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3,081,698	3/1963	Childress et al.	101/ESD
3,180,260	4/1965	Joseph.....	101/379X
3,245,341	4/1966	Childress et al.	101/ESD
3,253,540	5/1966	Lusher	101/ESD
3,276,358	10/1966	Lusher	101/ESD
3,387,557	6/1968	Decker et al.	101/35
3,418,926	12/1968	Hakogi.....	101/35
3,450,043	6/1969	Flax.....	101/ESD

FOREIGN PATENTS

646,394	11/1950	Great Britain.....	101/41
748,362	5/1956	Great Britain.....	101/41
785,781	11/1967	Great Britain.....	101/35

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[54] **OFFSET PRINTING ON CURVED SURFACES**
19 Claims, 35 Drawing Figs.
[52] U.S. Cl..... 101/35,
101/379
[51] Int. Cl..... B41f 17/30
[50] Field of Search..... 101/35, 36,
37, 41, 379

References Cited

UNITED STATES PATENTS

1,150,280	8/1915	Lomas.....	101/35X
1,238,229	8/1917	Weiler.....	101/35X
1,326,843	12/1919	Brewer.....	101/35X
1,334,822	3/1920	Varble.....	101/35
1,611,679	12/1926	Rees.....	101/35
1,972,854	9/1934	Angerstein.....	101/35
1,992,037	2/1935	Mulder.....	101/35X
2,748,696	6/1956	Murray.....	101/379X
2,917,994	12/1959	Tripp.....	101/36

ABSTRACT: A print is made of an object having a surface with a considerable contour variation by first printing the image on an intermediate carrier surface which is capable of being deformed in such a manner that it will envelop the required area of the surface upon which printing is to be done without wrinkling and without allowing relative movement or sliding between the object surface and transfer surface as they are brought into conforming contact and then separated. The image may be transferred from the intermediate carrier surface either by the application of an electric field while the intermediate carrier and the object are in contact, or by applying a thin layer of a suitable liquid to the object surface prior to applying the intermediate carrier thereto.

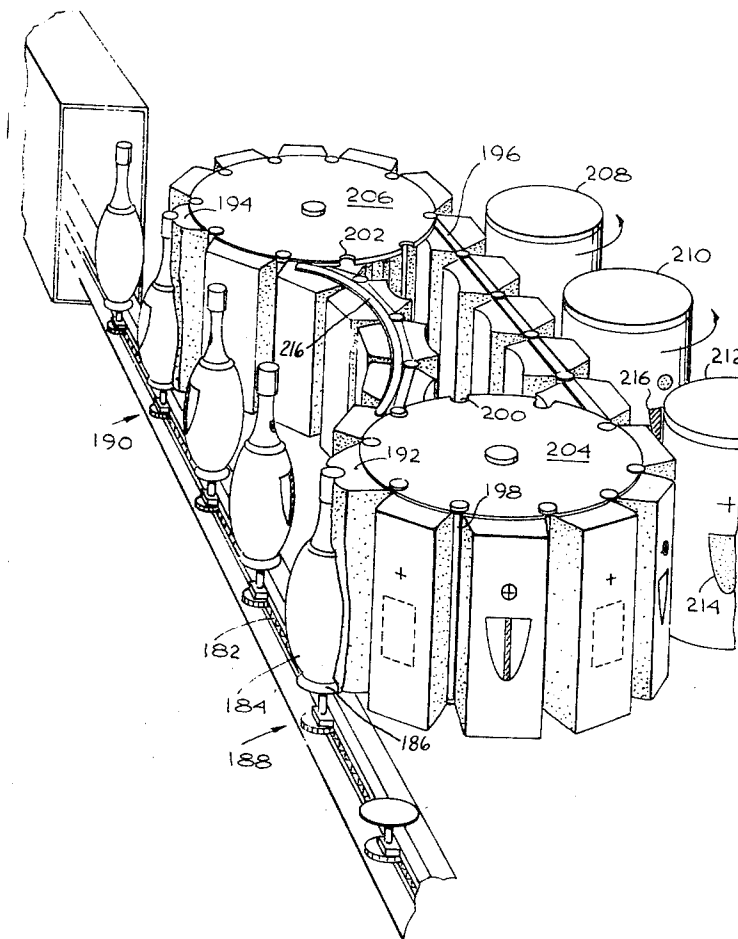


Fig. 1A

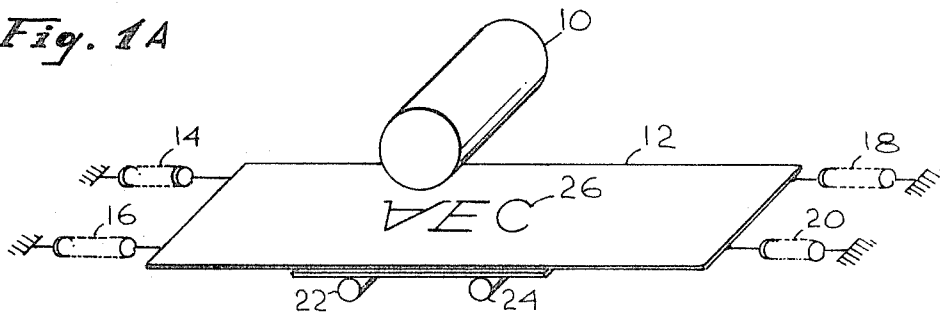
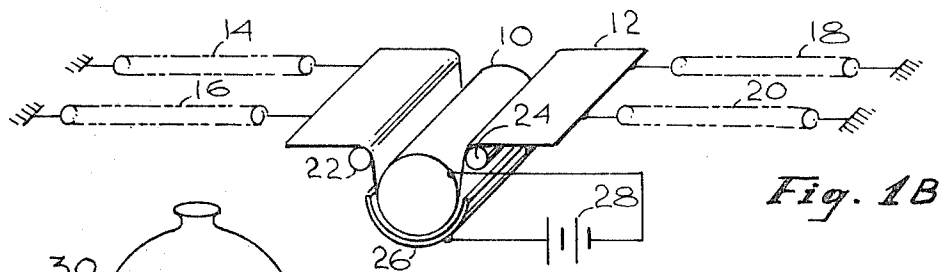


Fig. 1B

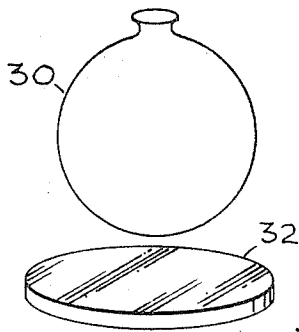


Fig. 2A

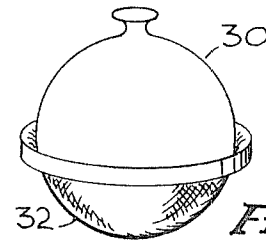


Fig. 2B

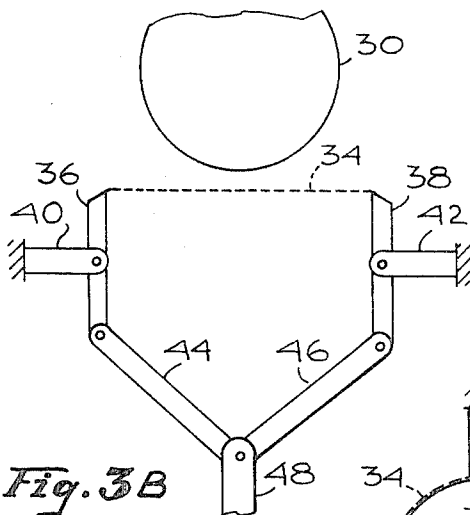


Fig. 3B

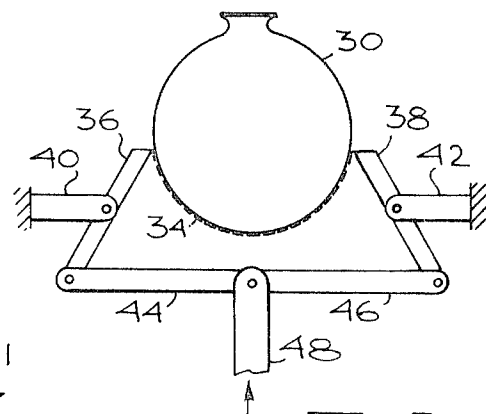


Fig. 3C

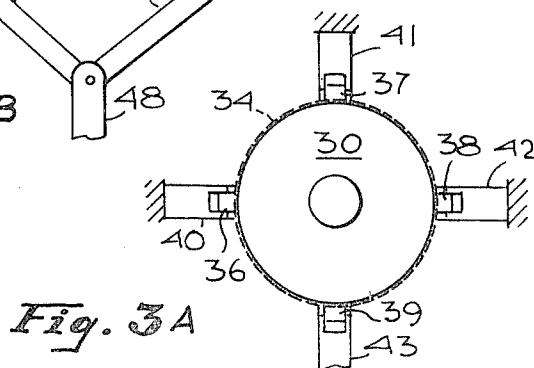
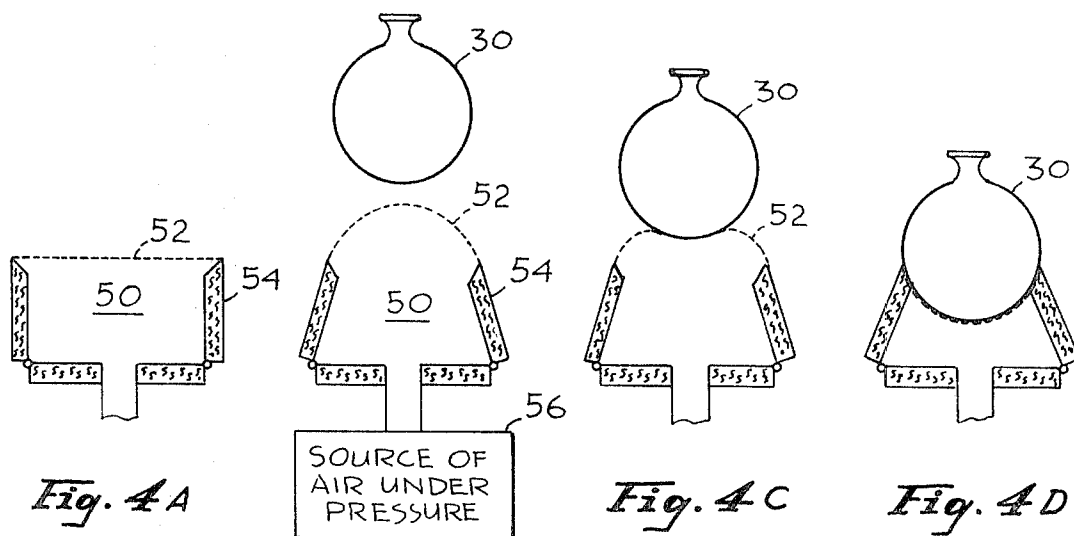
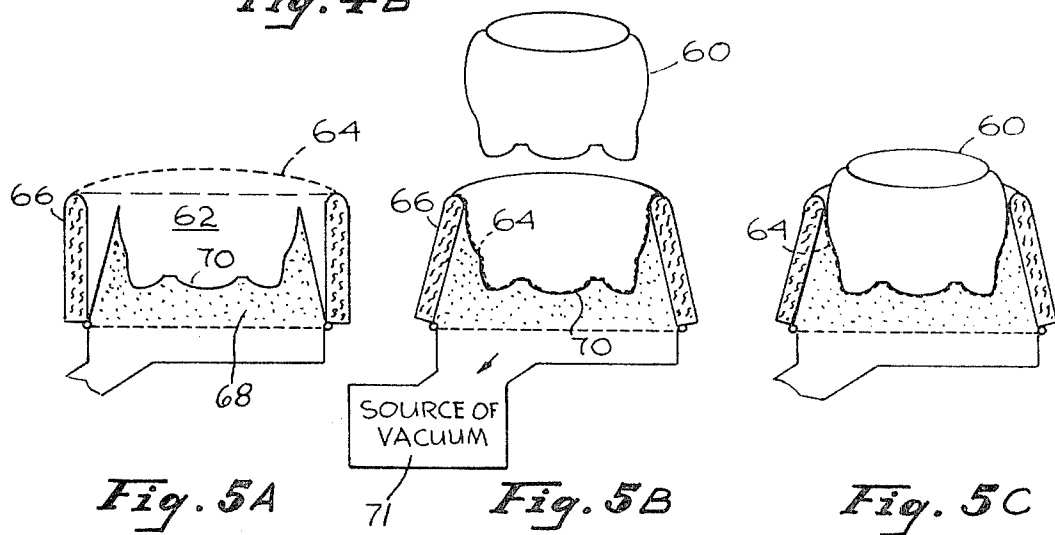
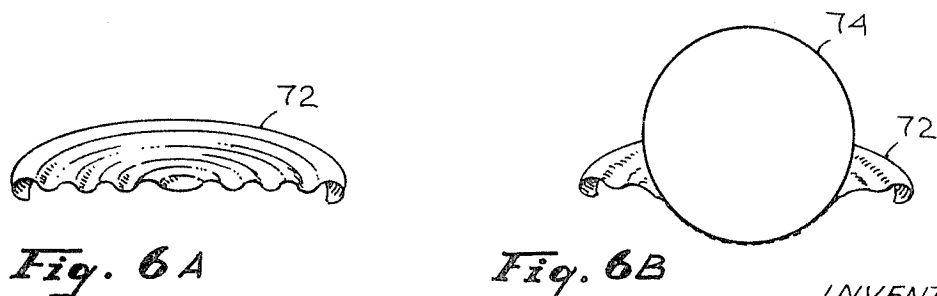


Fig. 3A

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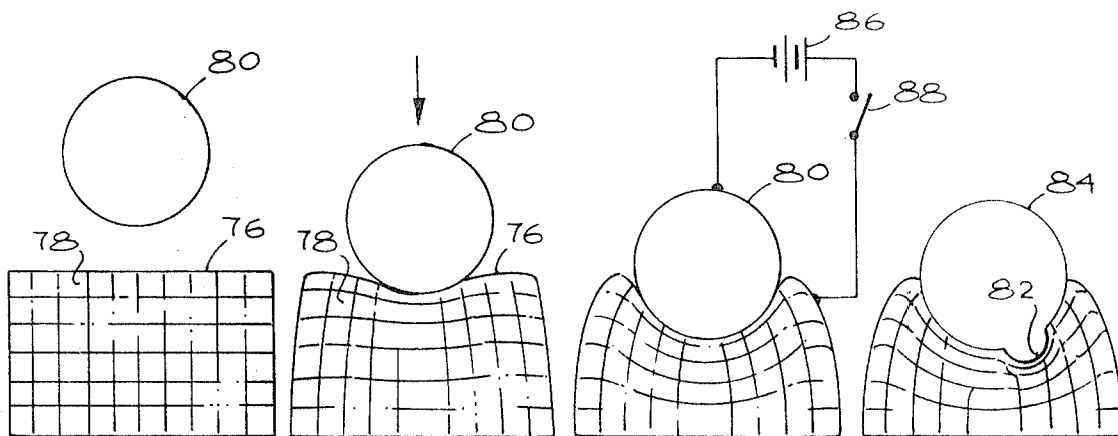


Fig. 7A

Fig. 7B

Fig. 7C

Fig. 7D

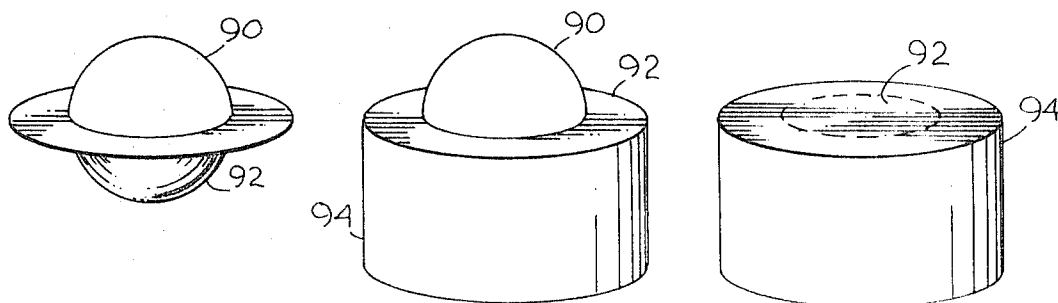


Fig. 8A

Fig. 8B

Fig. 8C

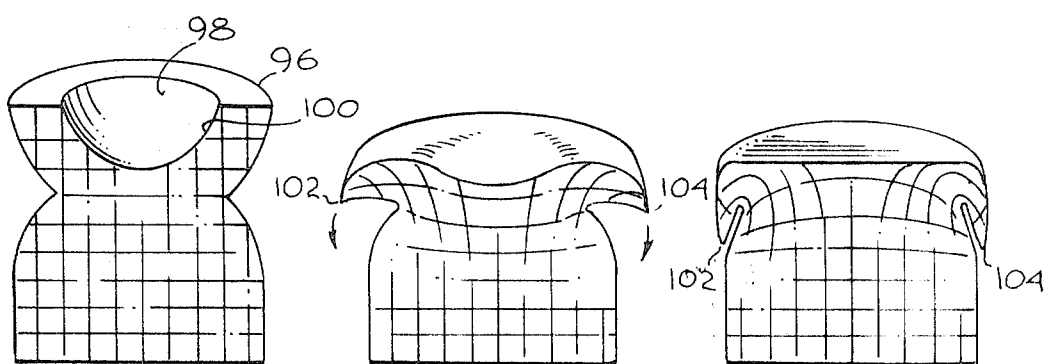


Fig. 9A

Fig. 9B

Fig. 9C

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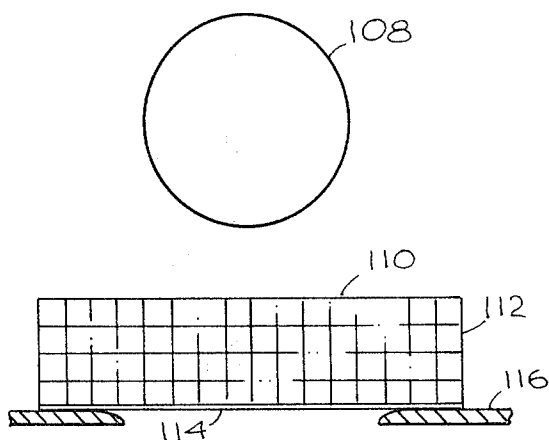


Fig. 10A

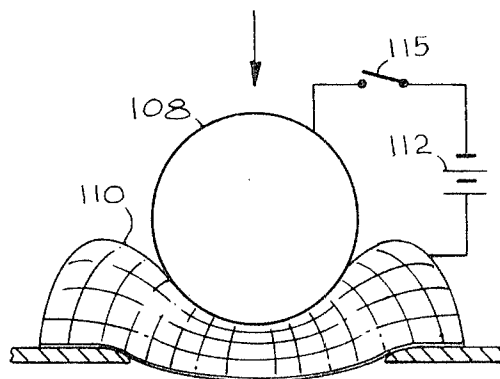


Fig. 10B

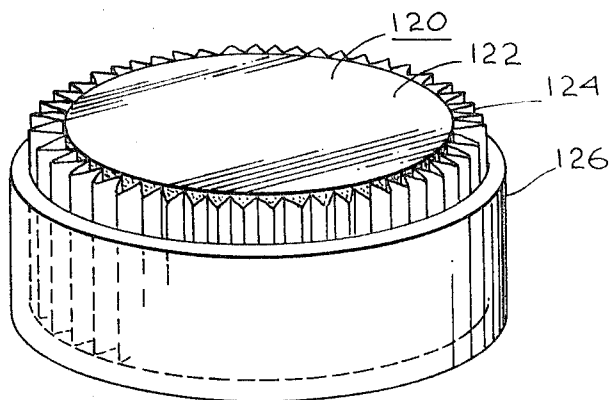


Fig. 11A

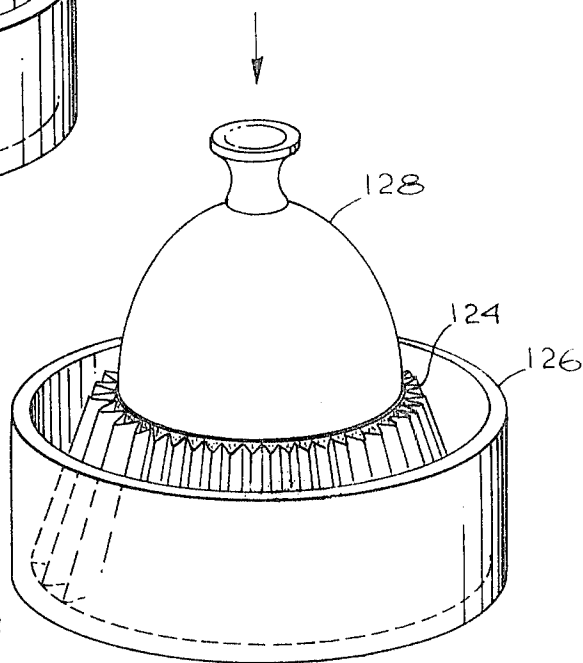


Fig. 11B

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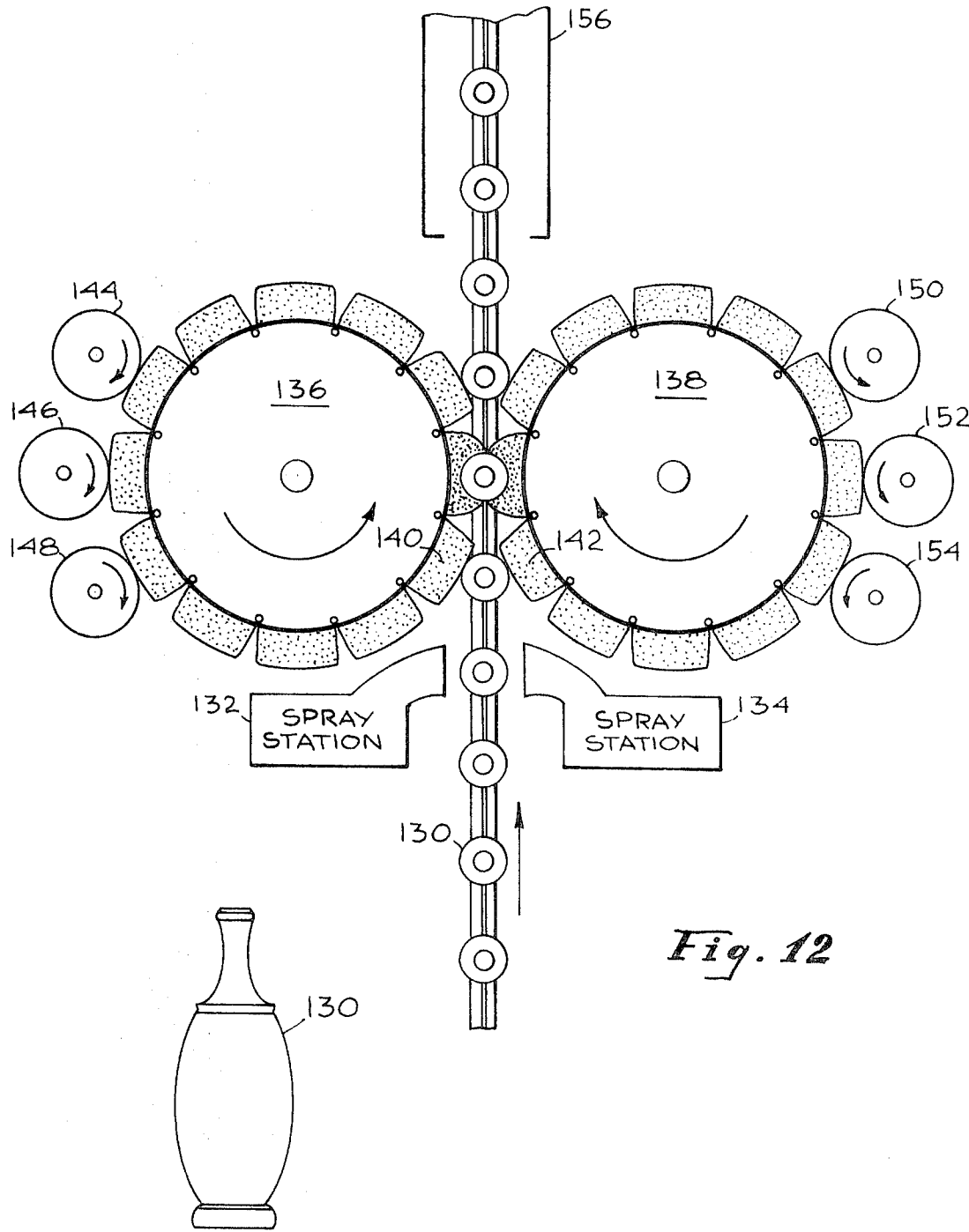


Fig. 12

Fig. 12 A

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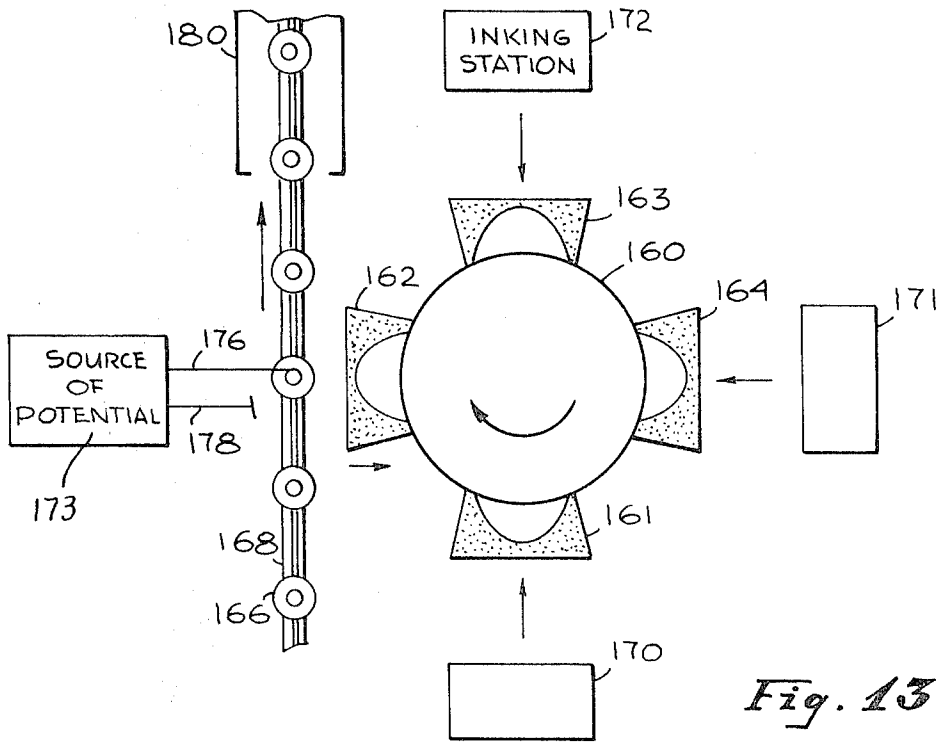


Fig. 13A

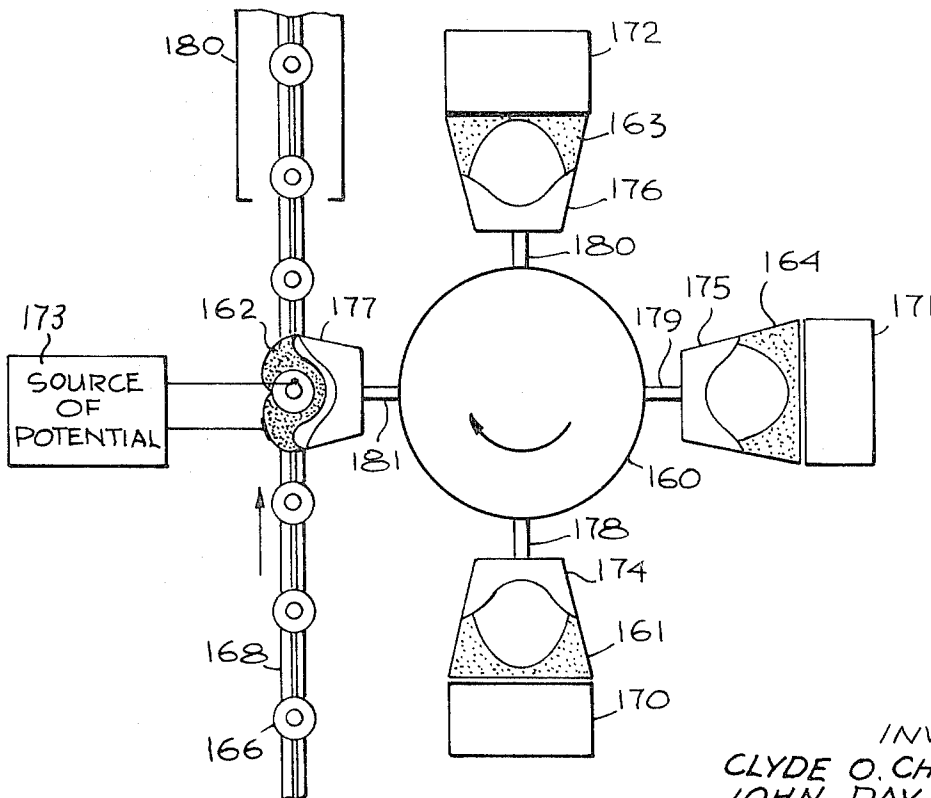


Fig. 13B

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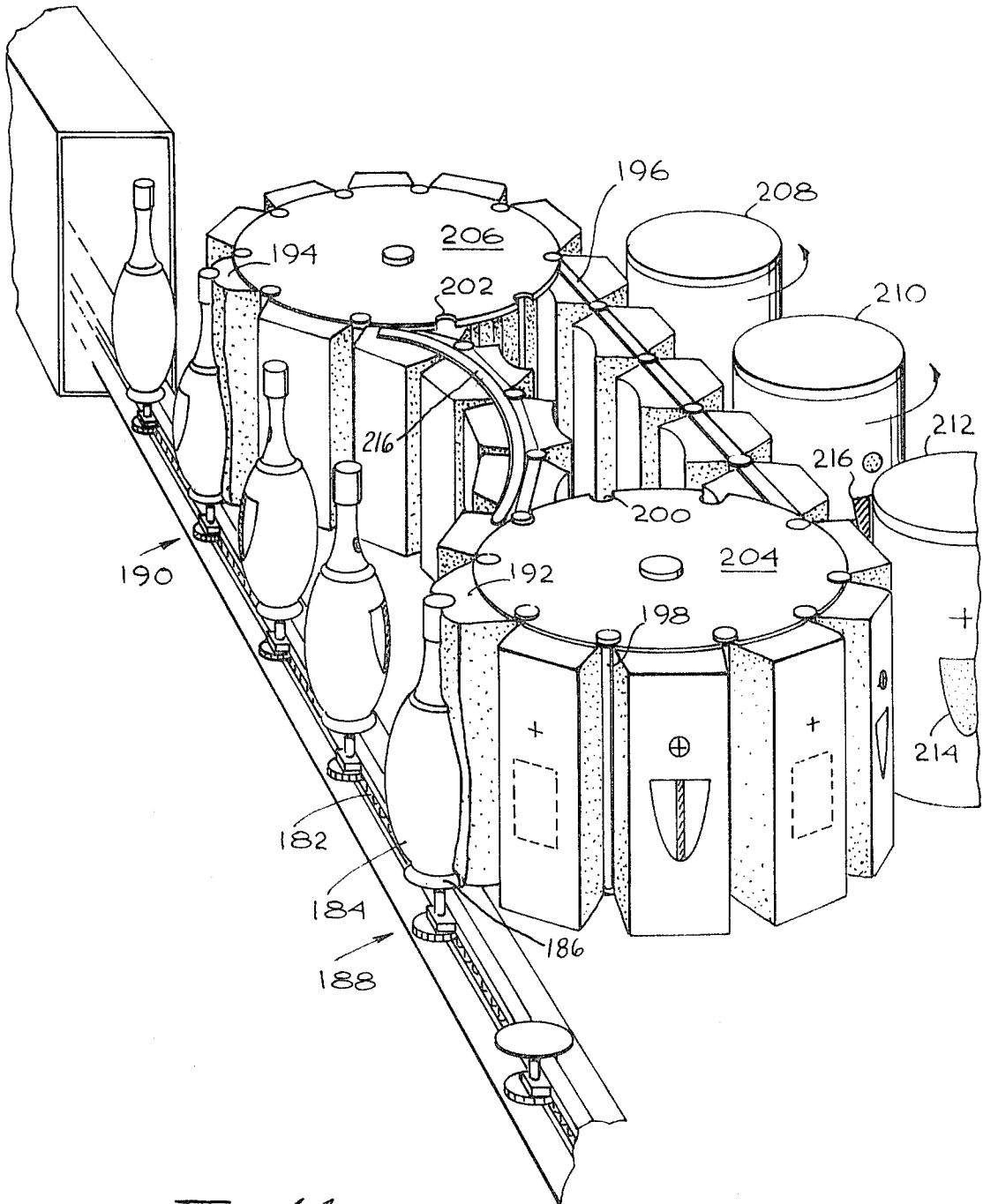


Fig. 14

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OFFSET PRINTING ON CURVED SURFACES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to offset printing and more particularly to improvements therein.

2. Description of the Prior Art

The problem of printing on objects such as containers of glass or plastic, which have curved walls, wherein the print is to cover an extensive area, still has no completely satisfactory solution. Contoured screens are used in some instances, which are matched to the gross container shape. Or where the container has a simple cylindrical or conical shape, it is rotated adjacent to a flat screen in synchronism with a suitable feed of ink through the screen. Where complex contoured surfaces require printing however, the use of contoured image screens has been resorted to. However, these are difficult to fabricate.

OBJECTS AND SUMMARY OF THE INVENTION

An object of this invention is the provision of an arrangement for enabling the printing on a wide variety of complex surface shapes without resorting to shaped image screens or the use of rotational juxtaposition of an object to a flat screen.

Another object of this invention is the provision of a novel offset printing technique whereby printing is afforded on a wide variety of complex surface shapes.

Still another object of this invention is the provision of a relatively inexpensive offset printing arrangement for printing on a wide variety of complex surface shapes.

These and other objects of the invention are achieved by employing an intermediate carrier surface such as a prestressed elastic membrane, or the surface of a porous material, either of which has the property that it can be deformed in such a manner that the surface will envelop the required area of the shaped object upon which the printing is to be transferred without wrinkling and without allowing relative movement or sliding between the object surface and the transfer surface as they are brought into conforming contact and removed from such contact. The image is first transferred to the intermediate carrier surface by any suitable means. The image carrier surface is then brought into contact with the receiving surface. Transfer from the intermediate carrier surface to the receiving surface is accomplished by suitable means such as by the application of an electric field or by a prior surface preparation of the image receiving surface with a suitable liquid.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B illustrate an arrangement for obtaining printing contact between a membrane intermediate carrier and a cylindrical surface;

FIGS. 2A and 2B illustrate an undesirable arrangement for obtaining printing contact between a membrane intermediate carrier and a spherical surface;

FIGS. 3A, 3B, and 3C illustrate an arrangement, in accordance with this invention, for offset printing on a spherical surface;

FIGS. 4A through 4D show, in section, an offset technique, in accordance with this invention, using predistortion;

FIGS. 5A, 5B, and 5C show, in section, another offset technique in accordance with this invention;

FIG. 6A and 6B show, in section, how to perform a membrane to secure offset printing in accordance with this invention.

FIGS. 7A, 7B, 7C, and 7D show another offset printing arrangement, in accordance with this invention;

FIGS. 8A, 8B, and 8C illustrate another arrangement for offset printing, in accordance with this invention;

FIGS. 9A, 9B, and 9C illustrate another arrangement for offset printing, in accordance with this invention;

FIGS. 10A and 10B illustrate how offset printing may be achieved, in accordance with this invention, using a thin foam pad;

FIGS. 11A and 11B illustrate an offset printing arrangement in accordance with this invention, using a pleated wall; and

FIGS. 12 and 12A, 13A, 13B and 14 illustrate practical realizations of offset printing using inventions described herein.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. 1A and 1B illustrate an arrangement for obtaining a conforming contact between an intermediate carrier and the surface of an object upon which it is desired to print using an offset printing technique. The object, by way of example, may be a cylindrical container 10. The intermediate carrier 12 may be a flexible member which is held stretched flat by means of the springs 14, 16, 18, and 20. Two rods 22, 24 are in contact with the bottom part of the carrier 12.

The printing 26 desired is placed on the surface of the carrier. The printing may be applied to the intermediate carrier in any of the ways known in the art, including silk screen printing or electrostatic printing, in the manner described in U.S. Pat. No. 3,081,698 to Childress, et al.

As shown in FIG. 1B, the cylindrical object 10 is moved downward until all of its surface area upon which printing is to occur is in contact with the corresponding surface area of the intermediate carrier. The mechanism for transferring the printing may be by the use of an electric field which is established between the cylindrical object and a backplate 26. A source of potential 28 is connected across these two to establish the electric field.

While the technique for printing which is shown in FIGS. 1A and 1B may be suitable for printing over a large area of a cylindrical surface, it is not capable of conforming to deeply textured surfaces, or to surfaces having local surface relief decorative variations, or to surfaces with an appreciable complex curvature. To print on a complex curved surface such as that of a hemisphere, the carrier membrane must be more freely deformable. A hemisphere or similar shape with a substantially smooth surface may be printed by using a tensioned elastic membrane as an intermediate carrier surface. However, it is difficult to print a substantial portion of a sphere by this method without slippage between the carrier surface and the sphere due to the progressively increased tension as the surfaces mate. This generally results in smearing of the image and great distortion due to the much greater surface of the receiving hemisphere which is twice that of the flat membrane of the same diameter. This is also not capable of achieving contact with small scale local variations of surface contour.

FIGS. 2A and 2B illustrate in section a container 30 which has a substantially spherical surface upon which it is desired to print using an intermediate carrier diaphragm or membrane 32. From FIG. 2A one can obtain an idea of the relative differences in surface area between the intermediate carrier 32 and the spherical surface of the container 30. As shown in FIG. 2B, when the container 30 has its spherical surface pushed into the intermediate carrier 32, the surface of the intermediate carrier stretches to accommodate the spherical surface and in doing this, as the container 30 is forced into larger and larger area contact with the intermediate carrier surface, the intermediate carrier surface under goes progressively increased tension resulting in a smearing of the image and distortion.

FIGS. 3A, 3B and 3C illustrate a technique for overcoming this problem, in a manner in accordance with the teachings of this invention. FIG. 3A is a plan view and FIGS. 3B and 3C are views in cross section. An intermediate carrier or membrane 34, having previously had printing thereon, is initially stretched flat across four or more vertical support members respectively 36, 37, 38 and 39. Each of these is pivotally supported on pivot members respectively 40, 41, 42, 43. As shown in the cross-sectional view, at the other end of each of the opposite vertical support members, 36 and 38, for exam-

ple, there are pivotally attached two transverse members respectively 44, 46. The other ends of all of the transverse members are pivotally attached to a center member 48.

It should be noted that the membrane 34 is represented as a dotted line for the purpose of illustrating its configuration as against the spherical container in FIGS. 3A and 3B.

FIG. 3B shows the various structures of the printing arrangement before the printing contact operation. FIG. 3C shows the arrangement of the printing operation during the actual process of printing. The spherically surfaced container 30 is lowered into contact with the diaphragm 34 until the diaphragm encompasses the full area of the container upon which printing is to occur. As shown, the member 48 is raised or moved upward as the container is moved downward which results in the progressive decrease of the peripheral tension on the membrane as the spherical surface is brought progressively into contact therewith. By this means the minimum tension necessary to achieve smooth progressive contact is maintained throughout to operation of bringing the two surfaces into contact. This minimizes the tendency of the membrane to creep on the surface with consequent smearing of the image. Again, the transfer of the print which was placed on the membrane prior to its being brought into contact with the container can be done by any number of known methods.

FIGS. 4A through 4D illustrate in section another arrangement, in accordance with this invention, whereby offset printing of a complex surface may be accomplished. In FIG. 4A, an air plenum 50 is defined by the region between an elastic membrane 52, which is supported on the top surface of a cylindrical wall 54, which is made of a material such as a compressible closed pore foam. This pore foam must have sufficient strength to hold the membrane 52 flat for receiving an image thereon. The application of the image to the top surface of the membrane may be by any of the known methods such as silk screening or electrostatic printing whereby electroscopic powder particles are applied to form the image desired to be transferred to a body or container 30 having a complex surface.

Air is emitted into the plenum 50 from a source of air under pressure 56. It causes the membrane 52 to distend outward and causes the compressible walls 54 to collapse inward. The object 30 is thereafter brought into progressive contact with the membrane 52 which permits a smooth progressive contact, ending up in the configuration shown in FIG. 4D, with the result that there is a minimal possibility of slippage between the membrane surface and the container surface.

The arrangement shown in FIGS. 4A through 4D utilizes a predistortion of the membrane prior to contact between the surfaces. The membrane is caused to extend toward the object to an extent to substantially duplicate in form and area, but with a reverse curvature, that of the surface to be printed upon.

This general technique may also be used with containers or objects which have concave deformations. This is shown in section in FIGS. 5A, 5B and 5C which are sectional views and show the progressive steps in printing upon the surface of a body 60, which has these types of surface variations. A plenum chamber 62, as before, is closed at the top by an elastic membrane 64 which is supported by cylindrical side walls 66, made of pore foam. A porous resilient material form 68 which is sufficiently firm to hold its shape when pressure is applied thereto is in the base of the plenum. Its top surface 71 has the same configuration as that of the surface of the object 60 upon which printing is desired. The base of the plenum is connected to a source of vacuum 70. As shown in FIG. 5B, upon the application of the low pressure air to the base of the plenum, the membrane 64 is drawn down onto the surface 70 until it conforms thereto. The side walls 66 also bend inwardly to assist in this. The object 60 is then lowered until, as shown in FIG. 5C, its surface is in contact with the correspondingly deformed surface of the membrane 64. The transfer of the printed image from the membrane to the surface of the object 60 can then occur by the application of an electric field between the two, or other known techniques.

FIGS. 6A and 6B show another variation of the membrane transfer method in accordance with this invention wherein the predistortion of the membrane occurs when it is initially manufactured. FIG. 6A shows a partial section of a membrane 72. The membrane is fabricated in such a manner that it has a surface area substantially equal to that of the surface being printed. The membrane is shaped in a manner analogous to a Fresnel lens. For the case of a hemispherical printing surface, the membrane is molded to a form which may most simply consist of a series of concentric waves of pleats such that the surface which normally reposes in a substantially flat plane is extensionable into conforming contact without gross stretching of the membrane. An arrangement of this type is possible only because of the ability to print thereon using the electrostatic screen process of the above indicated Childress et al. patent whereby a powder image may be transferred to the membrane surface when substantially flat, as shown in FIG. 6A, and the image has substantially equal density in the hills and valleys of the membrane corrugations. FIG. 6B shows the membrane 72 being effectively wrapped around a body 74 having a cylindrical surface. No slippage occurs between the membrane and the surface of the body. An electric field is applied by connecting the body and the membrane, if they are sufficiently conductive to a source of potential. If these are not sufficiently conductive, then conductive electrodes may be employed which are placed so that the membrane and body are within the thus produced electric field.

A preferred arrangement, in accordance with this invention, which seems easiest to use and is most adaptable to high speed operation utilizes the surface of a fine texture open pore foam of a suitable elastomer as a transfer carrier for the print. A suitable material is a urethane foam manufactured by the Scott Paper Company under the trade name of "Scottfoam." The essential characteristics are that the material has extremely free compressibility and relatively high strength in tension. The action of such a material, when compressed by a contoured object surface may be seen in section in FIGS. 7A through 7D.

In FIG. 7A, the intermediate carrier comprises a block of an open pore foam elastomeric material 76 such as the urethane which has been mentioned. The end surface of this material is ruled off into a grid 78, for the purpose of illustrating the behavior of the material when it is compressed by the application thereto of the object 80, upon whose spherical surface printing is to occur. The printing is deposited on the surface of the block of material by an electrostatic printing technique such as that described in the Childress et al. patent. Thereafter, as may be seen in section in FIGS. 7B and 7C, the spherical surface upon which printing is desired is pushed into the urethane foam block to a depth which insures that the surface to be printed on is in contact with the surface of the urethane block. The deformation of the grid pattern 78 in FIGS. 7B and 7C illustrates the conforming action of the material as the sphere is depressed thereinto. It should be appreciated that because the material is freely compressible substantially equal pressure is exerted on the surface of the sphere by the opposing material, on the lowest point of the opposing material to the point near where the foam surface no longer touches the sphere. FIG. 7D shows the compression response of the foam to an abrupt local contour change 82 in an object 84. The length of the contacting cross section line of the foam surface is substantially the same as the line defining the surface of that portion of the sphere contacting the foam. The circular area depressed by a full hemisphere has a diameter substantially equal to the contacting circumference of this sphere. Accordingly, the foam contacting surface is approximately 1.23 times the hemisphere surface. The peripheral surface of the contacting foam is not stretched, as it would be with a taut elastic membrane, but is compressed so that a circle defined by the outer most contacting area is approximately 57 percent shorter than it is in its original flat state.

Referring back to FIG. 7C, the arrangement for transferring the powder image from the surface of the urethane foam to the spherical object 80 may be by the application of a poten-

tial from a source 86 which is connected across these objects through a switch 88. If the proper polarity potential is applied with respect to the polarity of the charge of the electroscopic powder used in making the powdered image, the powder image is transferred to the spherical surface 80 and remains there after the foam is removed.

It should be appreciated that in order to establish the transferring electric field between the powder image carrier and the image receiving object surfaces, a resistive region therebetween or inclusive must be established. This may be provided by the electrical properties of the image carrier, or image receiver, or by applying resistive coatings to their surfaces which provide the necessary resistance. The urethane foam has these resistive properties. The powder used for printing if thick enough and if nonconductive, can also provide this.

Since the cut surface of an open pore foam may present as little as 3 percent actual surface to receive the powder image, it may be necessary to modify this surface to retain the image deposit and prevent its loss into the depth of the foam. This may be done by increasing the closed surface and/or by electrical means. The surface changes must not interfere significantly with the compressive characteristics of the foam material and must not wrinkle when subjected to the area compression necessary to encompass the contours of the surface being printed.

One further characteristic is required of a surface in those applications where the surface must conform to depressions in the image receiving surface which is so situated that air might be trapped within the concavity formed between the two surfaces and thus prevent contact of the carrier surface with the object surface. In this case, one of the surfaces must be perforated or must be textured or grooved to allow air to escape either through the foam or along the surface. A number of techniques have been devised to provide the required surface or skin behavior.

In one obvious arrangement, the skin surface of the intermediate carrier may be made of a multiplicity of discrete small lands which allows the compression of the foam surface to take place but which provides sufficient closed surface area so that the image is not textured upon transfer to the receiving surface. A second arrangement is to texture or pleat the surface skin to allow controlled small scale folding to compensate for the required compression of the surface area.

Yet another arrangement may be to use a prestressed elastic film in combination with the foam, which has been formed or stretched to the contours of the final receiving surface prior to the attachment of said film to the foam surface.

A prestressed elastic film may be used, which has been formed or stretched to the contours of the final receiving surface, prior to the attachment of the film to the foam surface. The foam surface is first depressed or deformed to the position it will assume when conforming with the surface upon which printing is to occur. Thereafter the film surface is adhered to this depressed foam surface. The foam structure is then permitted to recover its original plane surface and the skin will retain the proper elastic response to reconfirm to the object thereafter.

FIGS. 8A, 8B and 8C illustrate in cross section an arrangement for obtaining prestressed skin. An object 90, which has the surface shape identical with the object upon which printing is desired has covering surface area thereof, upon which printing is to occur, covered by a thin elastic membrane 92, such as of rubber. The membrane is stretched evenly to the minimum tension necessary to avoid wrinkles around the center of the spherical surface.

As may be seen in FIG. 8B, a foam structure 94 has its surface covered with a thin adhesive layer, as is the surface of the membrane 92. The sphere and its partially converging membrane are depressed into the foam structure and are maintained depressed until the membrane adheres to the foam structure.

FIG. 8C, shows that the sphere is removed permitting the foam to recover its original shape. The skin 92 is now prestressed, and for printing it will assume the surface of the object to be printed upon without wrinkling or stretching. Other spherical objects upon which printing is desired are pushed into the foam to receive printing, in the manner shown in FIG. 8B.

Another arrangement for using prestressing techniques is shown in cross section in FIGS. 9A, B and C. A block of foam structure 96 has a recessed shape 98 cut therein whose contours will fit the contours of the object surface to be decorated. The elastic film surface 100 is attached by suitable adhesive to the recessed surface.

As shown in FIG. 9B, the edges 102, 104 are then pulled down, tensioned, and finally assume the position shown in FIG. 9C. The edges are pulled down until the recessed area assumes a stable plane surface. Thereafter, when an object having the spherical surface is applied to the prestressed surface, the edges will come back up and adhere thereto whereby the membrane will contact the printing surface of the spherical object. Obviously when the object or container upon which printing is to occur is pushed against the now presented plane surface, the ends 102, 104, will return to the configuration shown in FIG. 9A. The prestressed membrane has assumed the shape of the spherical surface upon which printing is to occur. The transfer of the ink from the membrane to the object surface is then accomplished by the application of a transferring electrical field, for example.

In the previous examples of printing, in accordance with this invention, it has been assumed that the thickness of the compressible foam material was utilized to perform the function of total contour accommodation. It may be mechanically advantageous in some instances, to use a thinner layer of foam material and to assist in the contour accommodation by permitting the foam to flex.

An arrangement which accomplishes such a purpose is shown in cross section in FIGS. 10A and 10B. A spherical object 108 is positioned above the printing surface 110 of a compressible foam material 112. The thickness of the compressible foam material is less than the thickness of the spherical object 108. An elastic membrane 114 which is held by a frame 116, approximates the function of the lower layers of foam material where the thickness of the foam material exceeds that of the object upon which printing is to occur. The frame 116 has an appropriately shaped opening to accommodate the extrusion therethrough of the foam material which occurs, when as shown in FIG. 10B, the object is depressed into the foam to obtain enough surface in contact with the surface 110 of the foam material so that printing will occur over the area of contact.

It should be appreciated that prior to applying the object to the surface 110, an image is deposited thereon. When the object 108 has been brought in contact with the surface 110 sufficiently to insure that the entire area to be printed is covered, then a potential from a source 112 may be applied between the foam and the object by closing a switch 115. Thereby, if the image is made of electroscopic powder particles these powder particles are caused to adhere to the object after it is removed from its contact with the surface 110. The surface 110 may have a thin diaphragm placed thereover which adheres to the underlying foam. The rectangular grid sketched over the representation of the foam indicates how substantially equal pressure is exerted on the surface of the object from its lowermost and central point of contact with the foam to the region which the foam begins to extend away from the object. Thereby, a clear printing can be achieved without any smearing. Smearing occurs when there is a difference in pressure produced over the area where printing is to occur, which pressure difference can lead to sliding motion and thus a smearing of the image.

The characteristic feature of offset printing, in accordance with this invention, is that the surface of the intermediate carrier is maintained free to converge toward the object upon

which printing is to occur as the object is pressed into the off-set carrier. This feature is called the conforming characteristic of the carrier. The conforming characteristic of the foam may be controlled by a modification to control the compressibility and recovery rate. This may be done by increasing the localized resilient response of the foam material, by coating the foam structure filaments in local areas with resilient elastic coatings. Using a hypodermic needle, one may inject additional filaments of self-vulcanizing elastomers into the structure, and by appropriate laminations or insertions of stronger or weaker elastic of flexible materials.

The most valuable use of techniques for controlling compressability and recovery of the urethane foam may be utilized to control the outer wall of the structure that must collapse or lean toward the center as an object is depressed into the surface of the structure. Various structures have been devised that are effective for this purpose, such as a wall or closed core resilient polymer foam (a product manufactured and sold as "Insulite,"TM) which is laminated to the peripheral wall of the carrier structure. Other techniques have used spaced vertical strips of thin fiberglass epoxy laminate.

FIGS. 11A and 11B illustrate how a wall may be reinforced to control its resilience. In FIG. 11A there may be seen a block of foam 120, having a prestressed membrane 122 over its surface. The outer wall of the foam is adhesively adhered to a folded or pleated steel wall 124 which surrounds the wall of the foam. This spring wall may be operated with a secondary rigid wall 126. FIG. 11B shows a container 128 which is inserted into the carrier to have printing applied to the surfaces thereof. It will be seen that the wall folds inward and away from the rigid wall 126.

The wall 126 of FIG. 11A may be mounted over an opening in the manner shown in FIG. 10, to allow less depth of foam to be used than would be otherwise required. This opening may be backed by a closed plenum. An additional tangent elastic member is adhered to the bottom of the foam placed over the opening in the plenum. The plenum may be attached to a source of air pressure which is controlled to inject air, after completion of an image transfer cycle, to accelerate the recovery of the carrier to its original plane shape. Proper regulation of the air pressure may be used to compensate for fatigue of the foam structure that may take place after the long, continuous operation.

While the operation of transferring a powder image form the intermediate carrier to the object has been described herein as being performed by the application of a transferring electrical field, in accordance with this invention, other arrangements may be employed. One such arrangement for effectuating the transfer may be by the application of a thin layer of a suitable liquid over the surface of the object to be printed whereby the powder image deposit may be made to adhere preferentially to the object surface. It is not necessary and is generally undesirable that this liquid wet the powder image deposit in depth, nor is it generally desirable that it have a solvent action on the powder material. Inert liquids leaving essentially no residue on the container surface have proven most effective, although it is possible to utilize material that may be desirable on the final surface of the object. An example of one of these materials is a silicone emulsion which is used as a lubricant for glass surfaces and also as an antistatic coating for plastic containers. A thin moistened layer of the silicone emulsion is applied to the object upon which the printing is to occur over the surface region where the printing is to be applied. A thin moistened layer is capable of creating a bond with the uppermost layer of the powder image deposit, which bond is substantially stronger than the electrostatic bond which exists between the surface of the carrier and the powder image. The internal cohesive forces that bind the powder particles to each other are not disturbed and may, in fact, be enhanced by exerting pressure between the surfaces which brings the individual particles into more intimate contact. In this manner an image may be transferred intact to the final object surface.

A wide range of liquids have been found suitable for forming this thin transfer line. For example, various alcohols, mineral spirits, glycerin, and glycol have been used successfully. Selection of liquids is dictated by the method of application to the object surface and by the effect of the liquid on the object surface, on the transfer surface and the powdered ink. The liquid may be applied by spray or by wiping. It should wet the object surface and form a thin substantially even film. In general, it should have little or no solvent effect on the powder or the object surface.

FIG. 12 is a schematic arrangement, shown in elevation, of an apparatus for printing on irregularly shaped objects such as bottles, in accordance with this invention. FIG. 12A is an example of the shape of a bottle upon which it is desired to print. The bottles 130 are carried on a conveyor past two spraying stations respectively 132, 134. The spray used on the bottles can be one of those previously mentioned, such as alcohols, mineral spirits, glycerin, glycol and/or dimethylpolysiloxane. The bottle which is so coated is then carried between two revolving drums respectively 136, 138. The drums have affixed to their surfaces a plurality of spaced foam pads respectively 140, 142. The drums rotate in the manner indicated by the arrows. As the drums rotate, each one of the respective pads is passed by three linking stations, respectively 144, 146, 148 and 150, 152, 154. Each one of the inking stations comprise an electrostatic drum printer of the type shown in the aforesaid patent to Childress et al.

The three inking stations for the respective drums 136 and 138 deposit a three color image on each pad as it passes by these inking stations. Accordingly, when a bottle is moved into the region at which the drums are closest to one another, the pads effectively enclose a bottle and thereby the powder image is transferred from the foam pads to a substantial region of the bottle surface. As the conveyor line continues to move, the bottle passes from between the two pads and into a fixing chamber 156 wherein the image transferred to the bottle is fixed by heat.

Another arrangement for a production line, utilizing the techniques in accordance with this invention is shown in FIGS. 13A and 13B. Here a central rotatable drum 160 has mounted about its periphery inking pads 161, 162, 163, and 164. The bottles 166 are carried on a conveyor 168 past a printing station. There are three stations respectively 170, 171 and 172 which are provided for applying the three color images to the image receiving surfaces of the pads 161 through 164. The image receiving surface of each pad will comprise a membrane of the type described.

Each inking station may comprise an image screen with a suitable arrangement for transferring a powder image to the image receiving surface of the intermediate carriers 161 through 164. These inking stations again, may comprise arrangements such as are shown and described in the aforesaid Childress et al. patent.

At the image transfer station, a source of potential 173 is provided. It has two flexible contacts respectively 176 and 178. A bottle strikes a contact 176 when it reaches the image transfer station. The contact 178 will connect with the particular one of the printing pads which is extended to envelop a bottle at the image transfer station. It will be appreciated that in FIG. 12a the printing pads are all shown retracted. In FIG. 12b, the printing pads are all shown extended. Each pad is supported on a carrier respectively 174, 175, 176 and 177. Each one of these carriers in turn is supported by an extendable and retractable arm respectively 178, 179, 180 and 181. The mechanism for extending and retracting these arms and for turning the drum 160 a quarter of a revolution when each of these arms is retracted and thereafter to extend these arms is simple mechanical structure.

The center of each pad is cut out so that each pad is supported by its ends on the respective supports 174, 175, 176, and 177. A diaphragm is attached to the inside of each pad in the manner described in connection with FIG. 10A and 10B.

The conveyor belt 168 brings a bottle to the image transfer location. At this time all of the arms extend the pads. The three pads opposite the inking stations at this time receive an image while the fourth pad, which is at the image transfer station, effectively wraps around the bottle and contacts the source of potential whereby the image is transferred to the bottle. The arms are thereafter retracted. The drum 160 then makes another quarter turn. A new bottle is brought into position. All the pads are then moved outwardly to repeat the cycle just described. A fixing chamber 180 serves to fix the powder images which have been transferred to the bottles. From the foregoing description it should be appreciated that a three color image is deposited on each pad prior to its arrival at the image transfer station. This three color image is transferred in a single contact with the bottle.

There has accordingly been described and shown herein a novel, useful offset printing system wherein the offset image carrier is made of a material which enables the image carrying surface of the image carrier to conform to the surface of an object having a complex surface, in such a manner so that slippage is rendered substantially minimal between the surface of the carrier and the contacted surface, and the surface of the carrier is applied with a substantially equal pressure over and to all of the contacted surface of the object. A transfer of the image previously deposited on the surface of the carrier to the surface of the object can then be achieved in a number of ways including the application of an electric field or by the preliminary wetting of the surface of the object, etc.

FIG. 14 is perspective view illustrating another example of how the foam pads may be used to achieve offset printing in accordance with this invention. A conveyor 182 carries bottles 184 by means of suction fixtures 186 past image transfer locations 188, 190. It should be understood that each bottle is also held by a top conveyor attachment similar to the one shown on the bottom of the bottle. This has been omitted from the drawing in the interest of clarity. However, it is required to insure that each bottle is held firmly at each image transfer station. These image transfer locations are defined as the locations at which foam pads 192, 194 respectively apply to the bottle, a front image and a back image, or the two images which cover the bottle. The bottle is rotated 180° between the image transfer location 188 and 190. Any suitable technique may be employed for achieving image transfer, such as the electric field technique or the prewetting technique previously described.

The foam pads are supported one adjacent the other between two spaced flexible bands, 196 (only one of which may be seen). The bands are maintained spaced apart by tie rods 198, which in turn are spaced horizontally from one another by the distance between foam pads.

The tie rods fit into notches 200, 202, which are cut at the edges of two spaced, rotatably supported discs respectively 204, 206. There are similar spaced underlying discs which are not seen here. These discs serve as a backing for the tie rods which to turn strengthen and space the flexible bands 196. As the two discs 204, 206 (which have counterparts not shown, at the lower portion of the tie rods), rotate, each foam pad is passed by three rotating drum printers respectively 208, 210, 212. These rotating drum printers apply a three color image to each one of the pads. These images are alternately the front and the back images which are applied to the bottles. The rotating drums will each have two image screen respectively 214, 216, one of which applies the front image and the other applies the back image to alternate pads. In this manner, none of the pads is missed as it passes by a drum printer. The drum printer may be of the type described and shown in the Childress et al. patent.

Accordingly, the operation of the system schematically shown is one wherein each pad passes by the three drums which are rotating, to receive therefrom the three color image of either the front or the back image to be applied to the bottle. After the pads pass the three drums, the rods engage the notches in the rotating disc 204 and are carried to a first image

transfer station where the bottle is pressed into the foam so the approximately half of the bottle's surface is in contact with the foam. The front image is transferred to the bottle at that location. The bottle is then conveyed away from the first image transfer location, rotated 180° and conveyed to a second image transfer location. The foam pads are carried away from the first image transfer location, and are given an arc by way of a slotted guide 216, which serves to move the bands and thereby the pads out of the way of the bottles and also serves to tighten up the bands so that they are more positively engaged by the slots of the respective discs 204, 206. Also, the arc lengthens the travel of the foam pads over the travel of the bottle conveyor sufficiently to skip a pad over the arc distance. Thereby at the second image transfer location an alternate pad is brought into printing contact with a bottle. An alternate arrangement to the foregoing would be to move the pads in a straight line and to put a jog in the bottle conveyor belt.

At the second image transfer location 190, the back side of the bottle is pressed into the foam pad to effectuate image transfer. The bottles are then carried by the conveyor into the fixing oven 212.

Although particular embodiments of the invention have been described and illustrated herein, it is recognized that modifications and variations may readily occur to those skilled in the art and consequently it is intended that the claims be interpreted to cover such modifications and equivalents.

We claim:

1. An offset printing system for printing on the surface of an object having a curved surface comprising a resilient deformable image carrier having a portion thereof on which a powder image to be transferred to said object is deposited,

means for nonrotatably and progressively pressing said object curved surface against the portion of said image carrier upon which said image is deposited until all of said portion of said image carrier covered by said powder image conforms to said surface of said object,

movable, yieldable and restorable support means for supporting said portion of said image carrier upon which said image is deposited for progressively decreasing any peripheral tension which is caused thereon by said curved surface being progressively pressed into contact therewith for minimizing slippage and for establishing a substantially uniform pressure between the two contacting surfaces,

said support means being substantially inextensible and movable to pivot inward toward said object to permit movement of said image carrier as said object impinges thereon to alleviate increase in peripheral tension on said image carrier,

means for transferring said image from said image carrier to the surface of said object, and

means for separating said image carrier from said object.

2. An offset printing system as recited in claim 1 wherein said portion of said, image carrier is a yieldable membrane having ends, and there is included means for yieldably predistorting said membrane when an object is not in contact therewith to provide substantially nonslipping intimate contact with the surface of said object as said object is brought in intimate contact therewith.

3. An offset printing apparatus as recited in claim 2 wherein said means for predistorting said membrane comprises means for resiliently closing the ends thereof to form a closed chamber therewith, and means to predistort said membrane to a form substantially duplicating that of the surface to be printed including means for applying air pressure to one side of said membrane.

4. Offset printing apparatus as recited in claim 2 wherein said portion of said image carrier has the form of a series of concentric waves.

5. Apparatus as recited in claim 2 wherein said means for predistorting said membrane comprises a porous resilient elastomeric foam material, and there is included means for at-

taching said membrane to said material while said membrane is stressed.

6. An offset printing system as recited in claim 1 for printing on the surface of an object having a curved surface wherein there is included a means for holding said image carrier under peripheral tension.

7. Apparatus as recited in claim 1 wherein said resilient, deformable image carrier comprises a block of a resilient, compressible foam material, and a prestressed membrane adherent to a surface of said material to be resiliently deformable therewith.

8. Apparatus as recited in claim 1 wherein said deformable resilient carrier comprises an open pore foam of an elastomeric material which is yieldable in compression and substantially nonyieldable in tension when compared to its yieldability in compression.

9. Offset carrier apparatus as recited in claim 8 wherein said elastomeric material comprises urethane foam.

10. Apparatus as recited in claim 8 wherein said surface of said object over which said image is printed encompasses a portion of the volume of said object, and said elastomeric material has a thickness which exceeds the thickness of said portion of said volume of said object being printed upon.

11. Apparatus as recited in claim 8 wherein said surface of said object over which said image is printed encompasses a portion of the volume of said object,

said elastomeric foam has a thickness which is less than the thickness of said portion of said volume of the object being printed upon,

there is included means for supporting said elastomeric foam comprising rigid support means for supporting said elastomeric foam by its edges, and

there is included a resilient diaphragm stretched across the printing surface of said elastomeric foam.

12. Apparatus as recited in claim 11 wherein there is a resilient diaphragm stretched across the surface opposite to the printing surface of said elastomeric foam.

13. An offset printing system for printing on objects having image receiving surfaces comprising a plurality of offset carrier means, each consisting of a block of porous foamed elastomeric material having an image receiving surface on which an image is applied and a back surface which is opposite said image receiving surface,

means for moving said plurality of offset carrier means in a closed loop path,

a plurality of means for transferring images to the image receiving surface of each block or porous foamed elastomeric material of said offset carrier means positioned adjacent the closed loop path of said offset carrier means,

conveyor means for carrying objects to said closed loop path for nonrotatably pressing each object into an offset carrier means to compress said carrier means to a depth required to encompass at least substantially 90° of the periphery of said object required to press all of the image receiving surface of said object upon which printing is to occur against all of the image on said offset carrier means, means for supporting each block of elastomeric material by its back surface to provide a compression response to the pressure of said object in which the ends of said

elastomeric block adjacent its image receiving surface are bent inward toward said object and at least two of the ends of said back surface are retained substantially immovable.

means for transferring the image on said carrier means to said object while said object is pressed into said carrier means, and

means for fixing the image on said object.

14. Apparatus as recited in claim 13 wherein said conveyor means includes means for carrying each of said objects twice to said closed loop path and for rotating each object therebetween to achieve a front and back contact and printing of an object by two different offset carrier means.

15. Apparatus as recited in claim 12 wherein there are two means for moving said offset carrier means into two closed loop paths,

said conveyor means carries objects between said two closed loop paths, and

said closed loop paths are established sufficiently adjacent to one another to cause said offset carrier means on each conveyor to be pressed against an object therebetween to afford substantially simultaneous printing over substantially 360° of the surface of said object.

16. A system for offset printing an electrostatic powder image onto the surface of an object, said system comprising:

carrier means including a resilient compressible pad of an elastomeric porous foam material having a front surface and a back surface,

a prestressed elastic membrane bonded to the front surface of said elastomeric porous foam,

means for depositing a powder image on said prestressed membrane,

means for nonrotatably pressing said object against said elastic membrane to compress said elastomeric porous foam material a distance required to apply all of said electroscopic powder image to the curved surface of said object,

means for transferring the image from said carrier means to the surface of said object, and

means for removing said carrier means for contact with said surface of said object.

17. Apparatus as recited in claim 16 wherein said means for applying an image to said front surface of said carrier means comprises means for applying an electroscopic powder image to said front surface, and said means for transferring the image from said front surface to the surface of said object comprises means for establishing an electric field across said surfaces.

18. Apparatus for offset printing as recited in claim 16 wherein said means for applying an image to the front surface of said carrier means includes means for applying an electroscopic powder particle image to said carrier front surface, and wherein said means for transferring said image from said front surface of said carrier means to the image receiving surface of said object comprises means for applying to the image receiving surface of said object a liquid coating to which said powder particle image adheres when applied thereto.

19. An offset printing apparatus as recited in claim 18 wherein said liquid coating is a dimethylpolysiloxane emulsion.