16 all share the same apex A as a point of rotation. Cones 10 and 16 are fixed in space, so that they rotate about their respective axes A-10, and A-16. Thus, rotation of flat annular surface 12, as defined by disc 14 and the above mentioned gearing, imparts rotational motion to cones 10 and 16 only about axes A-10 and A-16. A plurality of sets of cones can be placed around the circumference of the flat surface 12 and be driven by the same ring gear 34.

Figures 3 and 4 demonstrate that several sets of the cones 10 and 16 when placed around the periphery of the flat surface 12 can be timed one with another to cause synchronization of the respective discrete locations 20, 24 and 22, hereinafter referred to as timing marks.

An apparatus according to the invention is illustrated in greater detail in Figures 5 and 6 and include a stationary base table 50, mounted on a machine base frame 52 that houses a continuous motion cam drive such as a model 362, manufactured by Ferguson Machine Co. (not illustrated). In a preferred embodiment, the table 50 may be divided into ten equally spaced divisions or stations D1-D10. Eight printing station assemblies 54 are rigidly mounted, one at each of eight of the stations D1-D8 around the periphery of the table 50. One cleaning roll assembly 56 is also mounted to the table 50 at station D9, and one cam driven, arc following, print transfer assembly 58 that indexes ware W into position for decorating is located at station D10. More or less divisions and arrangements are possible depending on the application.

(Hereinafter suffix reference numerals are dropped where position is not relevant).

A rotatably mounted turret table 60, driven by the continuous motion cam drive housed in the base of the frame 52 is adapted to rotate and carry 10 collectors C1-C10 (two shown). A ring gear 62 is carried by the turret 60 and functions as described above in reference to Figure 4.

Figure 7 is an illustration of a single printing station assembly 54. It includes a vertical mounting frame 73 attached to table 50, onto which is mounted one etch cone 72 sleeved over shaft 71; one transfer cone 74 carrying silicone transfer surface 75; and a gear box 76, which houses two spiral bevel gears 78 and 80 mounted respectively on shafts 71 and 81. Pinion gear 64 is carried outside of gear box 76 by shaft extension 81 of gear 80. The printing station assembly 54 also includes an ink application assembly 82 detailed in Figure 8 and described hereinafter.

Drive power for each print station assembly 54 comes from the rotating ring gear 62, which powers pinion 64 mounted commonly with angular bevel gear 80 and transfer cone 74. Shaft carrying etch cone 72 is preferably turned in an integral ratio with the transfer cone 74 via gear combination 78-80.

Ring gear 62, carried by turret 60, is driven about centreline C1 by a drive not shown. A working surface 163 of collector C, carried by turret 60, engages transfer surface 75 in intimate contact.

Etch cone 72 may be adjusted axially, in the direction of double headed arrow Ax, by means of a collar clamp 75 mounted in support arm 77 of frame 73. The etch cone 72 may also be adjusted circumferentially, in the direction of double headed arrow Cx, by locking screws 79 engaging shaft 71. The axial and circumferential position of transfer cone 74 may also be adjusted in a similar manner (not detailed). Thus, the axial and circumferential locations of the respective etch and transfer cones 72 and 74 may be adjusted for correct registration of design portions hereinafter described.

Figure 8 shows a detailed illustration of a preferred embodiment of the ink application assembly 82. A heated bath 90 holds a quantity of liquid ink 92. A pump 94, such as a Gerotor manufactured by W. H. Nichols Co., in flow communication with the bath 90, circulates ink 92 via a heated pipe 96 to outlet 98 at an inboard or small end 100 of etch cone 72. The ink 92 is urged along the length of the etch cone 72 (see arrows) to the outboard or large end 106 thereof by a free floating applicator blade assembly 104 including respective upper and lower blades 102 and 103. Because the angle of incline of the top of blade 102 is higher at the inboard end 100 of etch cone 72 than the outboard end 106, and because the rotating cone surface 72 moves the viscous fluid against the blade 102 causing a high pressure region within the ink 92 along the interface therebetween, the ink 92 travels along the interface between the applicator blade 102 and the etch cone 72 from the smaller to the larger end. Thereafter, the ink 92 follows the cone surface near the larger end 106 back to the ink bath 90, completing the circulation path. The circulation maintains a continuous supply of ink 92 to fill design depressions 108 in the etch cone surface. Respective upper and lower blades 102 and 103 also act as doctor blades to remove excess ink 92.

In the present invention it is preferred that the inks 92 be of a thermoplastic type. The inks should be maintained at a selected temperature at or near the melting point or a temperature at which they exhibit a suitable viscosity. Thus, etch cone 72, pipe 96 and bath 90 are heated by resistance heaters 110, 112 and 114, respectively, to maintain the ink at a suitable working viscosity.

Figure 8 also shows a free floating doctor blade assembly 116, which is similar in construction to the applicator blade assembly 104, and which ensures that all the ink 92 is scraped from the etch cone 72. It has been found that applicator blade assembly 104 is capable of both application and doctoring. Thus, doctor blade assembly 116 is usually held in a standby mode in the event of a failure of the former.

Figure 9 better illustrates the free floating or gimballed relationship between the doctor blade assembly 116 and the etch cone 72. Note that the same relation holds true for applicator blade assembly 104. Respective right and left blades 118 and 120, located in slots 119 and 121 of blade holder 122, are held at acute angles 1a and 2a to the surface of the etch cone 72. Each is made to contact the cone 72 along a respective line of contact or ray R1, R2 of the cone surface. Two blades 118, 120 are used for self alignment or seating purposes. Thus, the blade holder 122 needs only to be urged towards the cone 72 to cause both blades 118 and 120 to come into intimate contact with the cone 72. Only axial positioning (i.e. into the page of the drawing) is required for the holder 122 to ensure proper blade to cone contact.

Pneumatic piston 124 urges the doctor blade assembly 116 into position. Piston 124 engages holder 122 by means of a suitable bearing 125 located in hole 127 of blade assembly 116. Pneumatic piston 124 carries drive pin 124'. Ball bearing 125 may be secured to a distal end of pin 124'. Hole 127 having sidewalls and a flat bottom is formed in rear face 122 of blade assembly 116 and receives ball bearing 125 therein. The blade assembly 116 is free to gimbal in the direction of double headed arrow Gx as shown. When pneumatic piston 124 is actuated, ball bearing 125 driven by pin 124' moves against the flat bottom of hole 125 to drive the blade assembly 116 and blades 118 and 120 against cone 72. The blades 118 and 120 seat against the cone along respective rays R1 and R2.

Assembly 116 may be adjusted in the ray direction Rx and laterally thereof in the direction Lx by adjustment of the position of the piston 124 relative to the blade assembly 116. Adjustment may be made by adjustment screws and the like relative to table 50.

Figures 10A, 10B and 10C show other blade/cone configurations for both application and doctoring purposes.

In Figure 10A, as in all of the contemplated applicator/doctoring assemblies, the machine centre CL passes through the apex A of the etch cone 72. The apex for the blades 118a and 120a in assembly 116a, the holder 122a, as well as respective locating slots 119a-121a of holder 122a also coincide with apex A. While the angles 1a, and 2a of blades 118a and 120a may be different from those illustrated in Figure 9, the same resulting self alignment occurs. In Figure 10b, the doctor blade assembly 116b has blades 118b and 120b located in respective slots 119b, 121b of holder 122b, both leading to the right. In Figure 10c, the assembly 116c, blades 118c and 120c, and holder 112c are part of an integrally formed machined block.

The cleaning assembly 56 is shown in place at D9 on the machine base table 50 in Figure 6. It is simply a solid conical surface or cone 160 for example of steel or (for example of steel or aluminium) geared via pinion 162 with ring gear 62 to roll against the collectors C as they pass overhead. Any ink that has been left on the collectors C (resulting from an incomplete transfer to ware or missing ware at the transfer station D10), is transferred to the cone 160. A scraping blade assembly 164 floatably mounted in pressure block 165 (similar to applicator/doctor assembly in Figure 3) removes excess ink from the surface of the cone 162. The cleaning assembly 56 ensures clean collectors C before reprinting in each cycle.

A feature of the present invention, shown schematically in Figure 6, that is useful in establishing accurate set up of the printing apparatus, is the use of levelling plates 166, onto which are mounted the collectors C, the printing station assemblies 54, and the cleaning assembly 56. These levelling plates 166 are individual mounting pads which are adjusted to an accurate mounting position during set up with locking adjustment screws 168. They can then be used as precision mounts for supporting the print station assemblies 54 including corresponding etch cones 72 and transfer cones 74. They also can be used for positioning the collectors C.

In conventional decorating devices ware must be printed to check registration of the design colours. In the present invention an inspection of the collectors C will allow the operator to check registration prior to printing ware. Fine adjustments to registration can be easily accomplished by the adjusting screws 79 and collar clamp 75 hereinbefore described. Since the cleaning station assembly 56 removes all ink upon each complete rotation of turret 60 registration can be quickly rechecked and adjusted prior to actual production.

Referring now to Figures 5-8 the following is a brief description of the operation of the apparatus of the present invention shown therein. As turret 60 rotates, it synchronously drives each pair of etch cones 72 and transfer cones 74. Each etch cone 72 receives a supply of ink as hereinbefore described. Design impressions 108, etched or engraved in the surface of etch cone 72, receive the ink after application/doctoring, and an ink formed design 109 is available for offset to elastomeric silicone surface 75 carried by transfer cone 74. Silicone surface 75 and etch cone 72 roll in intimate contact against each other. The ink 92 in the impressions 108 is transferred as a semi-solid cohesive mass from the former to the latter (see reference numeral 109). The collectors C1-C10 each encounter successive printing station 54 locations D8 to D1 (counterclockwise in Figures 5 and 6) as the turret 60 rotates, and their working surfaces 163 receive thereon a design portion 109 of composite design 109' from each successive printing station in registration with the others. At print transfer station D10 the composite design 109', formed by each successive transfer of design portions 109 from each transfer cone 74, may be transferred to ware W. The ink is transferable because each successive surface encountering the ink has a higher affinity for it than the previous one.

It should be understood that silicone surface 75 is compressible. Accordingly, the silicone surface 75 is distorted or compressed along its line of contact with etch cone 72 when it comes into contact therewith. When compressed or distorted, silicone surface 75 and etch cone 72 share a common apex. The distortion is necessary in order to ensure that the ink is forced against the silicone surface 75.

In one embodiment of the present invention, shown in

Figure 11, the rotating turret 60 holds ten collectors C1-C10 in the form of equally spaced flat surface silicone arc sections.Design portions 109 of a multicoloured decoration or design 109' are printed from each silicone surface 75 of the transfer cones 74 in the respective printing stations 54 at D1-D8. The radius of curvature Rc of each collector C (sometimes hereinafter the word "radius" and "curvature" are used interchangable for simplicity) is normally determined, in one embodiment, by the geometry of the ware W to be decorated (i.e. a portion of its developed surface hereinafter described). Normally the curvature Rc of the collectors C will not coincide with the radius of curvature Rt of the turret table 60. However, if apex A' of the ware W can be orientated to simultaneously coincide with the centre Cc of the collectors C, then a nonslip rolling action between a cone and the silicone surface of the collectors C can be established.

Figures 12A-12C show how ware W must be positioned as the turret 60 revolves and the collectors C pass over the ware W at print transfer station D10. Such positioning requires rotational and translational manipulation. The ware W to be decorated is orientated so that it rolls against the arcuately shaped collectors C without slipping. The ware W must be positioned or orientated so that its apex A' is shared by the centre Cc of the collectors C at all times of contact, so that a non-stretching non-skidding rolling contact can result.

It should be noted that this requirement for changing ware position results because the radius of curvature Rc of each collector C is different for each style of ware and different from the radius of curvature Rt of turret 60. The latter is specified by the radial location of the collector C on the machine turret 60. The radius of curvature Rc of each collector C, centred at Cc, is dictated by developed surface S of the conical ware W to be decorated (see Figure 13A). The length L of the arc section, defining collector, C is dictated by the circumference of the ware W to be decorated along the line or path of application P, substantially centrally of collector C.

In Figure 12B, the ware W is angularly orientated so that its apex A' is shifted to follow the centre Cc of the collector C by the angular difference B° between the radius Rc of the collector C and the radius Rt of turret 60. The axis AW of the ware W is orientated so that ware apex A' is coincident with the centre Cc of collector C. In the example herein shown, the collector C is mounted so that its midpoint m coincides with turret radius Rt, but, since the curvature Rc of the collector C does not coincide with the curvature Rt of the turret 60, the respective leading and trailing edges l and t of the collector C are inboard (to the left in Fig. 12A) of mid point m by x units from the full extent of the turret radius Rt. Further, since collector radius Rc has a centre or origin Cc different from turret centre C, the ware W located at turret radius Rt must be rotated about its point of contact Pc with collector C. The difference in this angular position is illustrated in Fig. 12B & C, where Rc respectively leads and lags Rt by B°. Thus, ware W must be rotated at its point of contact Pc about contact axis Ap by 2B°.

In Figure 15B, ware W is shown in contact with collector C along a line of contact or ray RW shared therebetween. Contact axis AP is normal to ray RW at contact point PC. It is given that ware ray RW, measured from contact point PC, should be in radial alignment with turret radius Rt at midpoint m of collector C. Any angular or lateral shift therefrom is measured relative thereto. It is therefore required that: (1) the ware W be moved to an initial position, upon engagement with leading edge 1 of collector C, whereby its contact point PC is shifted x units inboard of its position at midpoint m and (2) the ware ray RW is rotated B° about contact axis AP counterclockwise (CCW) of turret radius Rt. (For purposes of the discussion, ware axis AW and ware ray RW lie in the same plane, and rotation of the ware W about contact point PC occurs about contact axis AP also in such plane).

Referring to Figs. 12A-12C, as the leading edge 1 of collector C first meets the ware W in Fig. 12B, the ware W is translated by x units and rotated counterclockwise by B°. At the midway position m, shown in Figure 12A, the contact point PC is at midpoint m of collector C, lateral translation is zero units and ware axis AW is at zero degrees rotation about contact axis AP. Finally, as the collector C advances further, the ware W is translated and rotated so that axis AP is positioned x units inboard (to the left in Figure 12C) and ware axis AW is rotated B° clockwise (CW) at the trailing edge t of the collector C. Thus, the ware experiences compound movement from each encounter with a collector C.

Figure 14, at positions (A) through (C) and Figs. 15A-15B demonstrate how a cam 140 is used to continuously position the ware W to align its apex A' with the collector apex A". The generated motion of the ware W, carried in chuck 150 is a combination of two motions at the point of contact PC, namely (1) a pivoting action of the ware about contact axis AP (perpendicular to the upper sidewall of the ware W); and (2) translation thereof along the radius of curvature Rt of turret 60, sometimes hereinafter referred to as radial line Rt.

The arc following arrangement is accomplished as follows. Cam 140, driven synchronously with turret 60 via drive 52 (Fig. 5) and shaft 141 (Fig. 15A), has an outside profile 142 and an inside slotted profile 144. Let the radius of the cam 140 at the position shown in Fig. 14(A) be Ro- x and at Figure 14 (B) be Ro. Similarly, for a symmetrical object, at Figure 14 (C) the radius of cam 140 is Ro- x. Outside cam follower 146 is mounted in a laterally moveable yoke or frame 148, in print transfer assembly 58, and follows outside profile 142. Frame 148 is slidably mounted to table 50 by means of slide 149 and is restricted to linear motion thereby. The chuck 150 is carried in yoke 197, which is rotatably secured to frame 148 via rotatable bearing 175. The yoke 197 is moved radially with the frame 148 along turret radial line Rt by means of the frame mounted cam follower 146. As cam 140 rotates clockwise, (see the progression in Figures 14A-14C) the ware W is translated along Rt by x units. It should be noted from Figure 12 (A) that, as the collector C advances, its radius Rc is colinear with the radius Rt of turret 60 when the mid-point m of collector C lies along radial line Rt. Thus, the cam 140 adjusts the position of the print transfer assembly 58 so that the radial position of the ware W is displaced x units at the respective leading and trailing edges l and t of collector C, and zero at the midpoint m.

In order to correct for axis rotation, cam follower 152, carried by an arm 154, is operatively coupled to ware-carrying chuck 150 via the rotatable bearing 175 and supporting yoke 197. The chuck 150 is adapted to be orientated so that contact axis Ap of the ware

W at the point of contact PC with the collector C is normal thereto. It is important that the bearing 175 is located in a position vertically beneath AP. Thus, the ware W may be rotated about its contact axis Ap with collector C. In the position (A) shown in Figure 14, arm 154 is B° advanced (ie CCW), at Figure 14 (B) it is 0° advanced or in line with turret radial line Rt, and at Figure 14 (C) it is -B° advanced or B° degress retarded (i.e. CW). The combined motion provided by cam 140, maintains the ware ray RW aligned with the collector C to simulate two surfaces in non-slip-apex aligned-rolling-motion as described above.

The above system is workable for many ware shapes but requires a cam change for each ware profile. Further, for some shapes it would not be advisable to extend the principle beyond certain practical limits. For example, reference is directed to Figure 13B wherein there are shown two articles to be decorated, namely a cup WC and a bowl Wb. The cup, similar to the one illustrated in Figure 13A, has a moderately steep side wall angle αc and a large end diameter Dc. Axial length Xc is determined by the former two parameters. Surface wrap angle θc is a function of the axial length Xc and diameter Dc. In the case of a cup, the wrap θc angle is relatively small as shown. A collector Cc for the cup is fabricated to conform to the developed surface Sc thereof (see also Figure 13A), and the cup may be orientated as described above to produce apex coincidence with the collector Cc. The rotational and translational motion required is not severe. In the case of a bowl Wb, shown in Figure 13B, the wrap angle θb is large and the developed surface sb is consequently large. However, as a practial matter, a collector Cb for the bowl Wb could only be useful over some lesser wrap angle, e.g. $\theta b'$. Thus, there is a significant difference in coverage.

In the case of the cup Wc, all or part of the circumference over the developed surface thereof may be contacted (see cross hatched area), whereas in the case of a bowl Wb, the circumferential coverage in one pass would be limited to the modified wrap angle θb' (hatched area) over the developed surface SB. Further, while with a cam change it is possible to print a diversity of articles, it may be preferable in certain instances to utilize a simplified embodiment described hereinafter. Before such alternative method is discussed however, an indexing feature of chuck 150 will be described by reference to Figs. 5, 14 15A and 15B.

The purpose of the chuck 150 is to receive ware W and secure it at the correct angle for engagement with a collector C. In order to accomplish this, a plurality of indexable paddles 170 are secured to a rotatable block member 172. The latter is rotatably journalled in opposed openings 174 in opposed upstanding support members 173 of yoke 197. The block 172 carries ware mating chuck pads 176 and depressable spring loaded vacum pin 178.

In Figures 5 and 15b it can be seen that the ware W is indexed onto pad 176 when it is orientated horizontally (Q1) in Figure 15B). Axial spring 180, retained between flange 179 at distal end of pin 178 and bushing 182 mounted in paddle 170, is depressed by engagement of the pin 178 with the inside of the ware W as it mates with pad 176. The pin 178, sleeved through opening 182' in bushing 182, is coupled to a vacuum line 181 in paddle 170. The pin 178 has a notched portion 178' and foot valve 183 located at a proximal end thereof. The foot valve 183 is sleeved in chamber 181' communicating the inside of the ware W with vacuum line 180. As the ware W seats against mating pad 176, pin 178 moves foot valve 183 inwardly of chamber 181' opening vacuum line 181 to inside the ware W via notched portion 178' and thereby holding the ware W firmly into position.

Vacuum is maintained in three quadrants Q1-Q3 of the rotation of block 172 and is cut off at Q4 as follows (see arrows V). Sector shaft 185, located concentrically in opening 187 of block 172, carries seal edge 189. Vacuum line 194 has access to a space 191 between sector shaft 185 and the opening 187. The space 191 is normally under vacuum or reduced air pressure and communicates with the interior of the ware W over vacuum line 181 via ports 193. As the ware is loaded at Q1, the pin 179 and spring 180 are depressed opening foot valve 183. The ware W, secured by vacuum, is carried from Q1 to Q2 for decoration by engagement with collector C. Thereafter, it is moved to the idle position Q3 while still under vacuum, and thence to Q4, where seal edge 189 blocks port 193 to vacuum line 194. An air line 195 supplies air to port 193 in the Q4 position to supply air into vacuum line 181 thereby to blow the ware W off paddle 170 via the vacuum path described above. As the ware W moves sufficiently from pad 176, foot valve 183 closes and blocks the opening 182' in bushing 182. Vacuum is restored when the paddle 170 advances from Q4 toward Q1, seal edge 189 passing port 193 and foot valve 183 opening by loading new ware. A missed loading will therefore allow maintained vacuum integrity, since foot valve 183 will be maintained closed by spring 180 holding shaft 178 to the left. Sector shaft 185 can be rotated during set-up and for timing, but is then locked into stationary position.

The rotatable block 172 carrying the paddles 170 is driven by a barrel cam actuated drive 186, such as a 8/2 FH 62-120 roller gear drive manufactured by Ferguson Machine Co., through one of two journalled ends 174 of the rotatable block 172 (see Fig. 5). The drive 186 is actuated synchronously with the turret 60 via drive shaft 188 which includes slidable spline coupling 200, a pair of universal joints 201 one each at opposite ends of coupling 200 as shown, and opposed shaft extensions 199 coupled to each universal 201. One shaft extension 199 is coupled to drive 186 via a chain or pulley 205. The opposite shaft extension 199 is secured in bearing 195. Pulley 190 is mounted to free end of shaft extension 199. Another pulley 192 is coaxially driven with a bearing mounted pinion 194 engaging the ring gear 62. The pinion 194 and pulley 192 are appropiately secured by block 196, which is, in turn, secured to the base table 50 by frame member 198. Belt 197 couples pulleys 190 and 192.

For ten stations D1-D10 the ratio of the pinion 194 to the ring gear 62 is chosen such that each 1/10 rotation of the turret 60 causes shaft 188 to rotate one turn. Shaft 188 is splined at coupling 200 to move axially as frame 148 moves radially x units as described above. Also, universal joints 201 allow the shaft 188 to rotate while the frame is advanced and retarded over the 2B degree swing. As shaft 188 rotates once, it actuates drive 186 so that the barrel cam (not shown) therein causes the block 172 and paddles 170 carrying ware W to rotate intermittently 90°, or 1/4 turn, into quadrant Q2 just prior to the time that a collector C enters the print transfer station at D10. Note that the orientation of the paddles 170 at position Q2 is illustrated in Fig. 15B, and shows that ware W is ali-ned with collector C so that axis Ap, normal to the ware surface, is perpendicular to collector C. As the collector C comes into engagement with the ware W, friction causes the ware W to rotate in non-slipping relation with the collector C. The ware W then is indexed out of quadrant Q2 by a 1/4 rotation of block 172 to face downwardly in quadrant Q3 on the inboard side of print transfer device 58 as shown in Figure 5. Finally on the next indexing step, the ware W is moved nearly horizontal into the lowermost quadrant Q4 for ejection and removal by conveyor means (not shown). As explained above, at this portion of the cycle, vacuum is cut off by valve action within block 172 thereby releasing the ware W while the spring 180 and positive air pressure from air line 195 urge the ware away from plate 176 and onto conveyor means (not shown). On the next loading at quadrant Q1, the vacuum is reset.

In another embodiment of the present invention, preferable for printing large ware, it is proposed that the cam-following print transfer device 58 be held fixed in the position shown in Figure 14 (B) with all axes aligned. In order to accomplish this, the print collector C would be modified so that its radius of curvature Rc is aligned with and corresponds to that (Rt) of the turret table 60. The ware W would then be orientated by chuck 150 at a fixed position, e.g. aligned with the radius Rt of the turret 60. In Figure 13C, there is shown a reformed collector CS having a modified developed surface S'. The reformed collector CS has a radius of curvature RCS equal to the turret radius Rt and having the same centre C. A piece of conical ware or cup WC, such as in Figure 13B, has respective large and small end diameters DC and dc. The large diamter DC defines a circle having a perimeter π(DC), and likewise, the small diameter dc defines a circle having a circumference π(dc). In Figure 13C it is given that outboard margin Mo of modified developed surface S' has an arc length from respective leading to trailing edges l and t equal to the large circumference π(DC) of cup WC. The inboard margin Mi has a length which is different i.e. greater than the circumference π(dc) of the small end of cup WC. If it is also given that cup WC rolls without slipping then all points on cup WC move across modified surface S' without slipping. The large end of the cup WC will trace an arc in correspondence with the outboard margin Mo modified surface S'. However, the small end of cup WC will not trace an arc in correspondence with the inboard end Mo of surface S' because line Mi is longer than the circumference π dc of the small end of cup WC. If no slipping occurs between cup WC and reformed collector CS, along a line of contact Lc therebetween, then the collector CS must become progressively distorted. This is symbolized by the progressive angular shift of the dotted line B representing the distortion or bulge across collector CS. Note that as the deformed collector CS moves from right to left bulge B appears to rotate to the left. Also, line of contact LC remains fixed in alignement with turret centre C.

In Figure 16 the above is best illustrated in side section near the small end of the cup WC. The cup WC has stretched or pushed the collector CS away from itself as bulge B in the surface of the collector CS. The deformed collector CS carried by support 210 includes elastomer pad 212 having working surface 216 corresponding to the modified developed surface S'. The cup WC engages collector CS at 213. As the collector CS moves to the right, the small end of the cup WC forces or stretches the elastomer to the right.

This occurs because the length of arc traversed by the small end of the cup WC is less than the arc length of the inboard margin Mi of the collector CS. Since the ware WC does not slip, the elastomer pad 212 gives such that it may be forced out of the path of cup WC forming the bulge B.

The decoration (not shown) on the underside or working surface 216 of the pad 212 is correspondingly distorted or stretched by the forced fitting action. However, for certain types of decorations (e.g. florals) this is immaterial since it is not critical in appearance. On the other hand, in very symmetrical designs with exacting geometric shapes, the distortion caused by this stretch printing effect can be corrected by appropriate modification of the designs installed on the etch cones 72. This might be accomplished by iteration of design manufacture or by some computer assisted graphics technique to compensate therefor.

In another embodiment of the present invention, illustrated in Figures 17A and 17B, flatware W is substituted for the collectors C. In this arrangement the ware W itself is held against the rotating turret table 60 by reduced pressure operating through vacuum line 120 and hole 122 therein. The transfer cone 74 has an elastomer pad 220 thereon for carrying the design 221. The pad 220 is cut away to clear rim portions 224 of the ware so that it engages only the central portion 222 thereof.

In yet another embodiment of the present invention means are provided for printing the entire inside surface portion of the ware W. In Figure 18 for example, full print, flatware and hollow ware membrane collectors 230 may be adapted for providing a full print of the inside surface 231 of a piece of hollow ware W shown. The membrane collectors 230 include a frame member 232 of a rigid material having an opening 233 into which is disposed an elastic membrane elastomer 234 having a working surface 235. In this arrangement the membrane collectors 230 are periodically indexed into the turret 60 and carried by supports 231 at stations beginning with D8. Indexing of the membrane collectors 230 may be accomplished manually or by mechanical means not shown. As each membrane collector 230 is rotated about in a direction shown by the arrows it encounters the various print stations 54 (see Fig. 5), contacts the transfer rolls 74 and receives on its working surface 235 the full extent of the various colours of the design 236. Each membrane collector 230 is then indexed from the turret 60 and aligned for engagement with a piece of ware W as illustrated. The ware W is placed below the membrane collector 230 and a piston or plunger 238 having a deformable shaped face 240 engages with the elastomer 234. The shaped face 240 distorts the elastomer 234 so as to intimately conform with the entire surface of the inner portion 237 of the ware W. Thereafter the piston 238 is withdrawn and the ware W has the design 236 transferred thereto on all portions of the inside surface 237. Thus, full coverage of hollow ware can be accomplished using the flexible membrane collector technique.

Figures 19A and 19B show in cross section the detail of the arrangement illustrated in Figure 18 wherein the ware W may be a glass or glass-ceramic article. The membrane collector 230 is placed above the ware W. The elastomer 234 is distorted by the shaped face 240 which is urged there against. The material forming elastomer 234 is preferably a silicone compound such as Dow Corning "L" type, room temperature vulcanizing Silastic (DC-L-RV). The design 236 on the underside or working surface 235 of elastomer 234 transfers onto the ware W by intimate contact. The profile of the shaped face 240 allows the elastomer to distort centre first, urging the elastomer 234 in contact with the centre 237 of the ware so that there is no trapped air during the printing operation. Shaped face 240 and elastomer 234 both together distort to conform to and reach rim 233. Thus the print proceeds from the centre 237 to the rim 233. Adjustable stops 239 establish spacing between shaped face 240 and frame 232. Support 21 and springs 260 resiliently carry collector 230, whereby the collector floats relative to the ware W.

In Figure 20 details of a backing device 340 for membrane collector 230 are illustrated. The turret 60 carries the backing device 340. A transfer cone 332 (in phantom) carries a portion 236' of the design 236 for printing to the design carrying side 234D of membrane 234. The backing device 340 includes a reciprocally movable plunger 342 carried by an apertured centering pin 344, sleeved within opening 346 of a back wall 350 of the backing device 340. The pin 344 is sleeved through an opening 348 in turret 60.

Depending sidewalls 352 appropriately secured to back wall 350, form a cylinder or cavity 372 in which plunger 342 is free to reciprocate between the extended downward position shown in solid lines and the upward retracted position shown in fragmented phantom. Sidewalls 352 include inwardly extending ears 362 and are adapted to engage and overlap outwardly extending lower ears 364 of slot 368 formed in a peripheral margin of plunger 342, thereby to limit or form a stop for plunger 342.. The circumferential slot 368 in plunger 342 receives "0" ring 366 to form an air seal between plunger 342 and sidewall 352 for cylinder 372. Backing device 340 is secured to turret 60 by means of tie bolts 354 threaded at one end in opening 355 of back wall 350 passing through opening 357 in turret 60 with nut (s) 359 holding the tie bolt (s) 354 from above. Centering pins 356 and 358 respectively located in a slot 356' and sleeved opening 358' in turret 60 accurately establish the position of backing member 340. In the position shown, plunger 342 is downwardly extended and engaged with membrane collector 230 by action of positive pressure over line 370.

The plunger 342 has a recess 378 and counterbore 382 therein, the former for receiving a porous ceramic plate 380 such as a ceramic material sold under the tradename TEGRAGLAS sold by 3M Co., grade 55 (55 micron pore size) or a plastic tradenamed POREX sold by Glasrock Prod. Inc,. Porous metals may be used if the pore size is relatively small. The materials noted above have or should have interconnected pores so that if some pores become blocked negative pressure may be maintained.

Compressible but fairly rigid materials such as felt, cloth or foam rubber may also be used in lieu of or in combination with the small porous plate 380. Such alternative materials may also be used as a skin S (see Figure 20A) over the porous plate 380, which would allow for a larger pore size. Such a skin S would add resilience to the support of membrane 234 and correct errors in contact pressure between transfer cone 332 and said membrane 234. This is especially useful if the membrane 234 is a relatively thin sheet of flexible material. In a preferred embodiment the membrane 234 has a thickness t of about 0.060 mm. Other thicknesses are useful for other applications.

Counterbore 382 allows communication of one end 384 of apertured pin 344 to communicate with the entire back surface 386 of plate 380. Apertured pin 344 is coupled to a source of reduced air pressure (not shown) over air line 389 therein. Thus a vacuum may be drawn against front face 390 of plate 380.

Collector 230 is secured laterally in slots 393 of slide blocks 392(reference numeral 11 in Figure 1) carried by back wall 352. In a preferred embodiment the TEGRAGLAS material (55 micron pore size) works well without leaving surface irregularities on the design side of the membrane surface. Lateral side margins 394 of plunger 342 engage opening 316 in the membrane frame member 232 to lock the collector 230 in position between blocks 392 and plunger 342. Alignment surfaces 400 of the latter prevent jamming as plunger 342 extends into opening 316 by application of air over line 370 with the collector 230 located as illustrated. The membrane 234 may be drawn against plunger 342 by reduced air pressure through plate 380. Thus the membrane is flat and may be printed by roll 332 without distortion.

Once the membrane 234 receives the design portion 236 on surface 234D, vacuum drawn over line 389 may be released to free membrane 234. Thereafter the piston 342 may be withdrawn to an upward position via reduced air pressure over line 370 (see fragmented phantom). In this position plunger 342 is withdrawn from opening 316 in frame 232 so that alignment surfaces 400 of plunger 342 clear upper edge 402 of frame 232. The membrane collector 230 may then be withdrawn from slide blocks 392 (out of page). Thereafter, another membrane collector may be inserted therein. Pressure may be applied over line 370 to drive plunger 342 down, locating the frame 232, while vacuum is drawn in line 389 to flush the membrane 234. Counter recess 396 in plunger 342 provides a clearance with inside face 397 of back wall 350 and ensures that applied air over line 370 is evenly distributed over the back side of plunger 342.

Reference is now directed back to Figures 19A and 19B and also to Figure 21. As explained previously the design 236 on the design side 234D of elastomer 234 transfers onto the ware W by intimate contact. The present invention makes it possible to print odd shaped ware contemplated herein, provided the face 240 of the printing plunger 238 is appropriately shaped. When the face 240 engages elastomer 234, the latter is stretched or deformed to conform therewith. Together the stretched elastomer 234 and face 240 engage the ware W, centre first, so that there is no trapped air during the printing operation. Shaped face 240 also distorts to conform to and reach rim 233. Thus, the print proceeds in a rolling-like motion from the centre 237 to the rim 233 of the ware W. Rolling-like contact may be characterized as instantaneous rolling motion at each instantaneous point of contact of the membrane 234 and ware W. Preferably, the face 240 has a configuration which, when it engages with the membrane 234 and thereafter the ware W, establishes a contact angle of about 15° with the ware W. The shape of face 240 is determined as hereinafter described.

Figure 21 illustrates a special case. A vacuum line 430 coupled to a source of reduced air pressure (not shown) is located in the plunger 422 and extends through face 424 to an opening (s) 433 in convolutions 434 thereof. If the shape of face 424 requires internal convolutions 434 by virtue of the shape to be printed (e.g., see profile of a typical saucer 436) means is required to cause membrane 234 to conform accurately to the head shape, In the example illustrated in Figure 21, the membrane 236 may be drawn into the convolutions 434 by means of reduced air pressure. Thus, the design may be accurately transferred to the ware W.

To derive the proper shape for the head 424 a number of useful methods are available. One, for example illustrated in Figure 22A, relies on an empirical, trial and error graphical approach which begins with an analysis of the shape of the ware W. Choosing a number of radial spaced points 1-n along the surface of the ware to be printed extending from the centre 237 to rim 233, determine tangents T_1-T_n at each respective point 1-n (i.e. tangents are perpendicular to corresponding normals N1-Nn). Rotate the tangents by a selected number of degrees to positions T_1'-T_n', thereafter reconctruct a surface S' formed of a series of said rotated tangents T_1'-T_n'. A reasonably good first approximation of a required head shape (less membrane thickness) can be derived from a simple surface. Unfortunately, the method may require a number of iterations and manual reshaping of the head derived thereby to be satisfactory. The requirement for multiple iterations even for a simple shape is time consuming and costly.

A preferred method of derivation results from a mathematical approach using finite element analysis. See for example <u>Finite Element Analyses: Fundamentals</u>, Richard H. Gallagher, Prentice Hall Inc., 1975 and <u>The Finite Element Method</u>, 3rd Ed., O.C.

Zienkiewicz, McGraw Hill Book Company (U.K.) Limited, 1977. The principles outlined in the above works provides a methodology for the use of finite element analysis as a technique in the solution of many engineering problems. Because the mathematics of finite element analysis is matrix orientated and complex, the technique is particularly adapted for use with a digital computer compatible with commercially available special purpose programs. For example a program known as ANSYS is specifically useful with the technique. By dividing the given head 424 into a group of connected figures or elements and defining boundary conditions for the element geometry, solutions may be derived by use of progressive computer runs to derive various shapes.

In the preferred process of finite element analysis as used herein and illustrated in Figures 22B and 22C, a two dimensional model of the object (piston 238 and face 240) is broken down into a selected number of connected rectangular elements E by a series of intersecting respective horizontal and vertical grid lines G_X+G_Y in an XY coordinate system. Intersections of the grid lines G_X-G_Y are called n nodes (see dots). In the X-Y coordinate system each node n has initial coordinates e.g. Xm, Ym. As the object is stressed or deformed by a given amount, boundary conditions may change and each node may move. The computer solves the general equations of stress, etc. during a run to determine new coordinates Xm' Ym' (see Figure 22C) resulting from the given stress, and the latter form a bank of data establishing initial conditions for the next computer run. By successive runs a shape for plunger is derived. If it is not workable, the equations of stress may be modified and initial conditions changed to derive a new shape. Also the head 424 may be manually reformed. The method of finite element analysis greatly accelerates the process to solution.

In attempting to determine various heads for use with various corresponding ware shape it was found extremely useful to approach the problem in an unconventional way. The conventional solution in finite element analysis is to take an arbitrary shape and determine the resulting shape as it is deformed. In the present situation, the shape into which the face 240 must be deformed (i.e. ware shape) is defined, therefore the final deformed shape of the face 240 is known. Thus, the analysis begins with a deformed head shape as seen in Figure 22B and is iterated back to an initial or desired starting head shape by successive release of the face 240 away from ware W (see Figure 22C). By applying negative stress, (i.e. moving the stressed or deformed face 240 away from ware W) and solving the stress equations in reverse a head shape evolves more quickly.

Another feature of the method is to constrain the stress release of face 240 by limiting the motion of each run to some small amount (e.g. 0.25mm per iteration). Further it is a constraint that certain nodes n along the portion of the face 240 in contact with ware W and certain ones in contact with a piston 238 are not free to move. For an example in the latter case, see Figure 22B wherein nodes in line Y-7 are colinear with the side of piston 238 and are not free to move except in the Y direction. Thus each successive position thereof is given by the amount of upward motion of the piston 238 given for each iteration. In Figure 22C the nodes along line

Y-7 always have known positions determined by the change in the position of the piston 238, that is Y +ΔY. For the former case, while all nodes n along the interface of the ware surface SW and head surface Sh may theoretically move, i.e. points Xn, Xn-1, Xn-2. etc., certain points are fixed for the calculation. In the preferred arrangement nodes along surface Sh of head in contact with ware are not free to move except those nodes within three nodes of extreme radial contact with ware. Thus, in Figure 22B this includes Xn to Xn-3. In the next iteration, if Xn' is still in contact with ware i.e. Xn=Xn', the same constraint applies. If, however, Xn $\neq$ Xn' the Xn-1' becomes the first node out of contact with ware thereby freeing Xn-4' and so on as the face 240 is successively withdrawn.

Finally, and very importantly, the angle of contact θc of the face 240 and ware W at a point where the face 240 separates therefrom (e.g. Xn') is constrained to a range of about 5° to 50°. The larger the angle of contact angle θc the lesser coverage may be accomplished. It has been found that a contact angle θc of about 15° is optimal since full coverage may be attained and ware warpage variations are accomodated.

Initially all node points are given coordinates Xm, Ym relative to the respective grid lines Gx, Gy forming the element. After iteration, there results a series of numbers representing new positions for the nodes Xm', Ym'. The resulting shape of the face 240 may be analyzed at the contact point and the contact angle θc calculated. If the resulting contact angle θc at Xn' is different (±) from the required or optimized angle, i.e. 15° the resulting contact angle θc may be compared with 15° in the form of a ratio:

$$15°/\theta = \pm g$$

The number g may then be used as a multiplier for each coordinate X', Y' in the network of newly calculated nodes in Figure 22C, to move its corresponding position linearly (+) or (-) by the amount represented by g. Thus, the data base after the so-called first run is updated or modified by g to yield a set of further modified coordinates X", Y" where g. (Xm', Ym') = (X",Ym"). Thereafter the computer program may be re-run with the modified corrected first run data base, i.e., X", Y". This modification of data is done for each run of ΔY.

The resulting shape of face 240 is defined by the final calculated modified data base after the head is fully withdrawn from the ware W. Doubtless certain changes may be required in the final shape of face 240,but the above described process substantially reduces trial and error. It should be appreciated that the above described methods are not the only ones available but are believed to be the most appropriate and preferred methods for deriving a head shape. Also, membrane thickness T is subtracted from the head shape.

It can be appreciated that in addition to full coverage of ware W, the membrane 234 may be stretched by face 240 such that the decoration is enlarged from its initial size on the unstretched membrane 234. Thus, there is provided a versatile device which may be useful in printing various sized articles of ware without significant changes in apparatus set up.

Since it is a feature of the present invention to print to a flat surface (e.g. collector, flatware, membrane collector, etc.) other embodiments are set forth below for the purpose of disclosing variations in the above concept.

In Figure 23A the ware W is carried by turret

60 and printed as it progresses through the various print stations (i.e. the ware E acts as a collector). Ware W is held in turret 60 by vacuum as set forth and described earlier herein with respect to Figures 17A-17B.

In Figure 23B a second turret 160 carries ware W from an inlet end 161 by means of a similar vacuum arrangement. The turret 60 carries collector C which may be flat, circular elastomer pads. After each collector C receives a full design 162, it engages a takeoff cone 164 which picks up design 162 and transfers it to ware W at the print station D10. The takeoff cone 164 may be similar to the one shown in Figure 17A except that it removes the design 162 from the collector C and transfers it to the ware W. In Figure 17A the transfer cone 74 receives a portion of the design from an etch cone to print a portion of the design onto the ware W acting as a collector. In the embodiment shown in Figure 23B the takeoff cone 164 receives the entire design from collector C for complete transfer to ware. Turret 160 acts as an automatic ware in/ware our carrier. The printed ware W is ejected from turret 160 at outlet 165.

In Figure 23E a side view of the arrangement of Figure 20 B is shown. Notice that turret 60 and second turret 160 are offset by the angle of takeoff cone 164. Also, during the interval when the takeoff cone 164 engages ware W the latter must follow arc Ac or path that coincides with the motion of takeoff cone 164 in the plane of second turret 160. The ware W may be mounted or secured in second turret 164 by means of a slideable chuck 167 which allows the ware to move in the direction of double headed arrow AW in order to follow arc Ac in the plane of turret 160 as the takeoff cone deposits its design onto the ware.

In Figure 23C a variation of the ware in/ware out arrangement of Figure 23B is illustrated. In this embodiment turret 60 carries a plurality of pivotally mounted membrane fixtures 170. Each carries a pair of respective inboard and outboard membrane collectors 172-I-172-O. Ware W may be carried about a path illustrated by the arrows by a conveyor (not shown) starting at inlet end 174 of turret 60. The outboard membrane collector 172-O, carries design 173 and means (not shown) but similar to the arrangement of Figures 19A-19B causes the outboard collector 172-O to be intimately contacted with ware for transferring the design 173 as the outboard collector 172-O and ware travel together with turret 60. After printing, the ware W is removed from engagement with outboard collector 172-O at outlet end 175 of turret 60. Thereafter the membrane fixture 170 pivots about support bearing 176 prior to entering inlet end 174. The now blank outboard collector 172-O thus becomes the inboard collector 172-I which may be printed and the inboard collector 172-I carrying design 173 moves to the outboard position. The former receives the design 173 from print stations as described earlier while the outboard collector 172-O simultaneously prints the ware.

Other variations are possible and within the scope of printing to any suitable flat surface and the like. For example, in yet another embodiment of the present invention, shown in Figure 23D, collectors C, carried by turret 60, print decoration or decal D to a decal medium 182 supported against collector C by cylindrical backing roll 180. Respective cylindrical wind and unwind rolls 186-188 serve known functions. The backing roll 180, and respective wind and unwind rolls 186 and 188 may be mounted on a common support 184 shown schematically. The common support may be articulated in the circumferential and radial direction of the turret as set forth hereinbefore relative to Figures 11-15b, to compensate for differences berween the respective geometries of the decal medium or web 182. the turret 60 and collector C. Also, forced or stretched printing as set forth in connection with the description of Figures 13 C and 16 may be accomplished.

It should be understood that in the above embodiment of Figure 23D, backing roll 180 should have a high coefficient of friction surface f for engagement with the medium 182. The surface f may be formed of relatively hard rubber. The backing roll 180 is cross hatched to show this feature. Alternatively, the roll 180 could be metal having a sleeved rubber cover or a suitable adhesive.

In either of the embodiments set forth above, it is important to maintain a nonslip relation between the backing roll 180 and the medium 182 and the collector C so that the medium does not move either radially or circumferentially relative to the backing roll collector. This ensures that the medium acts as a rigid surface fixed instantaneously with respect to the backing roll 180 and the collector C. Thus, distortion of the design D and mis-registration thereof is avoided.

Other arrangements of the apparatus of the present invention are possible. For example, multiple transfer stations may be provided at selected circumferential locations and, depending on the ware to be printed, one of the transfer locations may be utilized while others are left idle. This can more readily be appreciated if it is assumed that multicolour printing may be accomplished in about four of the print stations leaving table space for extra transfer stations.

The apparatus of the present invention is useful in lithographic, planographic, typographic or gravure printing processes. Thermoplastic inks are preferred but solid or aqueous based and organic inks that do not need to be fired can also be used. Printing can be made directly to ware or to decal paper but the preferred embodiment is to print to a silicone collector surface which subsequently transfers its multicolour print to ware in a single transfer step.

Each of the etch cones 72 may be formed with a portion of a design. One ink colour for each printing assembly 54 would be supplied to the ink applicator assembly 82 described above and registerable portions of the composite design would be each printed on the collectors C in sequence. As described above ware W may be indexed into position thereunder and sequentially printed with the composite design.

It is also possible to interpose an additional offset pickup cone at the transfer station D10 for printing to all variations of objects.

CLAIMS:

1. A printing apparatus comprising first means for establishing at least one portion of a design and second means for picking up the design portion by intimate contact therewith, said first means comprising a first conical surface having a first central cone axis and a cone apex lying on said axis, said first conical surface being mounted for rotation about said central cone axis with said apex fixed in space, said second means comprising a pickup surface radially located relative to a centre of rotation and a central axis passing therethrough, said second means being mounted for rotation about said central axis with its centre of rotation and the cone apex being coincident and located with respect to the first conical surface for contacting rolling engagement therewith, and said first central cone axis of said first conical surface orientated such that intimate contact between the first conical surface and said pickup surface occurs along a line of contact having a locus of points common to each surface in a non-slip relationship.

2. An apparatus as claimed in claim 1, whrein said first means further includes a second conical surface for intimately contacting said first conical surface having a respective second central cone axis and a cone apex lying thereon and being mounted for rotation along its respective central cone axis with its cone apex coincident with the cone apex of said first conical surface and the centre of rotation of said pickup surface, the second central cone axis of said second conical surface being orientated such that said second conical surface

shares a line of contact with said first conical surface and has a locus of points common to each one for intimate contact in a nonslip relationship.

3. An apparatus as claimed in claim 2, wherein the first and second conical surfaces and the pickup surface each share geometrical dimensions and ratios which are integers.

4. An apparatus as claimed in claim 2 or 3, further including doctoring means mounted for engagement with the second conical surface having at least two working surfaces each having an interface in close contact with the second conical surface, each interface lying along a locus of points upon the second conical surface and being apex coincident therewith.

5. An apparatus as claimed in claim 4, further including means for depositing an inking fluid at an inboard end of the doctoring means, and means for collecting over flow from an outboard end thereof, the doctoring means and second conical surface being orientated for allowing gravity flow of the inking fluid from the inboard to the outboard ends thereof.

6. An apparatus as claimed in claim 4 or 5, further including resilient driving means engaging the doctoring means of urging it on a seating relation with the second conical surface.

7. An apparatus as claimed in claim 6, wherein the resilient driving means includes a ball bearing means and a piston driving the same against the doctoring means, said ball bearing means permitting circumferential gimballing of the doctoring means relative to the second conical surface.

8. An apparatus as claimed in claim 7, wherein the resilient driving bearing includes means for maintaining the ball bearing means, the piston and doctoring means in fixed ray relation.

9. An apparatus as claimed in claim 1, wherein a plurality of the first and second means are spaced at selected radial and circumferential locations about the apparatus and further including at least one transfer station spaced adjacent to one of the first means including support means for securing an article to be printed for engagement with the second means along a line of contact therebetween.

10. An apparatus as claimed in claim 9, wherein the support means includes means for selectively, indexing the support means and article into and out of contact with said second means.

11. An apparatus as claimed in claim 10, wherein said transfer station is movable mounted and includes means operably coupled thereto for movable driving the transfer station such that it supports the article for radial and circumferential correspondence with the second means along the line of contact therebetween.

12. An apparatus as claimed in claim 11, wherein the article to be printed has a surface portion having a central axis of rotation and article apex therealong, the second means has a radius of curvature and corresponding centre thereof adapted to follow a path concentrically about the central axis of rotation of said second means, the line of contact between the article and the second means being a line shared between the article and second means, said line being colinear with a radius of curvature of the second means and a surface ray lying along the surface of the article which ray

intersects the article apex, and the means for driving the transfer station includes a camming means for driving the transfer station and article such that the article.apex is coincident with the centre of the second means and the radius of curvature of the second means is colinear with the surface ray of the article.

13. An apparatus as claimed in claim 12, wherein the article to be printed has a conical surface and the article surface line is a ray passing through the cone apex.

14. An apparatus as claimed in claim 12 or 13, wherein the article to be printed comprises a web of material and means including unwind and rewind rolls mounted in the transfer station to secure the web therebetween, and a backup roll secured to the transfer station therebetween urges the web into engagement with the collector in nonslip relation therebetween.

15. An apparatus as claimed in claim 10, wherein the article includes a surface for engagement with the second means and said second means includes a deformable elastic surface, the transfer station includes a means of securing the article in a position to forcefully engage a portion of said article with the second means and thereby deform the elastic surface of the collector in a nonslip relationship.

16. An apparatus as claimed in claim 15, wherein the means of securing the article includes a vacuum chuck.

17. An apparatus as claimed in claim 1, wherein the pickup surface includes a flexible membrane for intimately contacting the first means in the nonslip

relationship.

18. An apparatus as claimed in claim 1, including means for securing thereon articles to be printed, said articles being coated, such that a portion thereof includes the pickup surface for intimately contacting the first means in the non-slip relationship.

19. An apparatus, as claimed in claim 1, wherein the pickup surface is pivotally mounted with said second means and engages the first means in a radially inboard position and engages an article to be printed in a radially outboard position.

20. An apparatus as claimed in claim 2, further including transfer means for engaging the pickup surface including a third conical surface having a cone axis and cone apex lying thereon and said conical surface being mounted for rotation about its cone axis and orientated such that its cone apex is coincident with the apex of the first conical surface and the centre of rotation of said pickup surface, said third conical surface sequentially engaging each of the second means for receiving a design portion thereon by intimate contact with said second means along a line of contact including a locus of prints common to each surface in a nonslip relationship.

21. An apparatus as claimed in claim 1, further comprising third means including a cylinderical back up roll for engagement with the second means, and a web in the form of a flexible printing surface supported by said backup roll against the pickup surface for receiving thereon the design portion by intimate contact with said pickup surface.

22. An apparatus as claimed in claim 1, further including a conical cleaning surface having a central

cleaning surface axis and cone apex therealong said cleaning surface being mounted for rotation about the central cleaning surface axis and having its cone apex in correspondence with that of the centre of rotation of the second means and orientated to intimately contact said second means along a locus of points common thereto in a nonslip relationship.

23. A printing apparatus including means for applying ink to an ink carrying roll, and a self aligning roll and doctor assembly comprising: a tapered conical roll mounted for rotation about a longitudinal axis having an apex therealong, a doctoring means including a pair of fixed blade members, said doctoring means being resiliently mounted for engagement with the conical surface, each of said blade members having a working surface in close contact with said conical surface and lying along a line of contact having a locus of points common to the surface of the conical roll and intersecting the apex thereof.

24. A printing apparatus including means for transferring a design to a receiving surface of an article by intimate contact of the design thereagainst comprising: a transferring surface for carrying the design; respective means for carrying the transferring surface and the receiving surface of the article into engagement with each other; and means for orientated the receiving surface relative to the design into intimate nonslip rolling contact along a line of contact shared between the surfaces to affect the transfer of the design, such that a respective centre of the transferring surface and an apex of the receiving surface instantaneously

coincide during engagement.

25. An apparatus as claimed in claim 24, wherein the means for orientated the receiving surface relative to the design includes means for effecting at least one translational and rotational motion of the receiving surface relative to the transferring surface.

26. A apparatus as claimed in claim 25, wherein the means for effecting translational and rotational motion includes respective camming means responsive to the instantaneous position of the transferring surface, having at least one profile related to circumferectial and axial geometry of the receiving surface, the camming means being operatively coupled to the receiving surface for translating and rotating same in accordance with the position of the transferring surface,

27. An apparatus as claimed in claim 24, wherein the means of orientating the receiving surface relative to the design includes means for forcing the receiving surface against the transferring surface.

28. An apparatus as claimed in claim 27, wherein the transferring surface comprises an elastomeric block including a working surface for carrying the design in an initial relaxed surface configuration and the receiving surface includes a portion of a relatively nondeformable article for engaging with said working surface in a nonslip relation and deforming same along a line of contact offset from the initial relaxed surface configuration of said transferring surface.

29. An apparatus as claimed in claim 27, wherein the design carried by the transferring surface is graphically distorted by an amount relatively equi-

valent to the offset provided by the deformity occasioned by engagement of the transferring surface and the receiving surface such that the design transferred thereby becomes graphically corrected relative to the receiving surface.

30. An apparatus as claimed in claim 24, wherein the means for orientated the article includes a vacuum chuck adapted to engage a portion of the article for securing it in the indexing means.

31. A printing apparatus including means for printing an article with a separable design portion from a flexible design carrying working surface comprising: a frame having an aperture therein and an elastic membrane carried thereby, the flexible working surface formed of a portion of said membrane and disposed over said aperture, flexible actuator means adapted to engage the membrane opposite the design carrying working surface thereof causing deformation of the membrane into conformance with said actuator means, means for securing the article into opposition with the deformed membrane, and means for diving the actuator means and membrane into engagement with the article in a nonslip simulated rolling contact from a centre area thereof to an outer peripheral edge for separating the design portion from the membrane and transferring same to the article.

32. An apparatus as claimed in claim 31, wherein the working surface comprises an RTV silastic.

33. An apparatus as claimed in claim 32, wherein the actuator means comprises an elastomeric body having a shaped face for engaging the membrane, the membrane deformed thereby having a shape adapted to engage the article first from the centre to an outer peripheral edge thereof at a selected contact angle as said contact progresses.

34. An apparatus as claimed in claim 33, wherein the contact angle is from 5° to 50°.

35. An apparatus as claimed in claim 31, wherein the actuator means includes means for supplying reduced air pressure to a portion of the actuator engaging the membrane for assuring close contact of the latter thereagainst.

36. A printing apparatus including means for supporting a forward facing portion of a flexible working surface during application of a separable design thereon including a housing, a porous plate having a free face for engaging an opposed rearward facing portion of said flexible working surface being mounted within said housing, and a source of reduced air pressure coupled to said housing for establishing at the free face of said porous plate a reduced air pressure, said rearward facing portion of the flexible working surface being adapted to be located against said free face of the porous plate and drawn thereagainst to secure said membrane in close contact therewith.

37. An apparatus as claimed in claim 36, wherein said porous plate is selected from a porous material having a pore size of about 50 microns.

38. An apparatus as claimed in claim 36, further comprising a compressible resilient skin located intermediate the porus plate and the flexible working surface.

39. A method of printing comprising the steps of radially locating axes of rotation of a plurality of printing means about a central axis each axis of rotation including a printing means apex therealong, producing a plurality of transferrable design portions at each of said printing means, locating

a collector for engagement with each of the printing means concentrically about a centre of rotation corresponding to said central axis, and orientating the printing means axes and collector axes of rotation for engagement along a line of contact, such that centres of rotation of the collector means are coincident with the apex of each of said printing means, transferring the design portion from the printing means to the collector by intimate contact of one with the other along the common line of contact therebetween which line includes the apex of each printing means of the centre of rotation of the collector.

40. A method of printing wherein an inking fluid is applied to an ink carrying surface comprising the steps of: mounting the surface for rotation about a central axis establishing an apex for said surface along said axis, resiliently mounting at least one pair of doctoring surfaces for engagement in close contact with the surface, each doctoring surface lying along a respective line of contact having a locus of points common with the surface and intersecting the apex of the same; rotating the surface while at the same time applying inking fluid thereon.

41. A method of printing wherein a design is transferred from one surface to another by intimate contact of said surfaces along portions thereof comprising the steps of: carrying each of said surfaces about a respective centre of rotation and orientating one surface relative to the other so that a line of contact occurs therebetween for transferring the design from one to the other which line of contact instantaneously includes each respective centre of the rotation of the surfaces.

42. A method of printing from a flexible working surface having a separable design carried on one surface thereof comprising: deforming a portion of said working surface in opposition to the design carrying side thereof into conformance with a selected profile and driving the working surface into engagement with a design receiving surface of an article to be printed in a nonslip rolling-like contact from a centre area thereof to an outer peripheral edge thereby to separate the design from the working surface and transfer it to the article.

43. A method as claimed in claim 42, further comprising the step of selecting a profile for conformance of the working surface as a function of the design receiving surface to the deformed membrane to thereby have a shape adapted to engage the article first from the centre to an outer peripheral edge thereof at a selected contact angle as said contact progresses.

44. A method of printing a flexible working surface which is supported during application of a separable design thereon including the steps of supporting the flexible surface against a rigid plate of selected relatively small porosity, and pneumatically drawing the flexible working thereagainst without distortion thereof.

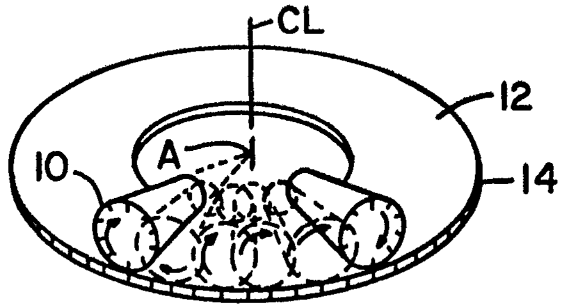

Fig. 1

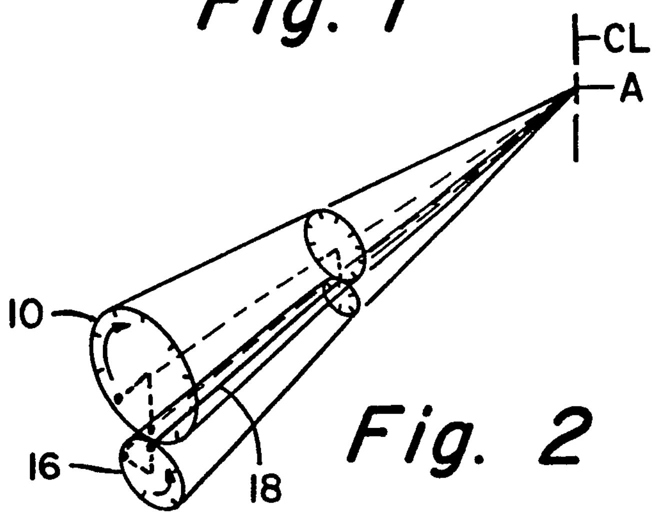

Fig. 2

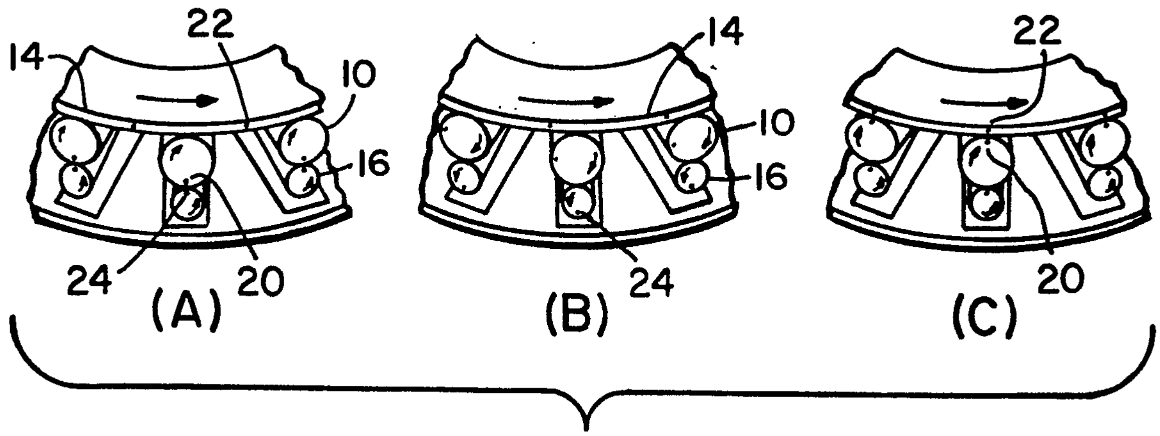

Fig. 3

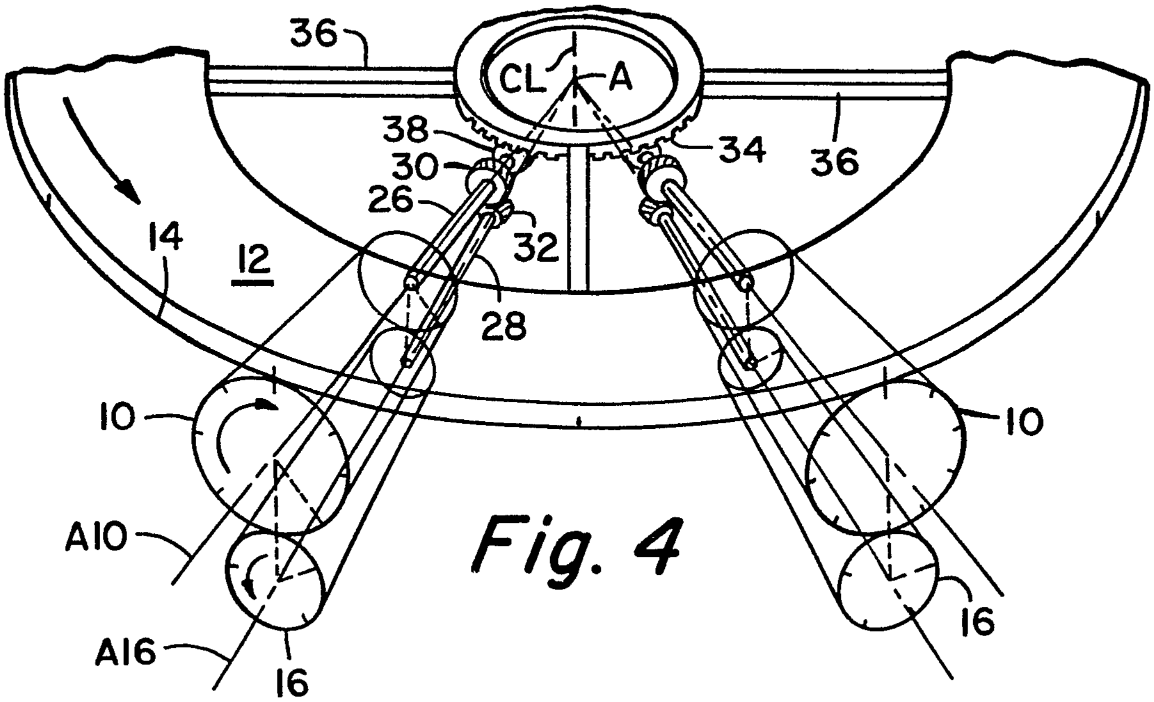
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Fig. 4

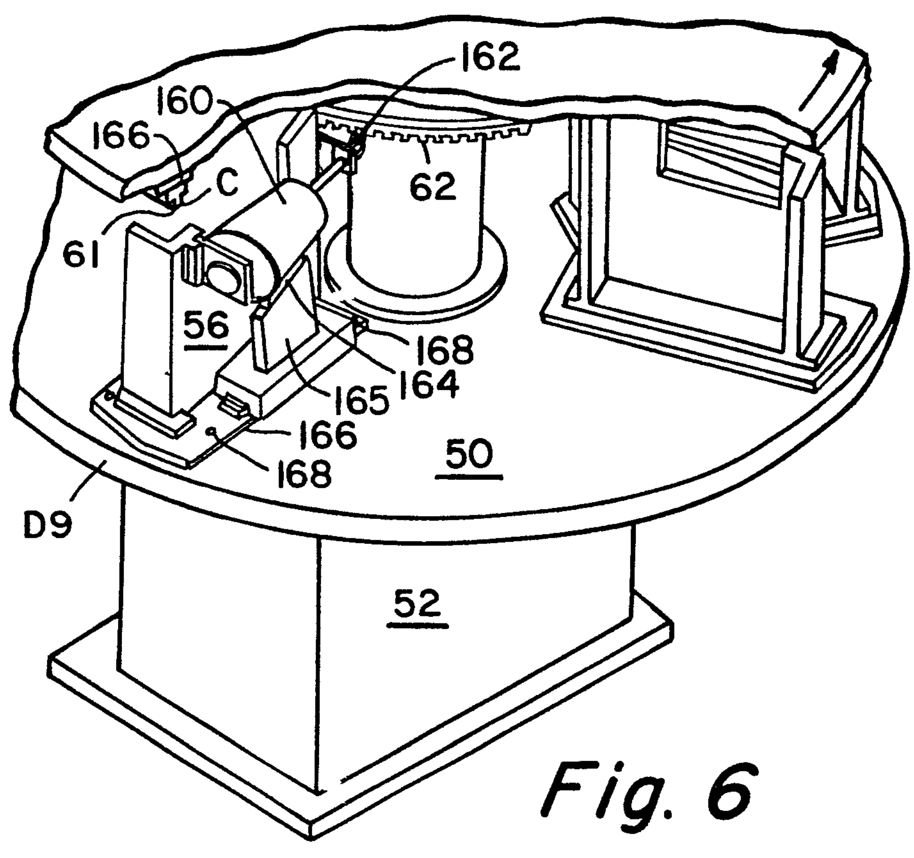
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Fig. 6

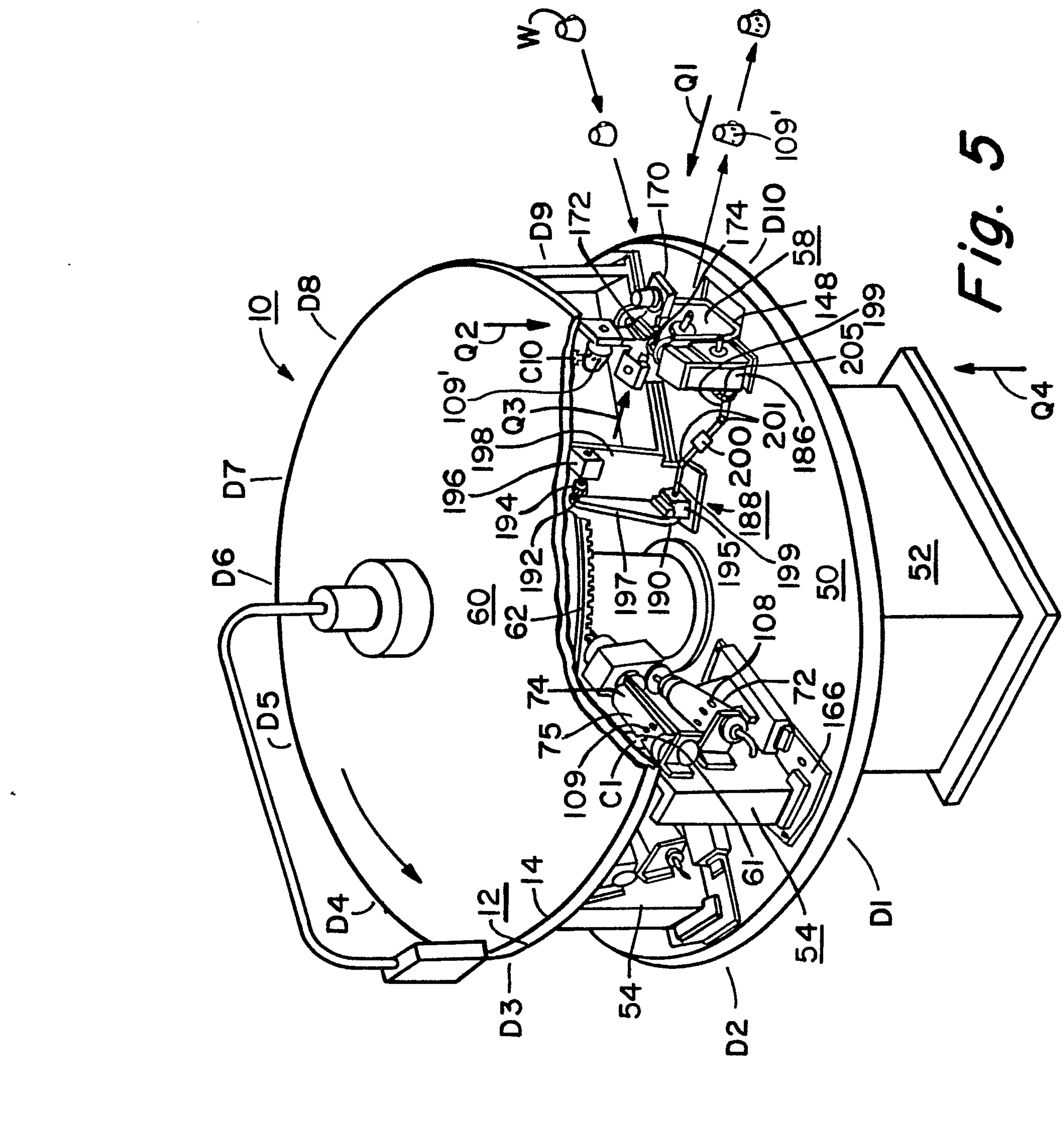
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Fig. 5

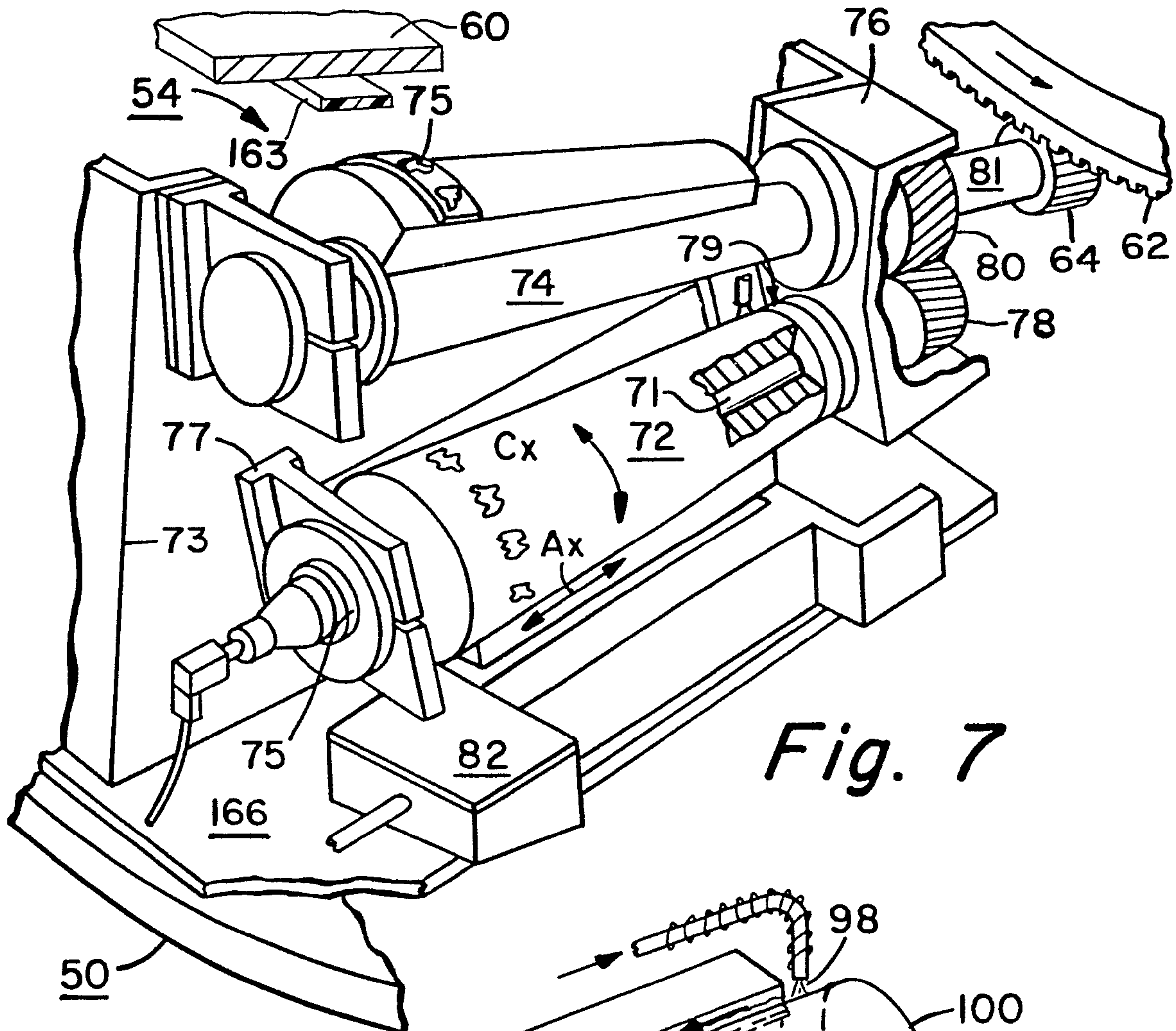
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Fig. 7

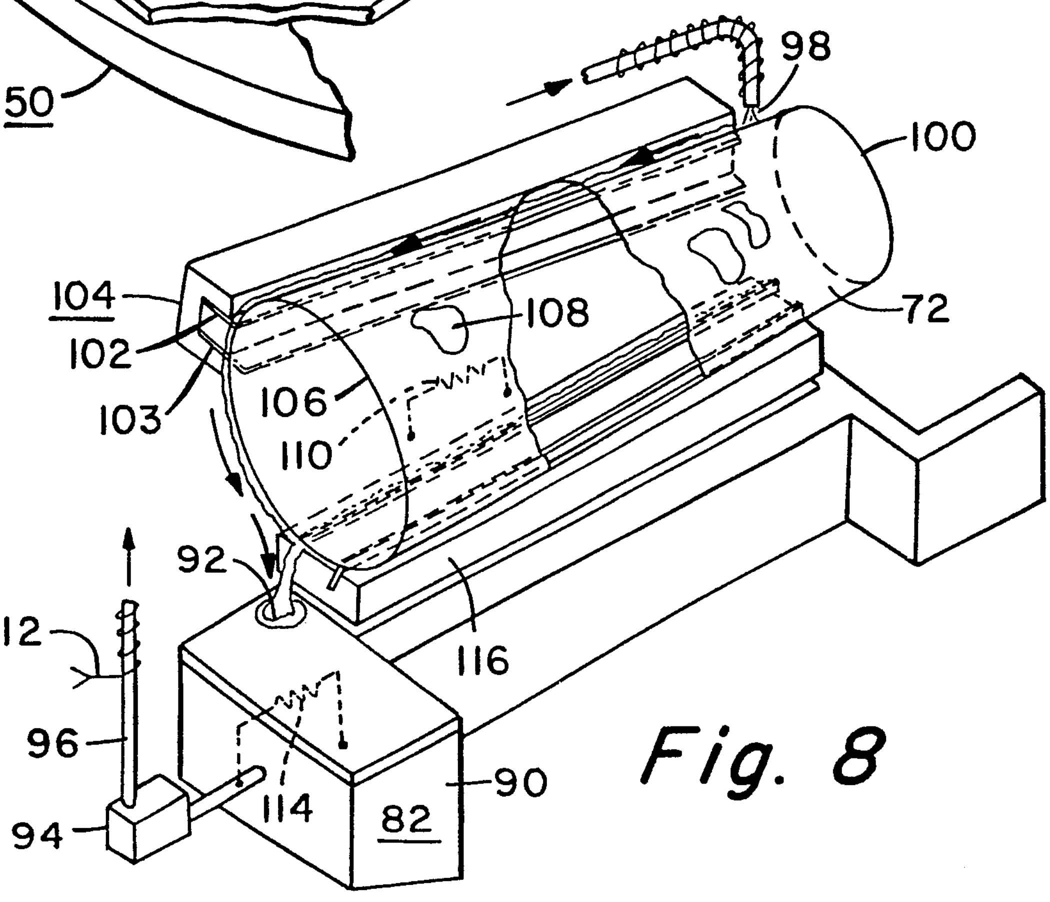
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Fig. 8

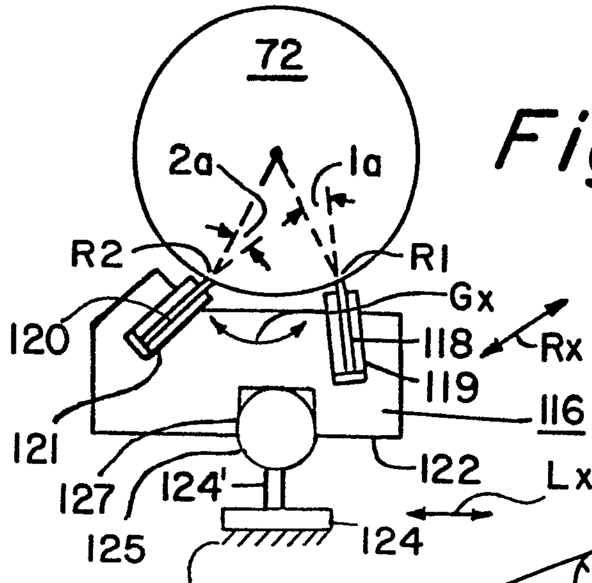


Fig. 9

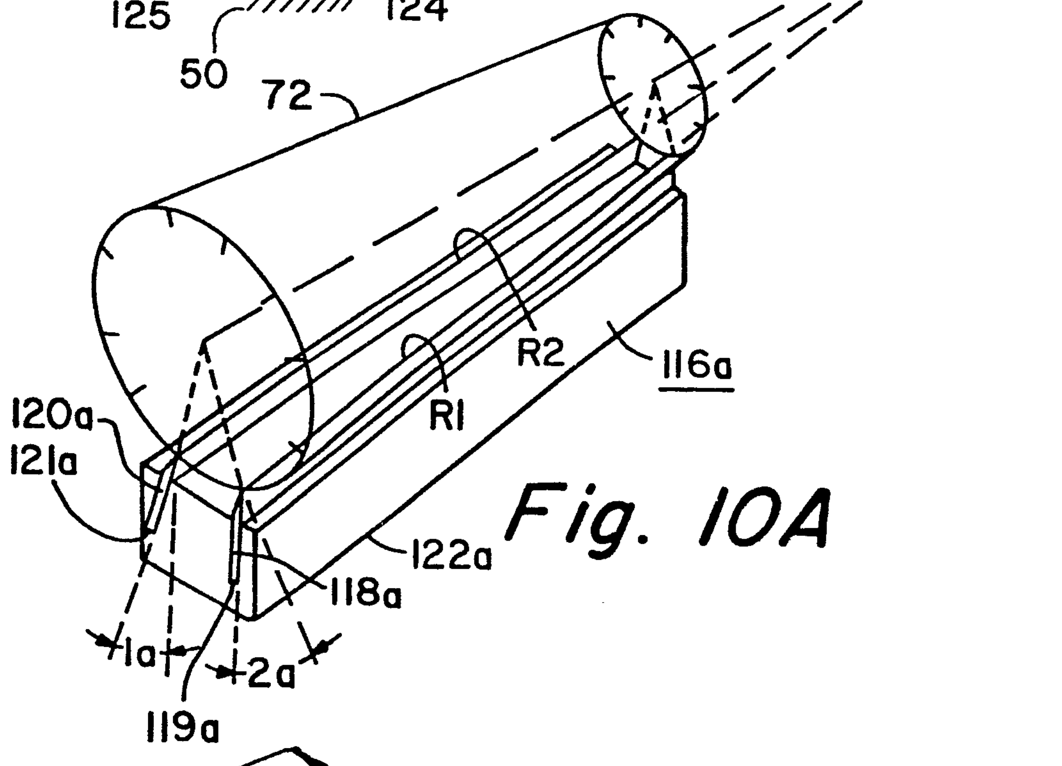


Fig. 10A

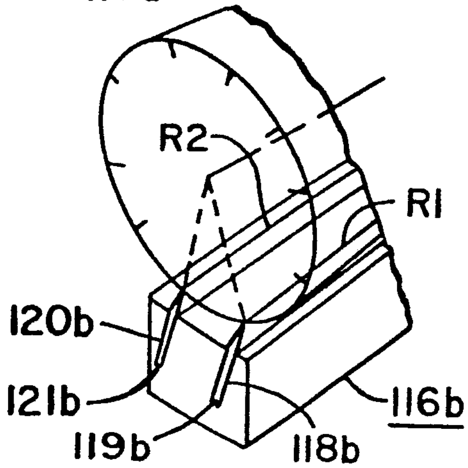


Fig. 10B

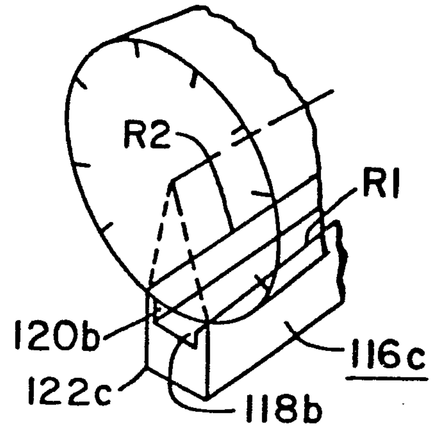


Fig. 10C

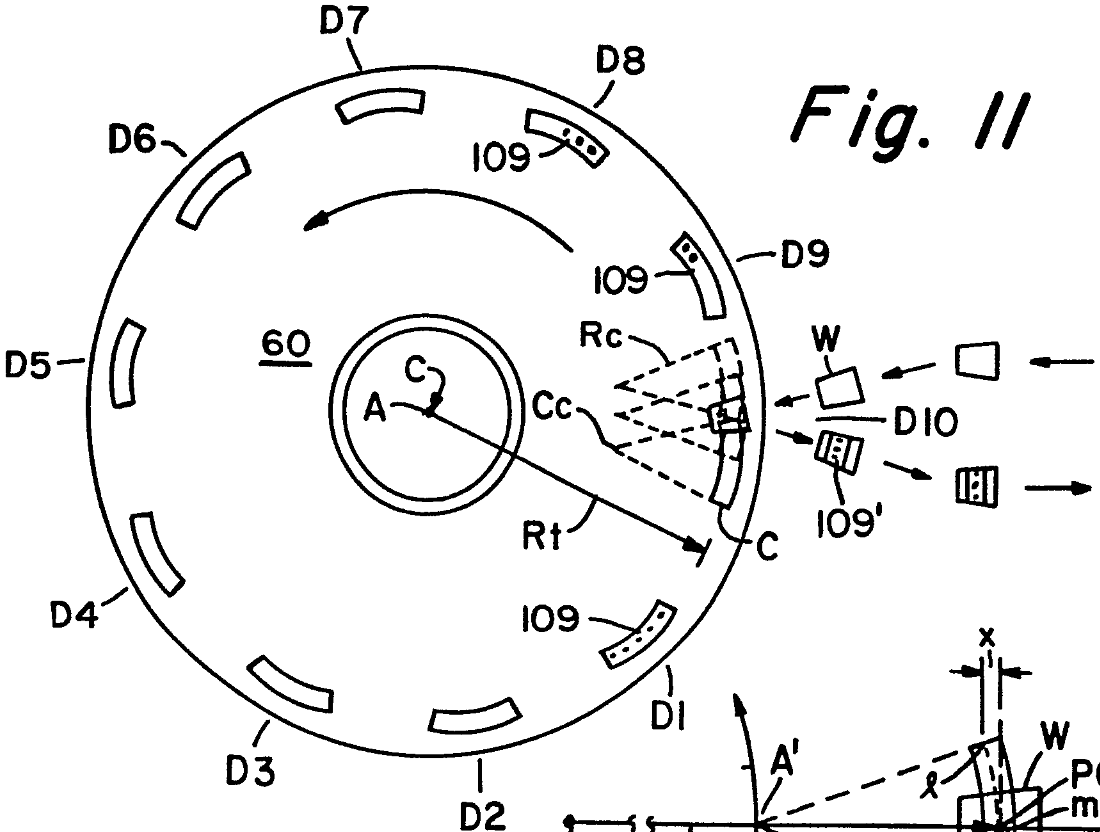


Fig. 11

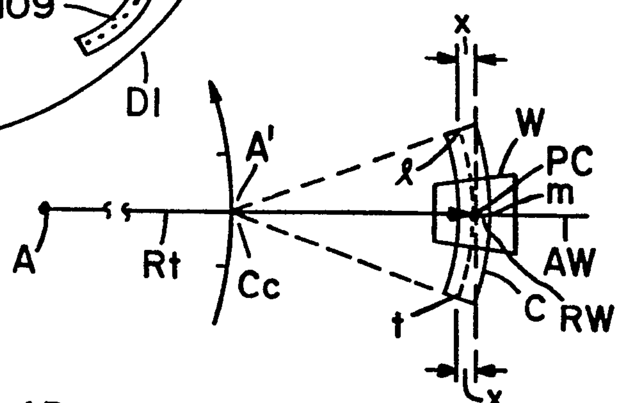


Fig. 12A

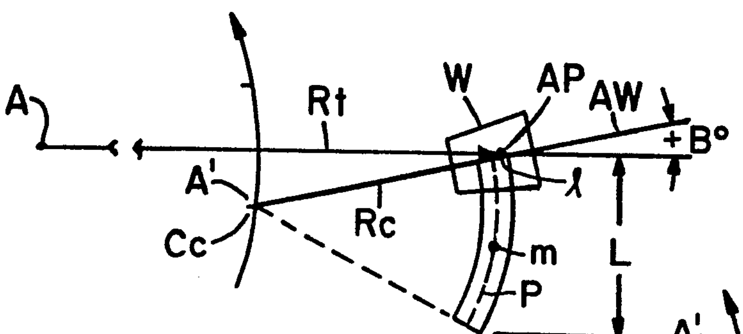


Fig. 12B

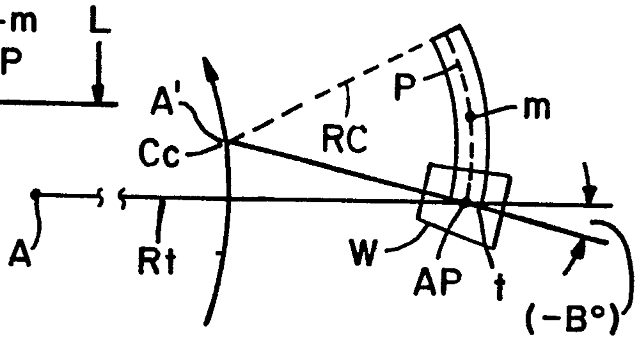


Fig. 12C

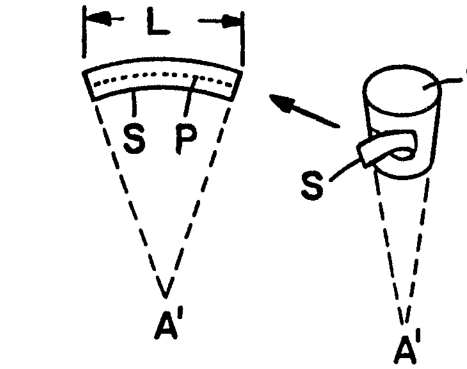


Fig. 13A

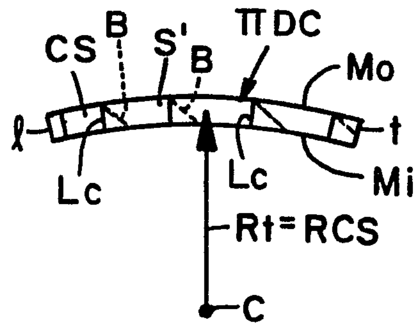


Fig. 13C

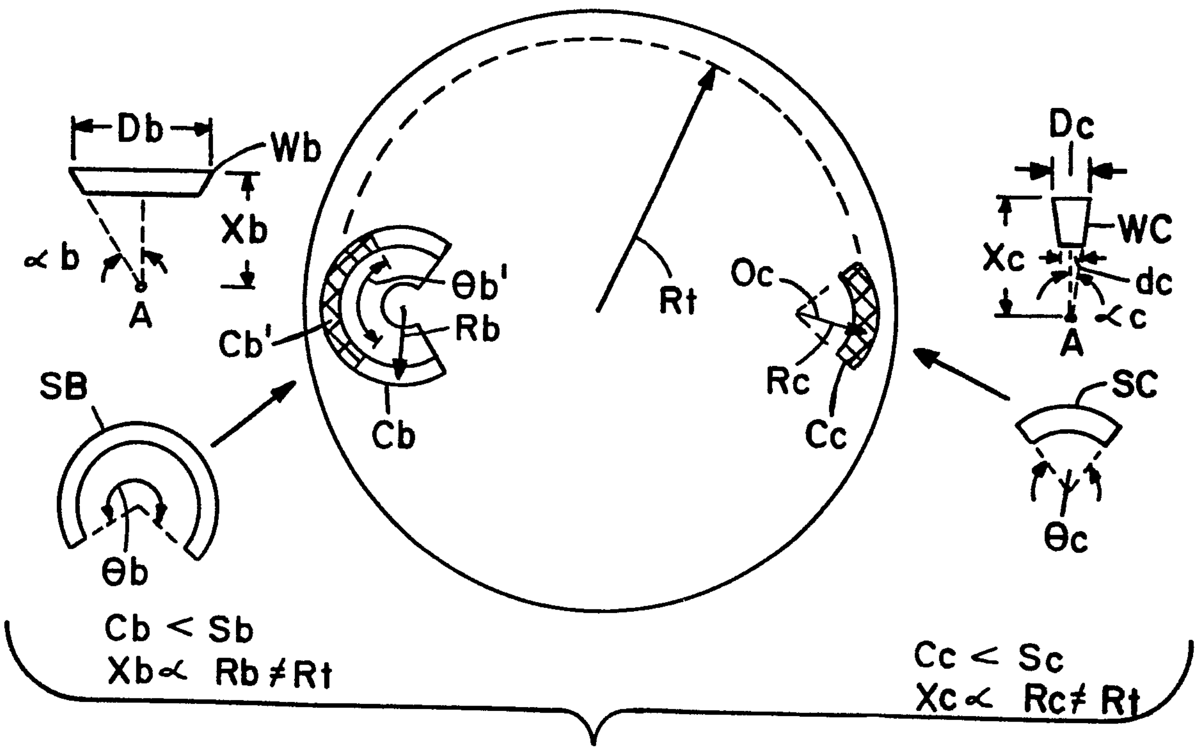


Fig. 13B

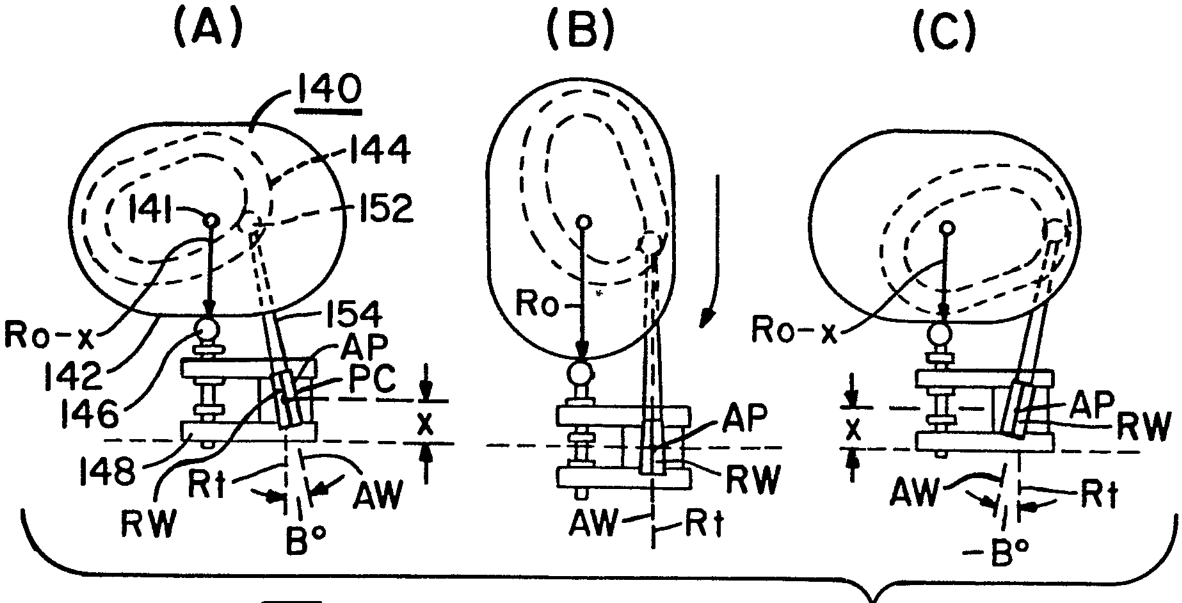


Fig. 14

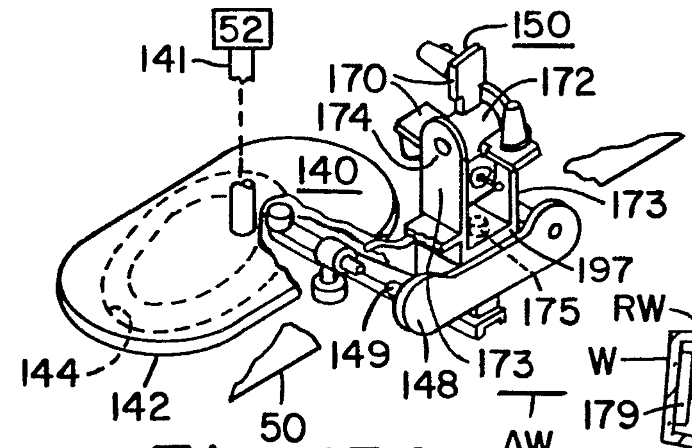


Fig. 15A

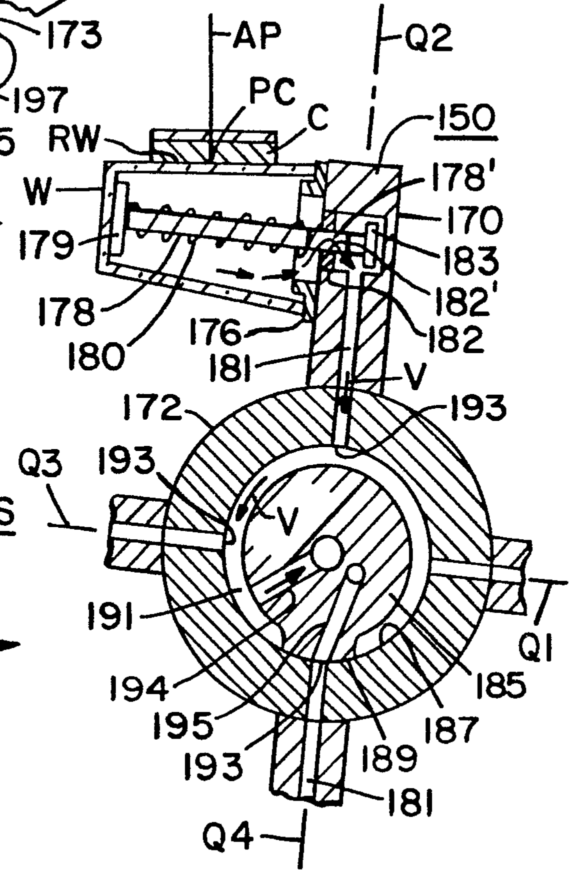


Fig. 15B

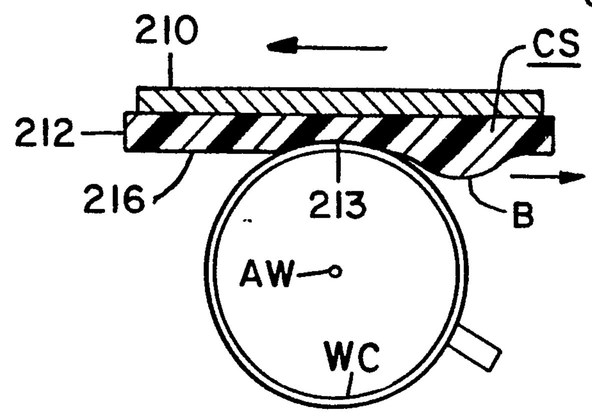


Fig. 16

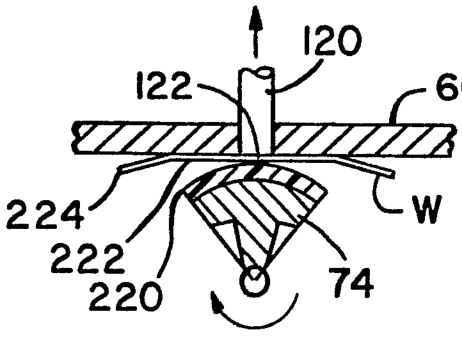


Fig. 17A

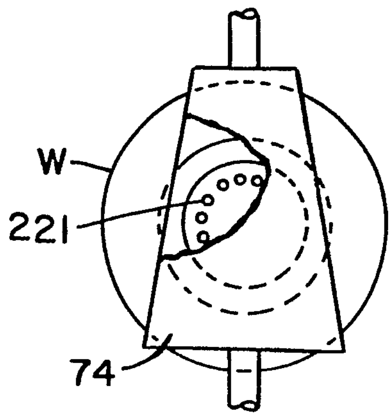


Fig. 17B

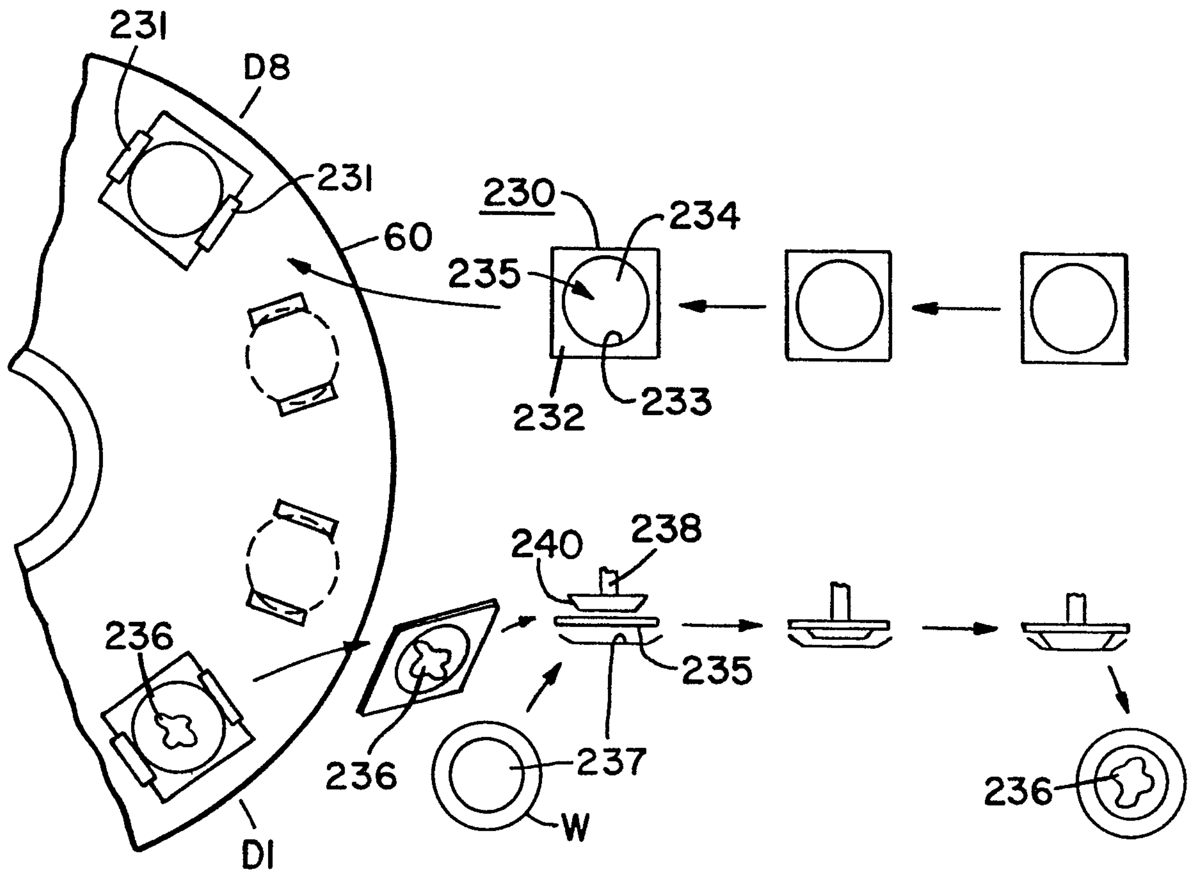
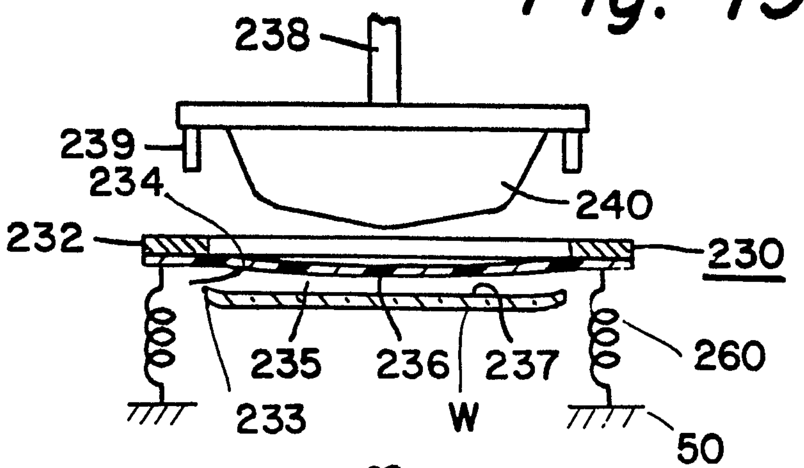


Fig. 18

Fig. 19A



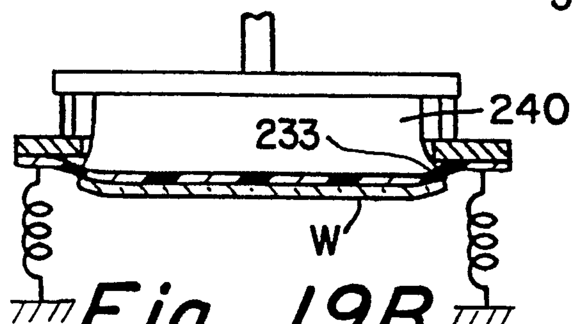


Fig. 19B

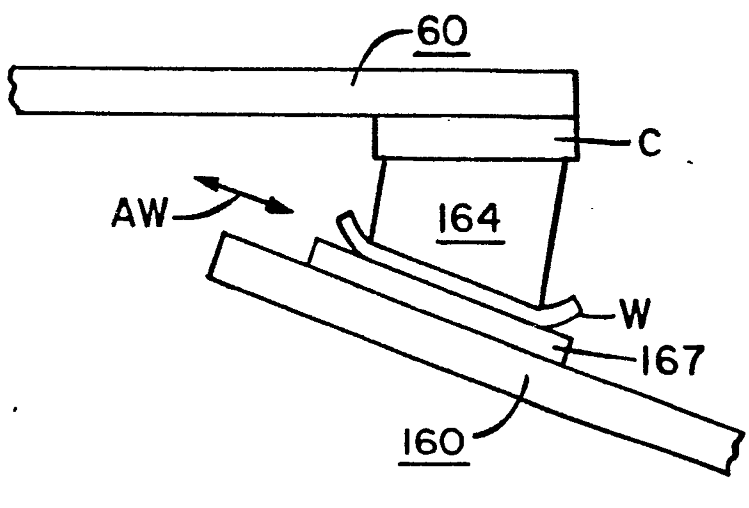


Fig. 23E

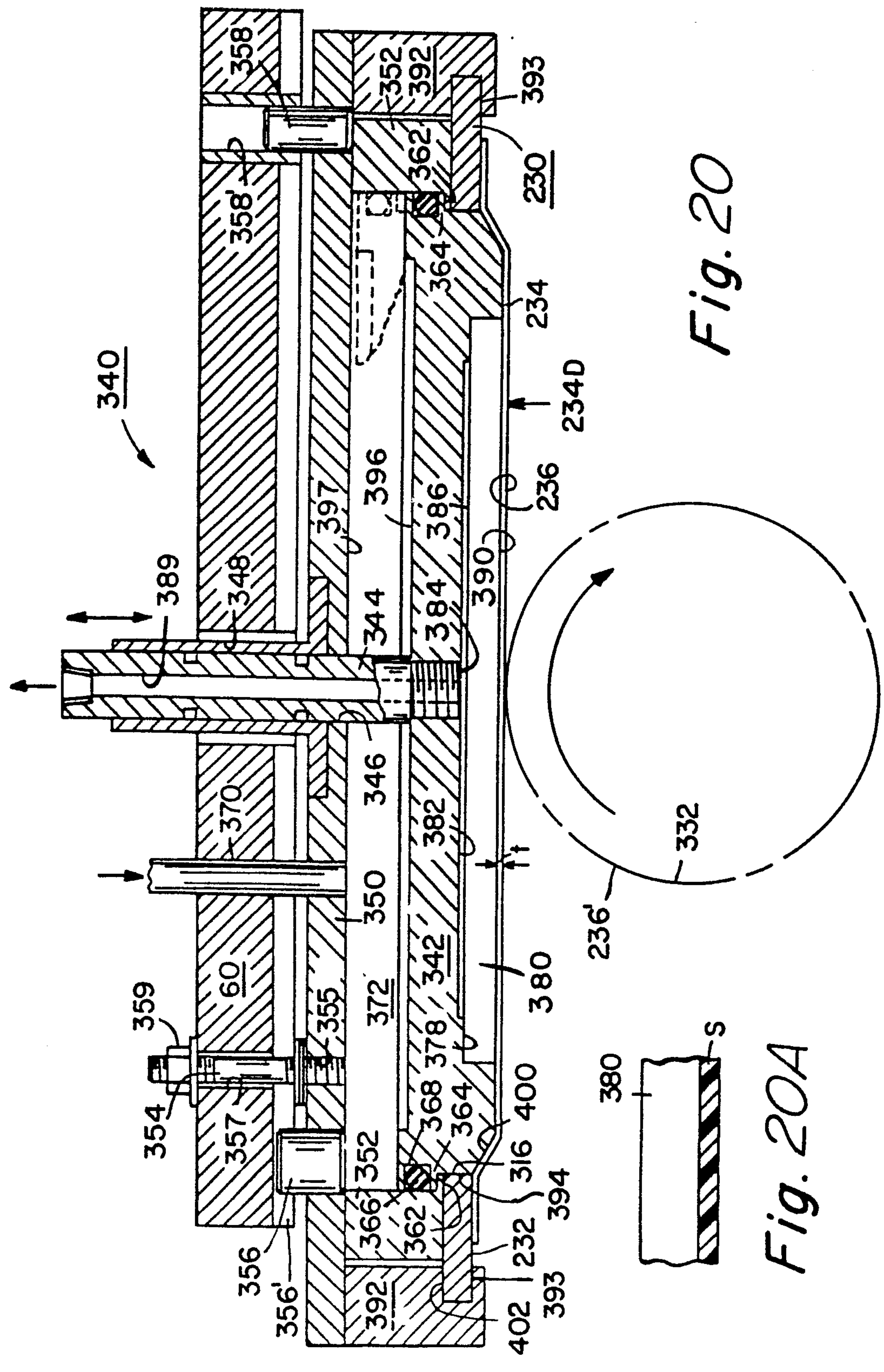


Fig. 20

Fig. 20A

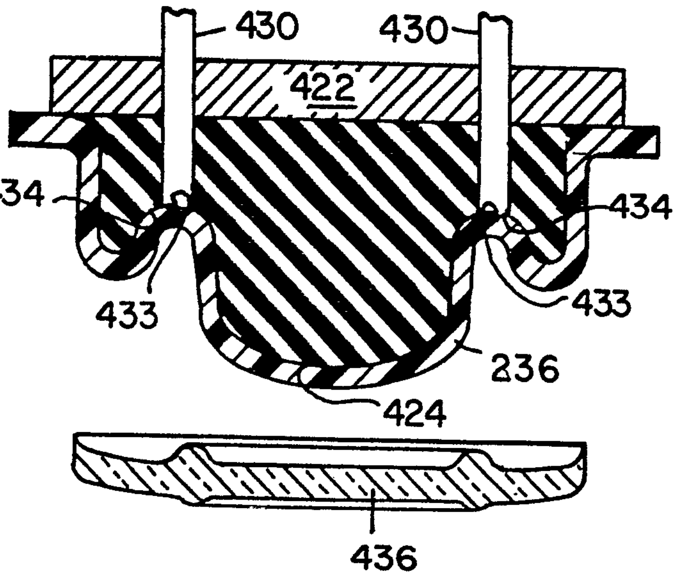


Fig. 21

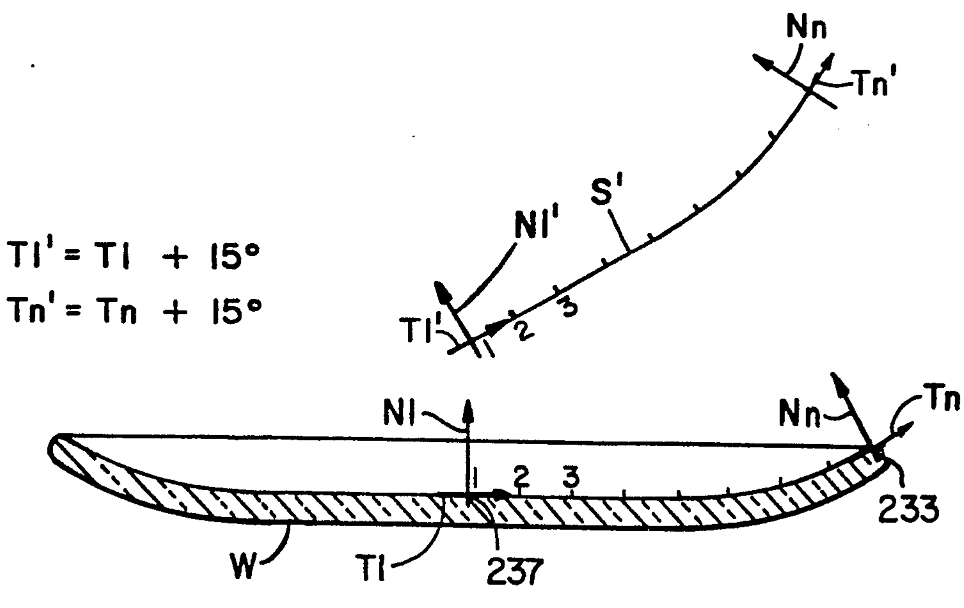


Fig. 22A

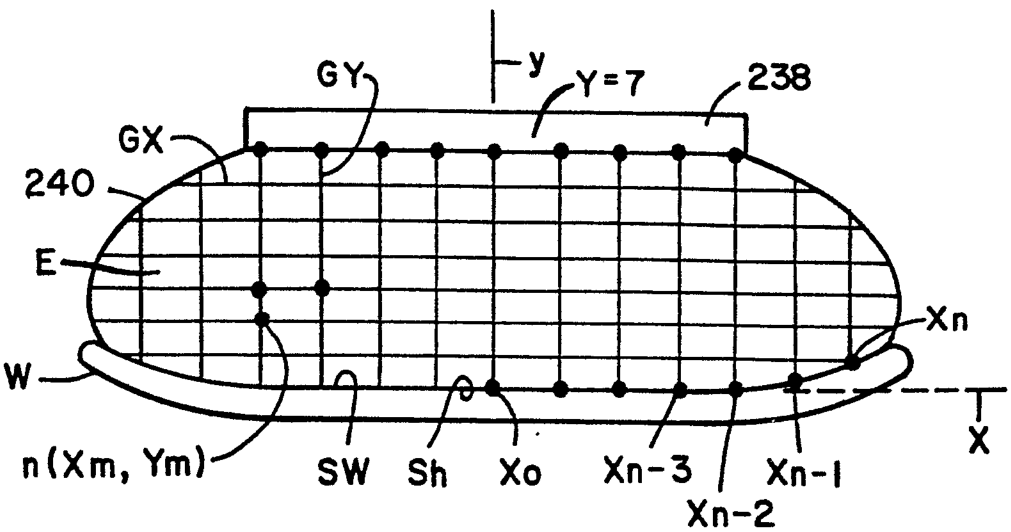


Fig. 22B

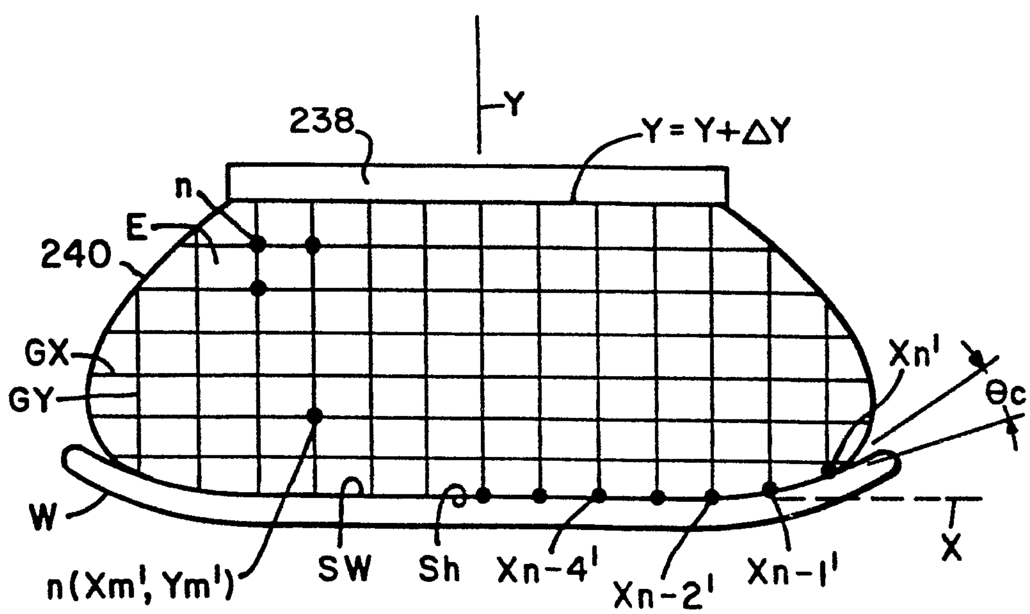


Fig. 22C

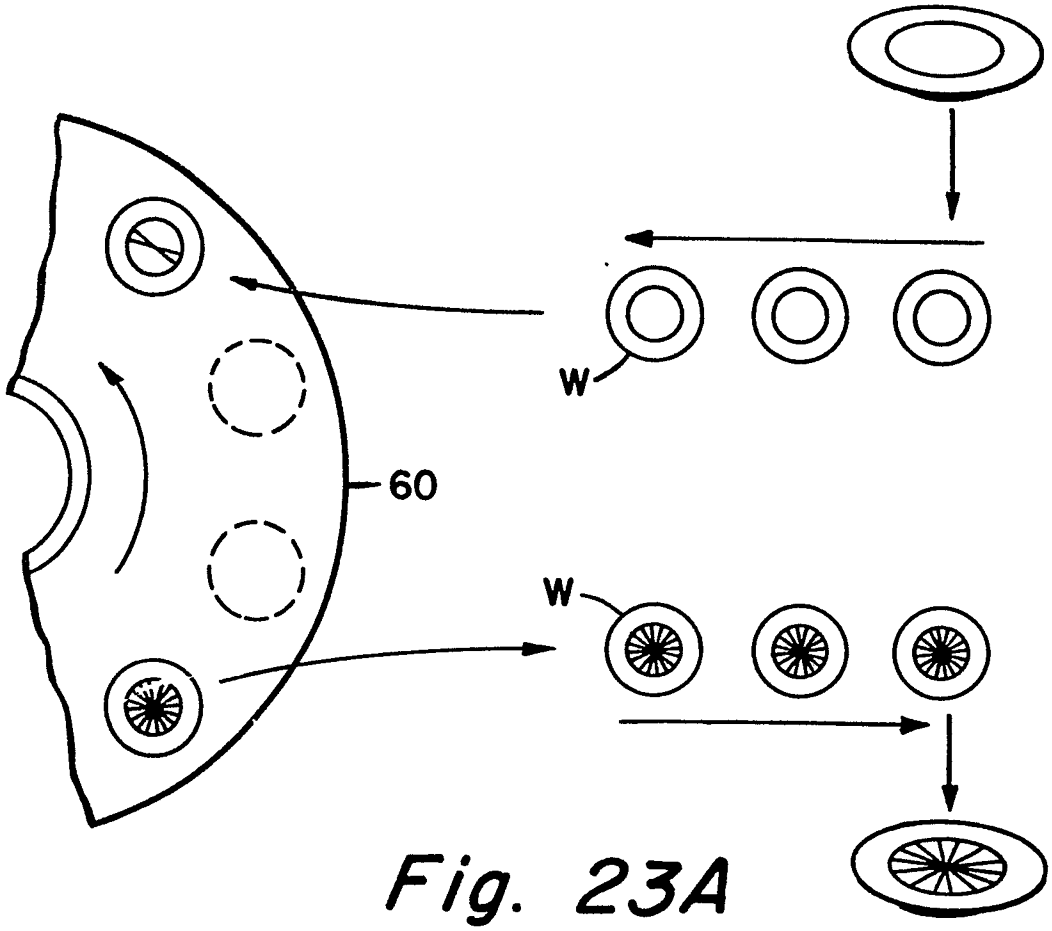


Fig. 23A

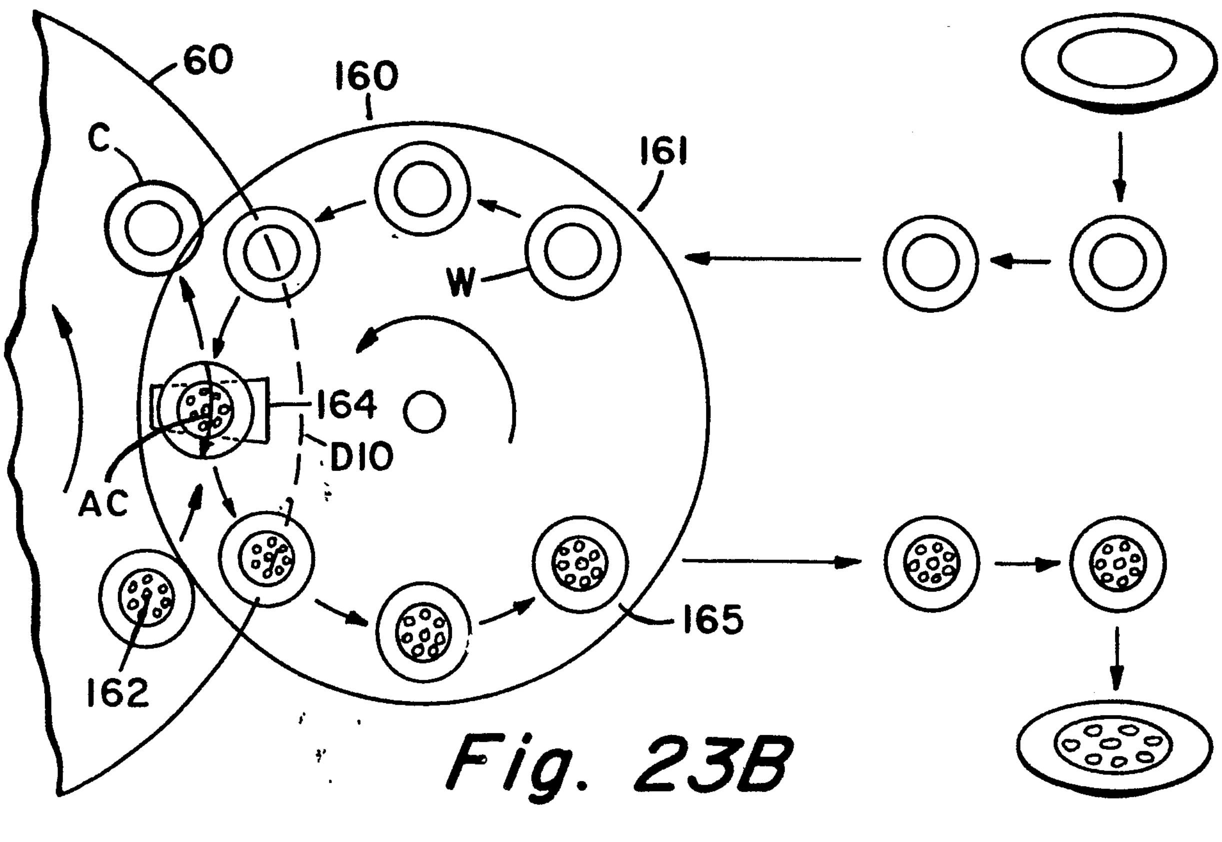


Fig. 23B

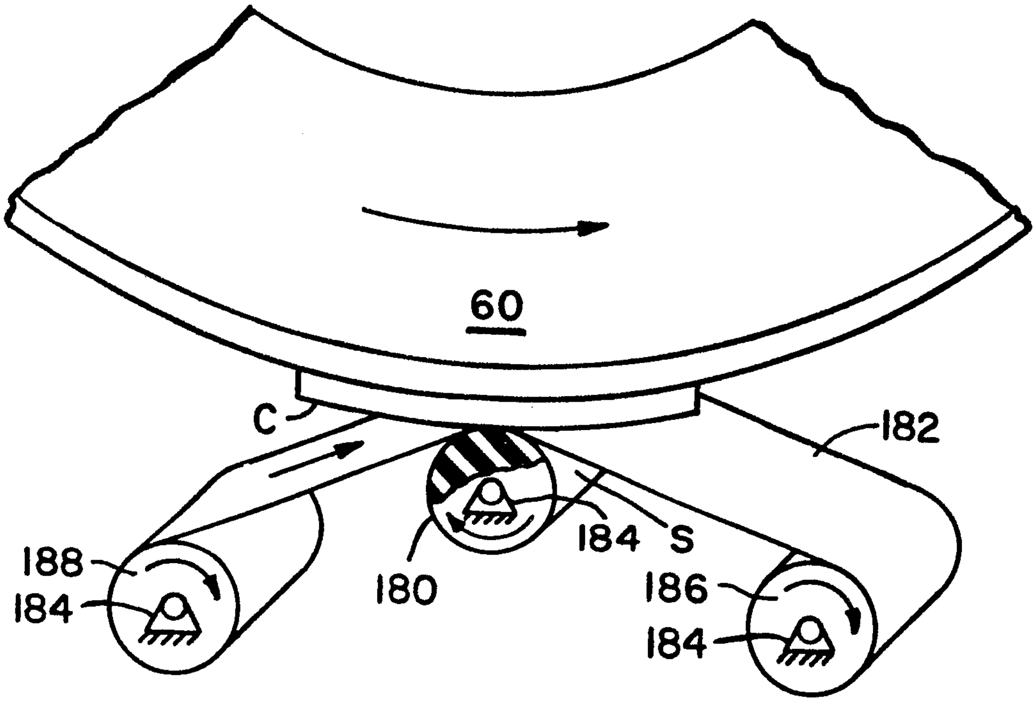


Fig. 23D

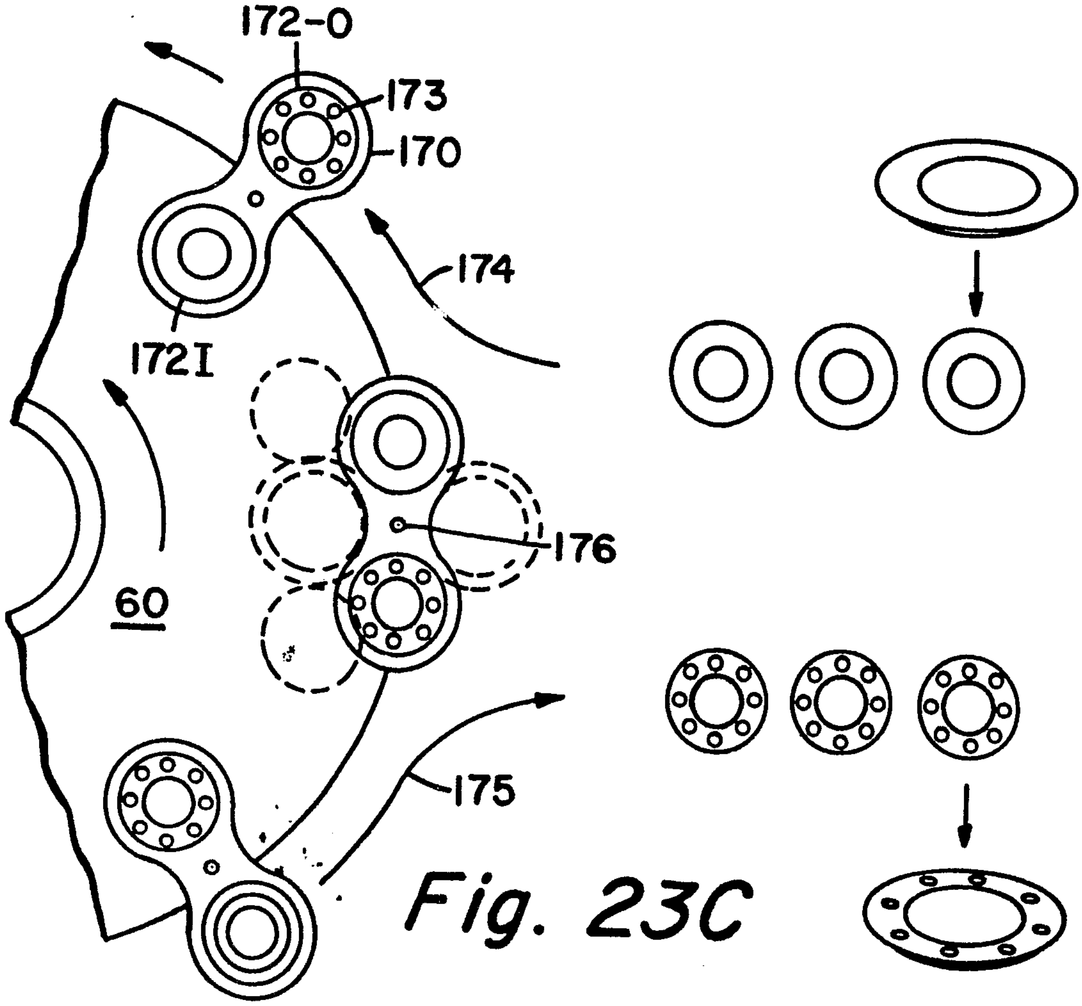


Fig. 23C