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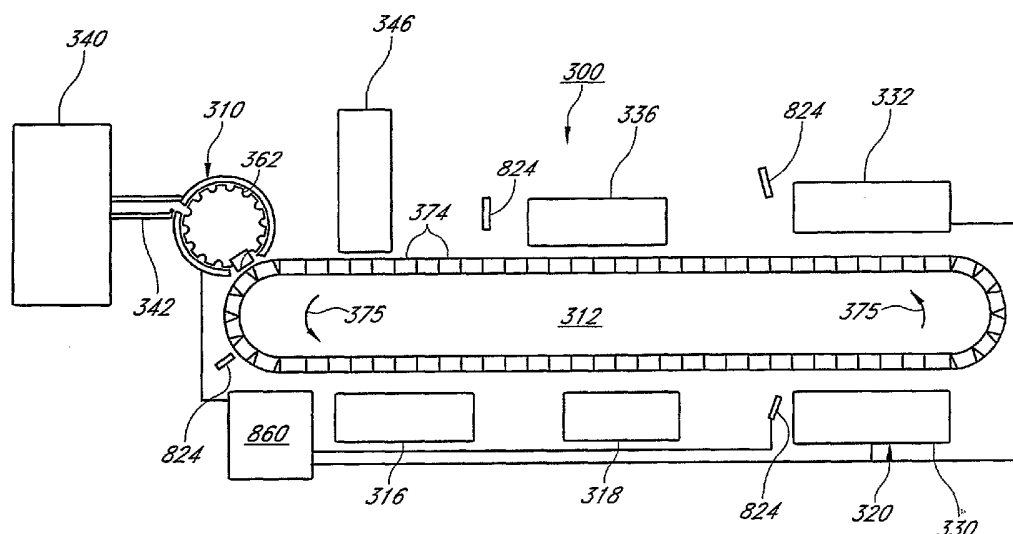
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(54) Title: COATING PROCESS AND APPARATUS FOR FORMING COATED ARTICLES



(57) Abstract: Methods and apparatus can be used to make coated articles with one or more layers. The layers can be applied by dip, spray or flow coating. The apparatuses and methods can make coated containers, preferably comprising polyethylene terephthalate, from coated preforms. In some arrangements, the apparatus and method permit the coated container or preform to be made in an energy-efficient manner that reduces the danger of coating damage and thus increases the efficacy of the final container.

COATING PROCESS AND APPARATUS FOR FORMING COATED ARTICLES

5 Related Applications

This application claims the priority benefit under 35 U.S.C. § 119(e) of the provisional applications 60/586,854, filed July 9, 2004, 60/644,044, filed January 14, 2005, and 60/672,321, filed April 18, 2005, which are hereby incorporated by reference in their entireties.

10 Background of the Invention

Field of the Invention

This invention relates to methods and apparatuses for making coated articles with one or more layers by dip, spray or flow coating. In one embodiment, this invention relates to an apparatus and method for making coated containers, preferably comprising polyethylene terephthalate, from coated preforms.

Description of the Related Art

Preforms are the products from which containers are made by blow molding. Unless otherwise indicated the term “container” is a broad term and is used in its ordinary sense and includes, without limitation, both the preform and bottle container therefrom. A number of plastic and other materials have been used for containers and many are quite suitable. Some products such as carbonated beverages and foodstuffs need a container, which is resistant to the transfer of gases such as carbon dioxide and oxygen. Coating of such containers has been suggested for many years. A resin now widely used in the container industry is polyethylene terephthalate (PET), by which term we include not only the homopolymer formed by the polycondensation of [beta]-hydroxyethyl terephthalate but also copolyesters containing minor amounts of units derived from other glycols or diacids, for example isophthalate copolymers.

The manufacture of biaxially oriented PET containers is well known in the art. Biaxially oriented PET containers are strong and have good resistance to creep. Containers of relatively thin wall and light weight can be produced that are capable of withstanding, without undue distortion over the desired shelf life, the pressures exerted by carbonated liquids, particularly beverages such as soft drinks, including colas, and beer.

Thin-walled PET containers are permeable to some extent to gases such as carbon dioxide and oxygen and hence permit loss of pressurizing carbon dioxide and ingress of oxygen which may affect the flavor and quality of the bottle contents. In one method of commercial operation, preforms are made by injection molding and then blown into bottles.

5 In the commercial two-liter size, a shelf life of 12 to 16 weeks can be expected but for smaller bottles, such as half liter, the larger surface-to-volume ratio severely restricts shelf life. Carbonated beverages can be pressured to 4.5 volumes of gas but if this pressure falls below acceptable product specific levels, the product is considered unsatisfactory.

Summary of the Invention

10 In one aspect, this invention relates to methods and apparatus for making articles, preferably plastic articles, having coatings comprising one or more layers. These layers may comprise thermoplastic materials with good gas-barrier characteristics as well as layers that provide UV protection, scuff resistance, blush resistance, chemical resistance, and/or active properties such as O₂ or CO₂ scavenging.

15 In some embodiments, a method for producing multilayer articles is provided. The method comprises delivering substrate articles to a transfer system. The substrate articles are passed along the transfer system to a loading system. The loading system places the substrate articles on carriers configured to hold the substrate articles. The carriers are selectively movable so as to carry the substrates along a processing line. A first coating

20 material is deposited onto at least a portion of each substrate article to form a first coating on each substrate article. The first coating material is removed from a lower section of each substrate article. In some embodiments, coating material is removed from the lowermost section of each substrate article. In some embodiments, a second coating is applied to at least a portion of the section of each substrate article after the first coating material is

25 removed from that substrate article.

In some embodiments, a method for producing multilayer articles is provided. The method comprises delivering substrate articles to a conveyor system. Carriers of the conveyor system are configured to hold the substrate articles. The carriers carry the substrates along a processing line. A coating material is deposited onto at least a portion of

30 each substrate article to form a first coating on each substrate article. The coating material is removed from a section of each substrate article. In some embodiments, excess coating

material is removed from each substrate article. In some embodiments, a material removal system is used to remove the material from the coated article.

In some embodiments, a coating system has a transfer system and a carousel system. The transfer system delivers substrate articles continuously or discontinuously to the
5 carousel system. In some embodiments, the transfer system batch feeds the substrate articles to the carousel system. In some embodiments, the carousel system has a loading system configured to take substrate articles from the transfer system and to deliver the substrate articles to the carousel system.

In some embodiments, substrate articles with an outer liquid coating are provided.
10 At least a portion of the outer coating can be removed by a material removal system. In some embodiments, the material removal system removes a portion of the coating in the end cap region of the article. In some embodiments, the substrate article is heated to a sufficiently high temperature to promote the coating material to recoat the portion of the article. In some embodiments, the article is self coated due to gravity causing the liquid
15 coating material to flow over the portion of each article.

In some embodiments, an apparatus for producing multilayer articles is provided. The apparatus comprises a transfer system configured to receive and carry substrate articles. A loading system comprises a plurality of loaders. The loaders are movable between a loading position and an unloading position. A plurality of moveable carriers can have
20 gripping mechanisms that are configured to hold selectively substrate articles. The loaders are configured to receive substrate articles from the transfer system when the loaders are in the loading position. The loaders are configured to deliver the substrate articles to the moveable carriers when the loaders are in the unloading position. The plurality of moveable carriers is configured to retain and carry the substrate articles along a processing line. A
25 coating unit is position alongside the processing line. The coating unit is configured to deliver material onto substrate articles retained by the carriers.

In some embodiments, movably carriers are attached to a conveyor. The carriers can have one or more gripping mechanisms. Each gripping mechanism can be dimensioned so as to fit within an interior of a corresponding substrate article (e.g., a preform or
30 container). Each gripping mechanism is movable between a first position for holding a substrate article and a second position for receiving a substrate article. In some embodiments, the gripping mechanism is in the form of a mandrel.

In some embodiments, a coating system is configured to coat substrate articles. The coating system comprises a controller in communication with the plurality of temperature sensors and a curing system configured to cure a layer of material on substrate articles. The controller selectively controls the output of the curing system in response to at least one
5 temperature signal from at least one of the sensors. In some embodiments, the temperature sensors are pyrometers or thermocouples. The temperature sensors can measure the temperature of the substrates during the production cycle.

In some embodiments, a transfer system delivers substrate articles to a carousel system. The transfer system comprises at least one starwheel system. The starwheel
10 system includes a plurality of peripheral pockets sized and dimensioned to receive substrate articles. The plurality of peripheral pockets is rotatable about a drive shaft of the starwheel system. In some embodiments, the transfer system comprises a plurality of starwheels. The starwheels can be arranged to transport substrate articles to a carousel system.

In some embodiments, a system for producing multilayer articles is provided. The
15 system comprises a conveyor system having carriers. Each carrier is configured to carry at least one substrate along a processing line. A coating system is positioned next to the processing line. The coating system comprises a delivery system that is configured to deliver coating material onto substrates retained on the carriers moving along the processing line. In some embodiments, the delivery system comprises a coating unit. A
20 modular tank system is movable and positionable with respect to the conveyor system. In some embodiments, the modular tank system comprises a tank configured to hold coating material and a pump in communication with the tank. The modular tank system is movable between a remote position and a delivery position. In some embodiments, when the modular tank system occupies the delivery position and the pump operates, the coating
25 material is delivered from the tank to the delivery system. In some embodiments, when the modular tank system occupies the delivery position and the pump operates, the modular tank system is next to the delivery system and coating material is delivered from the tank to the delivery system. In some arrangements, the conveyor system is a carousel system.

In some embodiments, the modular tank system comprises a transportation system
30 configured to roll along a support surface. The transportation system can comprise one or more wheel assemblies. In some embodiments, the transportation system comprises four

wheel assemblies mounted to a frame of the modular tank system. In some embodiments, the transportation system comprises linear slides.

The modular tank system can comprise a filtration system in fluid communication with the tank. The filtration system can comprise a plurality of filters configured to
5 removed substances or impurities from the coating material.

In a preferred embodiment, there is provided a process for the production of a coated article. The process comprises providing an article, preferably a container or preform comprising polyethylene terephthalate; applying to said article a coating of an aqueous dispersion of a thermoplastic epoxy resin to the article; and curing/drying the
10 coating. In embodiments where the article is a preform, the method preferably further comprises a blow molding operation, preferably including stretching the dried coated preform axially and radially, in a blow molding process, at a temperature suitable for orientation, into a bottle-container. In the process the thermoplastic epoxy coating is applied by dip, spray, or flow coating of the article and the coating and drying is applied in
15 more than one pass such that the coating properties are increased with each coating layer. The volume of coating deposition may be altered by the article temperature, the article angle, the solution/dispersion temperature, the solution/dispersion viscosity and the number of layers. The multiple coatings of preferred processes result in multiple layers with substantially no distinction between layers, improved coating performance and/or reduction
20 of surface voids and coating holidays. In addition, a preferred multiple coating process results in successive layers requiring decreasing amounts of coating material to thoroughly coat the article.

In preferred embodiments, the coating and drying process results in enhanced surface tension properties. Furthermore, in preferred processes, the drying process of
25 articles has a repairing effect on surface defects of the finished article. In addition, in preferred processes, the drying/curing process produces articles which exhibit substantially no blushing.

In accordance with one embodiment, there is provided a process for making thermoplastic resin coated articles, the process comprising: applying an aqueous solution or
30 dispersion of a first thermoplastic resin on the outer surface of an article substrate by dip, spray, or flow coating; withdrawing the article from the dip, spray, or flow coating at a rate so as to form a first coherent film; curing/drying the coated article until the first film is

substantially dried so as to form a first coating. Optionally, the method may further include applying an aqueous solution or dispersion of a second thermoplastic resin on the outer surface of an article substrate by dip, spray, or flow coating; withdrawing the article from the dip, spray, or flow coating at a rate so as to form a second coherent film; curing/drying
5 the coated article until the second film is substantially dried so as to form a second coating. In preferred embodiments, at least one of the first and second thermoplastic resins comprises a thermoplastic epoxy resin, and the first and second resins may be the same or different.

In accordance with a preferred embodiment, a method for dip coating articles is
10 provided comprising the steps of: a) dipping the article into an aqueous coating solution/dispersion contained either in a static vat or in a flow coater with the article rotating to achieve full exposure to the flow; b) withdrawing the article from the static vat or flow coater below the rate at which a coherent film is observed; and c) exposing the article and film to infrared heaters until the film is substantially dried, optionally while
15 cooling the article with air .

In accordance with a preferred embodiment, an apparatus for dip coating articles is provided comprising: an article conveyor that transports the articles through a dip coating system; a tank or vat containing an aqueous solution/dispersion coating material wherein the conveyor draws or dips the articles through the tank or vat; and a curing/drying unit
20 which comprises an oven or chamber in which a curing/drying source is located, wherein the articles are moved through the oven or chamber by the conveyor. The curing/drying unit is optionally coupled with a fan or blower for cooling the article with air. A preferred apparatus may further comprise a second tank or vat of coating material and a second curing/drying unit. In another preferred apparatus, the conveyor transports the articles back
25 through the tank and/or the curing/drying unit to provide a second coating on the article. A preferred apparatus may optionally include one or more drip removers positioned between the coating tank or vat and the curing/drying unit, or elsewhere before the curing/drying unit.

In accordance with another preferred embodiment, a method for coating articles is
30 provided comprising the steps of: a) spray coating the article with an aqueous coating solution/dispersion with the article rotating to achieve full exposure to the flow, b) spraying the article at a rate which a coherent film is observed; and c) exposing the article and film

to infrared heaters until the film is substantially dried; optionally while cooling the article with air.

In accordance with a preferred embodiment, an apparatus for spray coating articles is provided comprising: an article conveyor that transports the articles through a spray coating system; one or more spray nozzles is in fluid communication with an aqueous solution/dispersion of coating material, such as may be contained in a tank or vat; a coating material collector which receives unused coating material; and a curing/drying unit which comprises an oven or chamber in which a curing/drying source is located, wherein the articles are moved through the oven or chamber by the conveyor. The curing/drying unit is optionally coupled with a fan or blower for cooling the article with air. A preferred apparatus may further comprise a second tank or vat of coating material, a second grouping of one or more spray nozzles, and/or a second curing/drying unit, or, in providing a second coating, one or more components of the first spray coating system may be used. A preferred apparatus may optionally include one or more drip removers positioned between the sprayer and the curing/drying unit, or elsewhere before the curing/drying unit.

In accordance with another preferred embodiment, a method for flow coating articles is provided comprising the steps of: a) flow coating the article with an aqueous coating solution/dispersion with the article rotating to achieve full exposure to the flow, b) withdrawing the article from sheet of the flow coating at a rate which a coherent film is observed; c) exposing the article and film to infrared heaters until the film is substantially dried; and optionally d) cooling the article with air.

In accordance with a preferred embodiment, an apparatus for flow coating articles is provided comprising: an article conveyor that transports the articles through a flow coating system; a tank or vat containing an aqueous solution/dispersion of coating material that is in fluid communication with a fluid guide, wherein the coating material flows off of the fluid guide forming a sheet or falling shower curtain; a coating material collector which receives unused coating material; and a curing/drying unit which comprises an oven or chamber in which a curing/drying source is located, wherein the articles are moved through the oven or chamber by the conveyor. The curing/drying unit is optionally coupled with a fan or blower for cooling the article with air. A preferred apparatus may further comprise a second tank or vat of coating material, a second fluid guide, and/or a second curing/drying unit, or, in providing a second coating, one or more components of the first flow coating system may

be used. A preferred apparatus may optionally include one or more drip removers positioned between the coating tank or vat and the curing/drying unit, or elsewhere before the curing/drying unit.

In one embodiment, a preferred apparatus includes means for entry of the article
5 into the system; dip, spray, or flow coating of the article; optionally removal of excess material; drying or curing; optionally, cooling, during and/or after drying/curing, and ejection from the system. In one embodiment the apparatus is a single integrated processing line that contains multiple stations wherein each station coats the article thereby producing an article with multiple coatings. In another embodiment, the system is modular
10 wherein each processing line is self-contained with the ability to handoff to another line, thereby allowing for single or multiple coatings depending on how many modules are connected thereby allowing maximum processing flexibility.

In accordance with one embodiment, there is provided a multilayer article comprising: a substrate, and at least one layer comprising thermoplastic epoxy resin coating
15 material disposed on at least a portion of said substrate to form a coated article, wherein the coated article preferably exhibits substantially no blushing or whitening when immersed in water or otherwise directly exposed to water. In preferred embodiments, such articles also exhibit substantially no blushing or whitening when exposed to high humidity, including humidity of about 70% or higher. Such exposure or immersion to water or high humidity
20 may occur for several hours or longer, including about 6 hours, 12 hours, 24 hours, 48 hours, and longer and/or may occur at temperatures around room temperature and at reduced temperatures. In one embodiment, the coated articles exhibit substantially no blushing or whitening when immersed in or otherwise exposed directly to water at a temperature of about 0°C to 30°C, including about 5°C, 10°C, 15°C, 20°C, 22°C, and 25°C
25 for about 24 hours. In preferred embodiments, the substrate comprises a polymeric material, preferably a thermoplastic material chosen from the group consisting of polyester, polypropylene, polyethylene, polycarbonate, polyamides and acrylics. In embodiments wherein the article is a preform or bottle having a body portion and neck portion, the coating is preferably disposed substantially only on the body portion of the preform. In a
30 preferred embodiment, one or more additional coating layers are disposed on the article. In such three or more layer embodiments, preferably there is substantially no distinction between coating layers, and/or one or more additional layers comprise thermoplastic

materials. The coating layer(s) may contain one or more of the following characteristics in preferred embodiments: gas-barrier protection, UV protection, scuff resistance, blush resistance, chemical resistance.

In accordance with a preferred embodiment a multilayer container is produced, preferably a preform or bottle having a body portion and neck portion. Preferably the container, preform or bottle comprises a thermoplastic material substrate and one or more, layers of thermoplastic resin coating material. Preferably the thermoplastic substrate material is chosen from the group consisting of polyesters, polyolefins, polycarbonates, polyamides and acrylics. Preferably the coating layers contain one or more of the following characteristics: gas-barrier protection, UV protection, scuff resistance, blush resistance, chemical resistance. Preferably the coating is disposed substantially only on the body portion of the preform. In addition, the finished product preferably has substantially no distinction between layers.

In a preferred embodiment, the coated article or container formed from a coated preform shows substantially no blushing or whitening when exposed to water or high humidity at room temperature or reduced or elevated temperatures (with respect to room temperature) for a period of several hours or longer. In one embodiment, the coated article or container exhibits substantially no blushing when immersed in or otherwise exposed to water. In related embodiments, the infrared heating is replaced with flame curing, gas heaters, electron beam processing, or UV radiation optionally followed by or combined with cooling with air.

All of these embodiments are intended to be within the scope of the inventions herein disclosed. These and other embodiments of the present inventions will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiments having reference to the attached figures, the inventions not being limited to any particular preferred embodiment(s) disclosed.

Brief Description of the Drawings

Figure 1 is an uncoated preform as is used as a starting material for preferred embodiments.

Figure 2 is a cross-section of a preferred uncoated preform of the type that is coated in accordance with a preferred embodiment.

Figure 3 is a cross-section of one preferred embodiment of a coated preform.

Figure 4 is an enlargement of a section of the wall portion of a coated preform.

Figure 5 is a cross-section of another embodiment of a coated preform.

Figure 6 is a cross-section of a preferred preform in the cavity of a blow-molding apparatus of a type that may be used to make a preferred coated container of an
5 embodiment of the present invention.

Figure 7 is a coated container prepared in accordance with a blow molding process.

Figure 8 is a cross-section of one preferred embodiment of a coated container having features in accordance with the present invention.

Figure 9 is a three-layer embodiment of a preform.

10 Figure 10 there is a non-limiting flow diagram that illustrates a preferred process.

Figure 11 is a non-limiting flow diagram of one embodiment of a preferred process wherein the system comprises a single coating unit.

Figure 12 is a non-limiting flow diagram of a preferred process wherein the system comprises multiple coating units in one integrated system.

15 Figure 13 is a non-limiting flow diagram of a preferred process wherein the system comprises multiple coating units in a modular system.

Figure 14 is a non-limiting top view of one embodiment of a preferred process wherein the system comprises a single flow coating unit.

20 Figure 15 is a non-limiting front view of one embodiment of a preferred process wherein the system comprises a single flow coating unit.

Figure 16 is a non-limiting cross section view of one embodiment of a preferred process wherein the system comprises a single flow coating unit.

Figures 17A and 17B depict non-limiting views of one embodiment of a preferred IR drying/curing unit.

25 Figure 18 is a non-limiting top view of one embodiment of a coating system.

Figure 19 is a non-limiting perspective view of one embodiment of a transfer system of the coating system of Figure 18 wherein the transfer system is not loaded with preforms.

Figure 20 is a non-limiting partial top view of the transfer system of Figure 19 wherein the transfer system engages a preform.

30 Figure 21 is a non-limiting partial side view of the transfer system of Figure 19 wherein the transfer system engages a preform.

Figure 22 is a non-limiting view of one embodiment of a transfer system of a coating system.

Figure 23 is a non-limiting view of a portion of one embodiment of a carousel system of the coating system of Figure 18.

5 Figure 24A is a non-limiting side view of a portion of a loading system, wherein the loading system is not loaded with preforms.

Figure 24B is a non-limiting top view of a portion of the loading system and transfer system, wherein the coating system is not loaded with preforms.

Figure 25 is a non-limiting side view of one embodiment of a gripping mechanism.

10 Figure 26A is a non-limiting back view of one embodiment of a carrier of a carousel system.

Figure 26B is a non-limiting side view of one embodiment of a carrier of a carousel system.

15 Figure 27 is a non-limiting perspective view of one embodiment of a flow coating system of the coating system.

Figure 28 is a non-limiting cross-sectional view of a tank of the flow coating system of Figure 27.

Figure 29 is an enlarged cross sectional view along 29-29 of Figure 28.

Figure 30 is an enlarged view of a portion of a tank of a coating system.

20 Figure 31 is a non-limiting schematic illustration of one embodiment of a fluid system of a coating system.

Figure 32 is a non-limiting cross-sectional view of one embodiment of a collection tank of a coating system.

25 Figure 33 is a non-limiting illustration of a portion of a carousel system carrying preforms and a coating system coating the preforms.

Figure 34 is a non-limiting side view of a reservoir of the fluid system of Figure 31.

Figure 35 is a non-limiting illustration of a portion of a carousel system and one embodiment of a removal system.

Figure 36 is a non-limiting top view of one embodiment of a removal system.

30 Figure 37 is a non-limiting side view of the removal system of Figure 36.

Figure 38 is a non-limiting side view of one embodiment of a preform that is partially covered with coating material.

Figures 39A to 39E depict non-limiting views of various embodiments of removal systems.

Figure 40 is a non-limiting schematic illustration of one embodiment of a fluid system of a coating system.

5 Figure 41 is a non-limiting side view of a preform in a curing unit.

Figure 42 is a non-limiting cross-sectional view of one embodiment of a gripping mechanism holding a preform.

Figure 43 is a non-limiting side view of another embodiment of a preform in a curing unit.

10 Figure 44 is a non-limiting perspective view of a cooling system.

Figure 45 is a top plan view of a coating system in accordance with another embodiment.

Figure 46 is a perspective view of a portion of the coating system of Figure 45.

Figure 47 is a perspective view of a portion of the coating system of Figure 45.

15 Figure 48 is a non-limiting side view of a flow coating system of the coating system of Figure 45.

Figure 49 is a side view of a gripping mechanism and a preform, the gripping mechanism is in a first position for receiving the preform.

20 Figure 50 is a side view of the gripping mechanism of Figure 49 in a second position for holding a preform.

Figure 51 is a cross sectional view of a gripping mechanism in accordance with another embodiment.

Figure 52 is a cross sectional view of the gripping mechanism of Figure 51 holding a preform.

25 Figure 53 is a non-limiting side view of a gripping mechanism holding a preform.

Detailed Description of Preferred Embodiments

A. General Description of Preferred Embodiments

30 Methods and apparatus for coating articles comprising one or more layers are described herein. These layers may comprise thermoplastic materials with good gas-barrier characteristics as well as layers or additives that provide UV protection, scuff resistance,

blush resistance, chemical resistance, and/or active properties for O₂ and/or CO₂ scavenging.

As presently contemplated, one embodiment of a coated article is a preform of the type used for beverage containers. Alternatively, embodiments of the coated articles of the present invention could take the form of jars, tubes, trays, bottles for holding liquid foods, medical products, or other products sensitive to gas exposure. However, for the sake of simplicity, these embodiments will be described herein primarily as articles or preforms.

Furthermore, the articles described herein may be described specifically in relation to a particular substrate, polyethylene terephthalate (PET), but preferred methods are applicable to many other thermoplastics of the polyester type. As used herein, the term “substrate” is a broad term used in its ordinary sense and includes embodiments wherein “substrate” refers to the material used to form the base article that is coated. Other suitable article substrates include, but are not limited to, various polymers such as polyesters, polyolefins, including polypropylene and polyethylene, polycarbonate, polyamides, including nylons, or acrylics. These substrate materials may be used alone or in conjunction with each other. More specific substrate examples include, but are not limited to, polyethylene 2,6- and 1,5-naphthalate (PEN), PETG, polytetramethylene 1,2-dioxybenzoate and copolymers of ethylene terephthalate and ethylene isophthalate.

In one embodiment, PET is used as the polyester substrate which is coated. As used herein, “PET” includes, but is not limited to, modified PET as well as PET blended with other materials. One example of a modified PET is “high IPA PET” or IPA-modified PET. The term “high IPA PET” refers to PET in which the IPA content is preferably more than about 2% by weight, including about 2-10% IPA by weight.

One or more layers of a coating material are employed in preferred methods and processes. The layers may comprise barrier layers, UV protection layers, oxygen scavenging layers, carbon dioxide scavenging layers, and other layers as needed for the particular application. As used herein, the terms “barrier material,” “barrier resin,” and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which, when used to coat articles, preferably adhere well to the article substrate and have a lower permeability to oxygen and carbon dioxide than the article substrate. As used herein, the terms “UV protection” and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which, when used to coat articles,

preferably adhere well to the article substrate and have a higher UV absorption rate than the article substrate. As used herein, the terms "oxygen scavenging" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which, when used to coat articles, preferably adhere well to the article substrate and have a higher oxygen absorption rate than the article substrate. As used herein, the terms "carbon dioxide scavenging" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which, when used to coat articles, preferably adhere well to the article substrate and have a higher carbon dioxide absorption rate than the article substrate. As used herein, the terms "crosslink," "crosslinked," and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials and coatings which vary in degree from a very small degree of crosslinking up to and including fully cross linked materials such as a thermoset epoxy. The degree of crosslinking can be adjusted to provide the appropriate degree of chemical or mechanical abuse resistance for the particular circumstances.

Once a suitable coating material is chosen, an apparatus and method for commercially manufacturing a coated article is necessary. One such method and apparatus is described below.

Preferred methods provide for a coating to be placed on an article, specifically a preform, which is later blown into a bottle. Such methods are, in many instances, preferable to placing coatings on the bottles themselves. Preforms are smaller in size and of a more regular shape than the containers blown therefrom, making it simpler to obtain an even and regular coating. Furthermore, bottles and containers of varying shapes and sizes can be made from preforms of similar size and shape. Thus, the same equipment and processing can be used to coat preforms to form several different types of containers. The blow-molding may take place soon after molding and coating, or preforms may be made and stored for later blow-molding. If the preforms are stored prior to blow-molding, their smaller size allows them to take up less space in storage. Even though it is often times preferable to form containers from coated preforms, containers may also be coated.

The blow-molding process presents several challenges. One step where the greatest difficulties arise is during the blow-molding process where the container is formed from the preform. During this process, defects such as delamination of the layers, cracking or crazing of the coating, uneven coating thickness, and discontinuous coating or voids can

result. These difficulties can be overcome by using suitable coating materials and coating the preforms in a manner that allows for good adhesion between the layers.

Thus, preferred embodiments comprise suitable coating materials. When a suitable coating material is used, the coating sticks directly to the preform without any significant delamination and will continue to stick as the preform is blow-molded into a bottles and afterwards. Use of a suitable coating material also helps to decrease the incidence of cosmetic and structural defects which can result from blow-molding containers as described above.

One common problem seen in articles formed by coating using coating solutions or dispersions is "blushing" or whitening when the article is immersed in (which includes partial immersion) or exposed directly to water or high humidity (which includes at or above about 70% relative humidity). In preferred embodiments, the articles disclosed herein and the articles produced by methods disclosed herein exhibit minimal or substantially no blushing or whitening when immersed in or otherwise exposed directly to water or high humidity. Such exposure may occur for several hours or longer, including about 6 hours, 12 hours, 24 hours, 48 hours, and longer and/or may occur at temperatures around room temperature and at reduced temperatures, such as would be seen by placing the article in a cooler containing ice or ice water. Exposure may also occur at an elevated temperature, such elevated temperature generally not including temperatures high enough to cause an appreciable softening of the materials which form the container or coating, including temperatures approaching the Tg of the materials. In one embodiment, the coated articles exhibit substantially no blushing or whitening when immersed in or otherwise exposed directly to water at a temperature of about 0°C to 30°C, including about 5°C, 10°C, 15°C, 20°C, 22°C, and 25°C for about 24 hours. The process used for curing or drying coating layers appears to have an effect on the blush resistance of articles.

B. Detailed Description of the Drawings

Referring to Figure 1, a preferred uncoated preform 1 is depicted. The preform is preferably made of an FDA approved material such as virgin PET and can be of any of a wide variety of shapes and sizes. The preform shown in FIG. 1 is a 24 gram preform of the type which will form a 16 oz. carbonated beverage bottle, but as will be understood by those skilled in the art, other preform configurations can be used depending upon the

desired configuration, characteristics and use of the final article. The uncoated preform 1 may be made by injection molding as is known in the art or by other suitable methods.

Referring to FIG. 2, a cross-section of a preferred uncoated preform 1 of FIG. 1 is depicted. The uncoated preform 1 has a neck portion 2 and a body portion 4. The neck portion 2, also called the neck finish, begins at the opening 18 to the interior of the preform 1 and extends to and includes the support ring 6. The neck 2 is further characterized by the presence of the threads 8, which provide a way to fasten a cap for the bottle produced from the preform 1. The body portion 4 is an elongated and cylindrically shaped structure extending down from the neck 2 and culminating in the rounded end cap 10. The preform thickness 12 will depend upon the overall length of the preform 1 and the wall thickness and overall size of the resulting container. It should be noted that as the terms "neck" and "body" are used herein, in a container that is colloquially called a "longneck" container, the elongate portion just below the support ring, threads, and/or lip where the cap is fastened would be considered part of the "body" of the container and not a part of the "neck." In other embodiments which are not illustrated, the neck portion 2 does not include a neck finish (e.g. it does not have threads 8) but does include the support ring. In other non-illustrated embodiments the neck portion 2 does not include a neck finish or a support ring.

Referring to FIG. 3, a cross-section of one type of coated preform 20 having features in accordance with a preferred embodiment is depicted. The coated preform 20 has a neck portion 2 and a body portion 4 as in the uncoated preform 1 in Figs. 1 and 2. The coating layer 22 is disposed about the entire surface of the body portion 4, terminating at the bottom of the support ring 6. A coating layer 22 in the embodiment shown in the figure does not extend to the neck portion 2, nor is it present on the interior surface 16 of the preform which is preferably made of an FDA approved material such as PET. The coating layer 22 may comprise one layer of a single material, one layer of several materials combined, or several layers of at least two materials. The overall thickness 26 of the preform is equal to the thickness of the initial preform plus the thickness 24 of the coating layer or layers, and is dependent upon the overall size and desired coating thickness of the resulting container.

Figure 4 is an enlargement of a wall section of the preform showing the makeup of the coating layers in one embodiment of a preform. The layer 110 is the substrate layer of the preform while 112 comprises the coating layers of the preform. The outer coating layer

116 comprises one or more layers of material, while 114 comprises the inner coating layer. In preferred embodiments there may be one or more outer coating layers. As shown here, the coated preform has one inner coating layer and two outer coating layers. Not all preforms of FIG. 4 will be of this type.

5 Referring to FIG. 5, another embodiment of a coated preform 25 is shown in cross-section. The primary difference between the coated preform 25 and the coated preform 20 in FIG. 3 is that the coating layer 22 is disposed on the support ring 6 of the neck portion 2 as well as the body portion 4. Preferably any coating that is disposed on, especially on the upper surface, or above the support ring 6 is made of an FDA approved material such as
10 PET.

The coated preforms and containers can have layers which have a wide variety of relative thicknesses. In view of the present disclosure, the thickness of a given layer and of the overall preform or container, whether at a given point or over the entire container, can be chosen to fit a coating process or a particular end use for the container. Furthermore, as
15 discussed above in regard to the coating layer in FIG. 3, the coating layer in the preform and container embodiments disclosed herein may comprise a single material, a layer of several materials combined, or several layers of at least two or more materials.

After a coated preform, such as that depicted in FIG. 3, is prepared by a method and apparatus such as those discussed in detail below, it is subjected to a stretch blow-molding
20 process. Referring to FIG. 6, in this process a coated preform 20 is placed in a mold 28 having a cavity corresponding to the desired container shape. The coated preform is then heated and expanded by stretching and by air forced into the interior of the preform 20 to fill the cavity within the mold 28, creating a coated container 30. The blow molding operation normally is restricted to the body portion 4 of the preform with the neck portion 2
25 including the threads, pilfer ring, and support ring retaining the original configuration as in the preform.

Referring to FIG. 7, there is disclosed an embodiment of coated container 40 in accordance with a preferred embodiment, such as that which might be made from blow molding the coated preform 20 of FIG. 3. The container 40 has a neck portion 2 and a body
30 portion 4 corresponding to the neck and body portions of the coated preform 20 of FIG. 3. The neck portion 2 is further characterized by the presence of the threads 8 which provide a way to fasten a cap onto the container.

When the coated container 40 is viewed in cross-section, as in FIG. 8, the construction can be seen. The coating 42 covers the exterior of the entire body portion 4 of the container 40, stopping just below the support ring 6. The interior surface 50 of the container, which is made of an FDA-approved material, preferably PET, remains uncoated so that only the interior surface 50 is in contact with the packaged product such as beverages, foodstuffs, or medicines. In one preferred embodiment that is used as a carbonated beverage container, a 24 gram preform is blow molded into a 16 ounce bottle with a coating ranging from about 0.05 to about 0.75 grams, including about 0.1 to about 0.2 grams.

Referring to FIG. 9 there is shown a preferred three-layer preform 76. This embodiment of coated preform is preferably made by placing two coating layers 80 and 82 on a preform 1 such as that shown in FIG. 1.

Referring to FIG. 10 there is shown a non-limiting flow diagram that illustrates a preferred process and apparatus. A preferred process and apparatus involves entry of the article into the system 84, dip, spray, or flow coating of the article 86, removal of excess material 88, drying/curing 90, cooling 92, and ejection from the system 94.

Referring to FIG. 11 there is shown a non-limiting flow diagram of one embodiment of a preferred process wherein the system comprises a single coating unit, A, of the type in FIG. 10 which produces a single coat article. The article enters the system 84 prior to the coating unit and exits the system 94 after leaving the coating unit.

Referring to FIG. 12 there is shown a non-limiting flow diagram of a preferred process wherein the system comprises a single integrated processing line that contains multiple stations 100, 101, 102 wherein each station coats and dries or cures the article thereby producing an article with multiple coatings. The article enters the system 84 prior to the first station 100 and exits the system 94 after the last station 102. The embodiment described herein illustrates a single integrated processing line with three coating units, it is to be understood that numbers of coating units above or below are also included.

Referring to FIG. 13 there is shown a non-limiting flow diagram of one embodiment of a preferred process. In this embodiment, the system is modular wherein each processing line 107, 108, 109 is self-contained with the ability to handoff to another line 103, thereby allowing for single or multiple coatings depending on how many modules are connected thereby allowing maximum flexibility. The article first enters the system at one of several

points in the system 84 or 120. The article can enter 84 and proceed through the first module 107, then the article may exit the system at 118 or continue to the next module 108 through a hand off mechanism 103 known to those of skill in the art. The article then enters the next module 108 at 120. The article may then continue on to the next module 109 or exit the system. The number of modules may be varied depending on the production circumstances required. Further the individual coating units 104 105 106 may comprise different coating materials depending on the requirements of a particular production line. The interchangeability of different modules and coating units provides maximum flexibility.

Referring to FIGS. 14, 15, and 16 there are shown alternate views of non-limiting diagrams of one embodiment of a preferred process. In this embodiment, the top view of a system comprising a single flow coater 86 is shown. The preform enters the system 84 and then proceeds to the flow coater 86 wherein the preform 1 passes through the coating material waterfall. The coating material proceeds from the tank or vat 150 through the gap 155 in the tank down the angled fluid guide 160 where it forms a waterfall (not illustrated) as it passes onto the preforms. The gap 155 in the tank may be widened or narrowed to adjust the flow of the material. The material is pumped from the reservoir (not illustrated) into the vat or tank at a rate that maintains the coating material level above that of the gap 155. Advantageously, this configuration ensures a constant flow of coating material. The excess amount of material also dampens any fluid fluctuations due to the cycling of the pump. As the preform passes out of the coating waterfall, excess material drips off into the material collection reservoir 170. The coating material collector (not illustrated) receives any unused coating waterfall and returns the material back to the coating tank or vat. The excess material is then removed from the bottom of the preform 88. The preform then moves toward the drying/curing unit 90 before being ejected from the system 94. As shown here, the preforms are allowed to rest before ejection to cool. The collection reservoir and coating material collector preferably empty into the reservoir that feeds the tank or vat so as to allow for reduction of waste from the system.

Referring to FIGS. 17A and 17B there are shown non-limiting views of one embodiment of a preferred IR drying/curing unit 90. As shown in FIG. 17A the unit 90 is open. The arrow at the bottom of the unit indicates how the unit would close. On one side of the processing line there is shown a series of ten lamps 200. Below the preforms there is

shown an angled reflector 210 which reflects heat towards the bottom of the preforms for more thorough curing. Opposite to the lamps is a semicircular reflector 230 which reflects the IR heat back onto the preforms allowing for a more thorough and efficient cure. Reflectors of other shapes and sizes may also be used.

5 Referring to FIG. 17B there is an enlarged section detailing the lamp placement in one embodiment of a preferred IR drying/curing unit 90. The lamps in this embodiment are adjustable 220 and may be moved closer to or farther away from the preform allowing for maximum drying/curing flexibility.

10 A preferred method and apparatus for making coated articles, more specifically preforms, is discussed in more detail below.

C. General Description of Preferred Materials

The articles disclosed herein may be made from any of a wide variety of materials as discussed herein. Although some articles may be described specifically in relation to a particular base preform material and/or coating material these same articles, and the methods used to make the articles are applicable to many other thermoplastics including, but not limited to, polyesters, polyolefins, polylactic acid, polycarbonate, and the like. Other suitable materials include, but are not limited to, polymeric materials, including thermoset polymers, thermoplastic materials such as polyesters, polyolefins, including polypropylene and polyethylene, polycarbonate, polyamides, including nylons (e.g. Nylon 15 6, Nylon 66) and MXD6, polystyrenes, epoxies, copolymers, blends, grafted polymers, and/or modified polymers (monomers or portion thereof having another group as a side group, e.g. olefin-modified polyesters). These materials may be used alone or in conjunction with others in multi-layer structures, blends or copolymers, and can also be combined with different additives, such as nanoparticle barrier materials, oxygen 25 scavengers, UV absorbers, foaming agents and the like. More specific material examples include, but are not limited to, ethylene vinyl acetate (EVA), linear low density polyethylene (LLDPE), polyethylene 2,6- and 1,5-naphthalate (PEN), polyethylene terephthalate glycol (PETG), poly(cyclohexylenedimethylene terephthalate), polylactic acid (PLA), polycarbonate, polyglycolic acid (PGA), polystyrene, cycloolefin, poly-4- 30 methylpentene-1, poly(methyl methacrylate), acrylonitrile, polyvinyl chloride, polyvinylidene chloride (PVDC), styrene acrylonitrile, acrylonitrile-butadiene-styrene, polyacetal, polybutylene terephthalate, polymeric ionomers such as sulfonates of PET,

polysulfone, polytetra-fluoroethylene, polytetramethylene 1,2-dioxybenzoate, polyurethane, and copolymers of ethylene terephthalate and ethylene isophthalate, and copolymers and/or blends of one or more of the foregoing.

As used herein, the term "polyethylene terephthalate glycol" (PETG) refers to a
5 copolymer of PET wherein an additional comonomer, cyclohexane di-methanol (CHDM),
is added in significant amounts (e.g. approximately 40% or more by weight) to the PET
mixture. In one embodiment, preferred PETG material is essentially amorphous. Suitable
PETG materials may be purchased from various sources. One suitable source is Voridian, a
division of Eastman Chemical Company. Other PET copolymers include CHDM at lower
10 levels such that the resulting material remains crystallizable or semi-crystalline. One
example of PET copolymer containing low levels of CHDM is Voridian 9921 resin.
Another example of modified PET is "high IPA PET" or IPA-modified PET, which refers
to PET in which the IPA content is preferably more than about 2% by weight, including
about 2-20% IPA by weight, also including about 5-10% IPA by weight. Throughout the
15 specification, all percentages in formulations and compositions are by weight unless stated
otherwise.

In some embodiments polymers that have been grafted or modified may be used. In
one embodiment polypropylene or other polymers may be grafted or modified with polar
groups including, but not limited to, maleic anhydride, glycidyl methacrylate, acryl
20 methacrylate and/or similar compounds to improve adhesion. In other embodiments
polypropylene also refers to clarified polypropylene. As used herein, the term "clarified
polypropylene" is a broad term and is used in accordance with its ordinary meaning and
may include, without limitation, a polypropylene that includes nucleation inhibitors and/or
clarifying additives. Clarified polypropylene is a generally transparent material as
25 compared to the homopolymer or block copolymer of polypropylene. The inclusion of
nucleation inhibitors can help prevent and/or reduce crystallinity or the effects of
crystallinity, which contributes to the haziness of polypropylene, within the polypropylene
or other material to which they are added. Some clarifiers work not so much by reducing
total crystallinity as by reducing the size of the crystalline domains and/or inducing the
30 formation of numerous small domains as opposed to the larger domain sizes that can be
formed in the absence of a clarifier. Clarified polypropylene may be purchased from
various sources such as Dow Chemical Co. Alternatively, nucleation inhibitors may be

added to polypropylene or other materials. One suitable source of nucleation inhibitor additives is Schulman.

In certain embodiments preferred materials may be virgin, pre-consumer, post-consumer, regrind, recycled, and/or combinations thereof. For example, PET can be virgin,
5 pre or post-consumer, recycled, or regrind PET, PET copolymers and combinations thereof. In preferred embodiments, the finished container and/or the materials used therein are benign in the subsequent plastic container recycling stream.

In preferred embodiments, a substrate that is an article such as a container, jar, bottle or preform (sometimes referred to as a base preform) is coated using apparatus,
10 methods, and materials described herein. The base preform or substrate may be made by any suitable method, including those known in the art including, but not limited to, injection molding including monolayer injection molding, inject-over-inject molding, and coinjection molding, extrusion molding, and compression molding, with or without subsequent blow molding. The substrate may be made of any material or combination of
15 materials, including glass, plastic, metal and the like. Polymers, such as thermoplastic materials are preferred. Examples of suitable thermoplastics include, but are not limited to, polyesters (e.g. PET, PEN), polyolefins (PP, HDPE), polylactic acid, polycarbonate, and polyamide.

Each of the one or more layers that coat the substrate is formed by applying a
20 coating layer composition according to methods disclosed herein. Preferred coating layer compositions include solutions, suspensions, emulsions, and/or dispersions comprising at least one polymeric material (preferably a thermoplastic material) and optionally one or more additives. Additives preferably provide functionality to the dried or cured coating layer (e.g. UV resistance, barrier, scratch resistance) and/or to the coating composition
25 during the process (e.g. thermal enhancer, anti-foaming agent). A polymeric material used in a layer composition may, itself, provide functional properties such as gas barrier, and the like.

The coating layer compositions may include aqueous and/or organic solvents, although it is preferred that the material minimize the amount of volatile organic
30 compounds (low VOC). When multiple layers are used, it is preferred that each layer be fully dried (i.e. the volatile solvent removed) before a subsequent layer is applied.

In embodiments of preferred methods and processes one or more layers may comprise barrier layers, UV protection layers, oxygen scavenging layers, oxygen barrier layers, carbon dioxide scavenging layers, carbon dioxide barrier layers, and other layers as needed for the particular application. As used herein, the terms "barrier material," "barrier resin," and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which, when used in preferred methods and processes, have a lower permeability to oxygen, carbon dioxide, and/or than the one or more of the other layers of the finished article (including the substrate). As used herein, the terms "UV protection" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which have a higher UV absorption rate than one or more other layers of the article. As used herein, the terms "oxygen scavenging" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which have a higher oxygen absorption rate than one or more other layers of the article. As used herein, the terms "oxygen barrier" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which are passive or active in nature and slow the transmission of oxygen into and/or out of an article. As used herein, the terms "carbon dioxide scavenging" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which have a higher carbon dioxide absorption rate than one or more other layers of the article. As used herein, the terms "carbon dioxide barrier" and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials which are passive or active in nature and slow the transmission of carbon dioxide into and/or out of an article. Without wishing to be bound to any theory, applicants believe that in applications wherein a carbonated product, e.g. a soft-drink beverage, contained in an article is over-carbonated, the inclusion of a carbon dioxide scavenger in one or more layers of the article allows the excess carbonation to saturate the layer which contains the carbon dioxide scavenger. Therefore, as carbon dioxide escapes to the atmosphere from the article it first leaves the article layer rather than the product contained therein. As used herein, the terms "crosslink," "crosslinked," and the like are broad terms and are used in their ordinary sense and refer, without limitation, to materials and coatings which vary in degree from a very small degree of crosslinking up to and including fully cross linked materials. The degree of crosslinking

can be adjusted to provide desired or appropriate physical properties, such as the degree of chemical or mechanical abuse resistance for the particular circumstances.

Other functionality provided by one or more coating layers, alone or together with other functionality, include color, including but not limited to dyes and pigments, adhesion promoters to enhance adhesion of the coating layer to the substrate and/or another coating layer, and abrasion resistance.

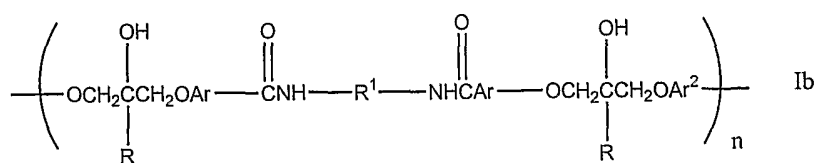
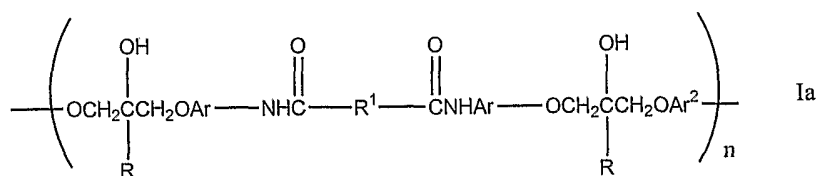
D. Examples of Preferred Coating Materials and Articles

1. Examples of Coating Materials

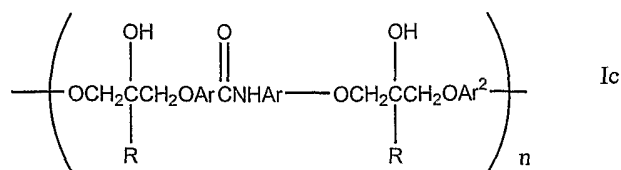
In one preferred embodiment, preferred coating materials comprise thermoplastic materials. A further preferred embodiment includes "Phenoxy-Type Thermoplastics." Phenoxy-Type Thermoplastics, as that term is used herein, include a wide variety of materials including those discussed in WO 99/20462. In one embodiment, materials comprise thermoplastic epoxy resins (TPEs), a subset of Phenoxy-Type Thermoplastics. A further subset of Phenoxy-Type Thermoplastics, and thermoplastic materials, are certain preferred hydroxy-phenoxyether polymers, of which certain polyhydroxyaminoether copolymers (PHAE) are further preferred materials. See for example, U.S. Pat. Nos. 6,455,116; 6,180,715; 6,011,111; 5,834,078; 5,814,373; 5,464,924; and 5,275,853; see also PCT Application Nos. WO 99/48962; WO 99/12995; WO 98/29491; and WO 98/14498. In some embodiments, PHAEs are TPEs.

Preferably, the Phenoxy-Type Thermoplastics used in preferred embodiments comprise one of the following types:

(1) hydroxy-functional poly(amide ethers) having repeating units represented by any one of the Formulae Ia, Ib or Ic:

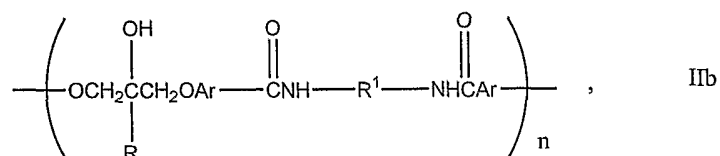
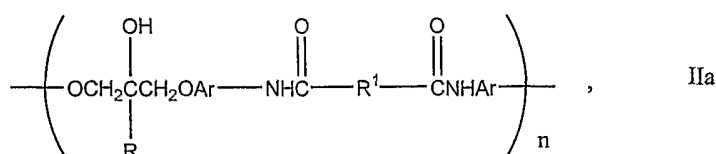


or

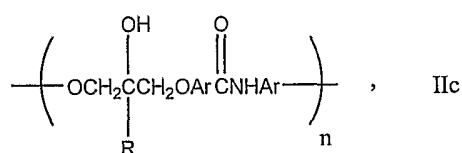


(2) poly(hydroxy amide ethers) having repeating units represented independently by any one of the Formulae IIa, IIb or IIc:

5

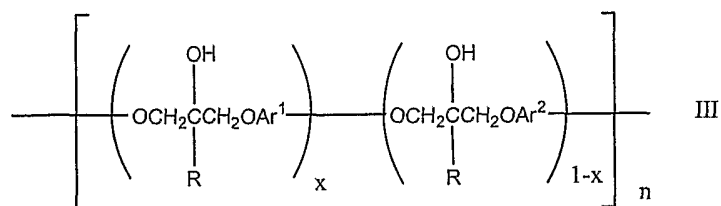


or



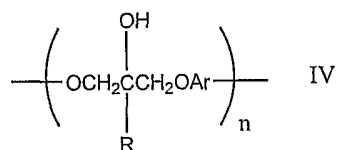
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(3) amide- and hydroxymethyl-functionalized polyethers having repeating units represented by Formula III:

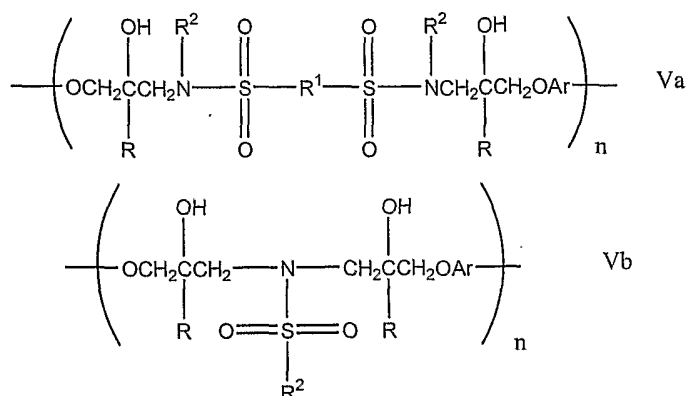


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(4) hydroxy-functional polyethers having repeating units represented by Formula IV:

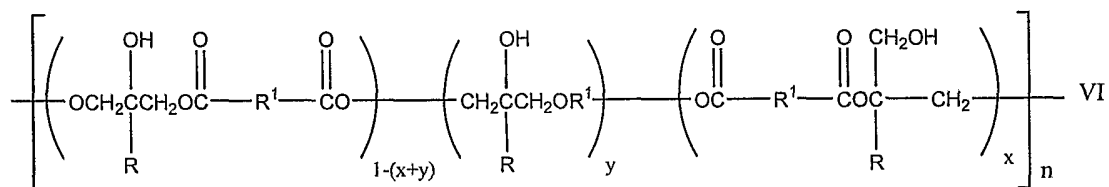


(5) hydroxy-functional poly(ether sulfonamides) having repeating units represented by Formulae Va or Vb:

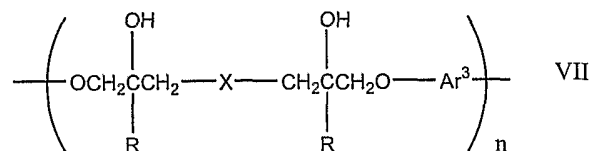


5

(6) poly(hydroxy ester ethers) having repeating units represented by Formula VI:



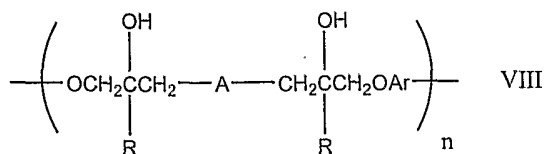
(7) hydroxy-phenoxyether polymers having repeating units represented by Formula VII:



10

and

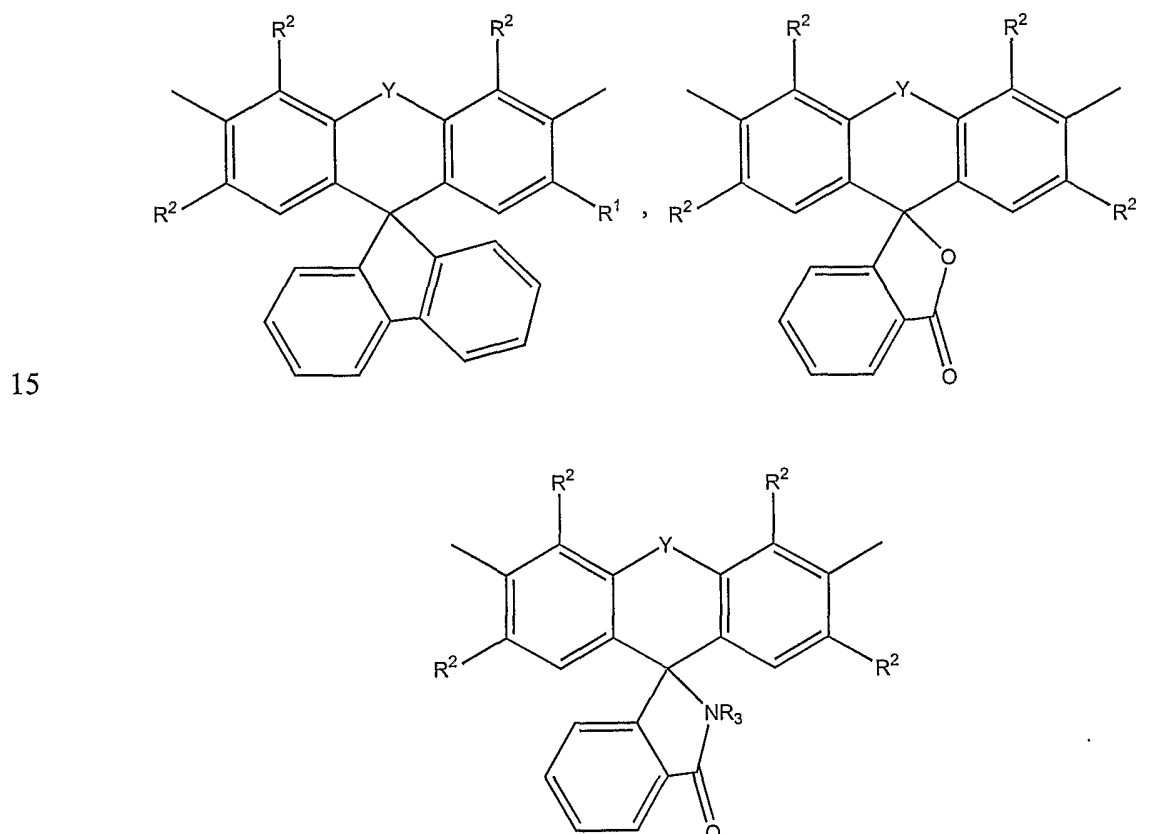
(8) poly(hydroxyamino ethers) having repeating units represented by Formula VIII:



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wherein each Ar individually represents a divalent aromatic moiety, substituted divalent aromatic moiety or heteroaromatic moiety, or a combination of different divalent aromatic

moieties, substituted aromatic moieties or heteroaromatic moieties; R is individually hydrogen or a monovalent hydrocarbyl moiety; each Ar₁ is a divalent aromatic moiety or combination of divalent aromatic moieties bearing amide or hydroxymethyl groups; each Ar₂ is the same or different than Ar and is individually a divalent aromatic moiety, substituted aromatic moiety or heteroaromatic moiety or a combination of different divalent aromatic moieties, substituted aromatic moieties or heteroaromatic moieties; R₁ is individually a predominantly hydrocarbylene moiety, such as a divalent aromatic moiety, substituted divalent aromatic moiety, divalent heteroaromatic moiety, divalent alkylene moiety, divalent substituted alkylene moiety or divalent heteroalkylene moiety or a combination of such moieties; R₂ is individually a monovalent hydrocarbyl moiety; A is an amine moiety or a combination of different amine moieties; X is an amine, an arylenedioxy, an arylenedisulfonamido or an arylenedicarboxy moiety or combination of such moieties; and Ar₃ is a “cardo” moiety represented by any one of the Formulae:



wherein Y is nil, a covalent bond, or a linking group, wherein suitable linking groups include, for example, an oxygen atom, a sulfur atom, a carbonyl atom, a sulfonyl

group, or a methylene group or similar linkage; n is an integer from about 10 to about 1000; x is 0.01 to 1.0; and y is 0 to 0.5.

The term "predominantly hydrocarbylene" means a divalent radical that is predominantly hydrocarbon, but which optionally contains a small quantity of a heteroatomic moiety such as oxygen, sulfur, imino, sulfonyl, sulfoxyl, and the like.

The hydroxy-functional poly(amide ethers) represented by Formula I are preferably prepared by contacting an N,N'-bis(hydroxyphenylamido)alkane or arene with a diglycidyl ether as described in U.S. Patent Nos. 5,089,588 and 5,143,998.

The poly(hydroxy amide ethers) represented by Formula II are prepared by contacting a bis(hydroxyphenylamido)alkane or arene, or a combination of 2 or more of these compounds, such as N,N'-bis(3-hydroxyphenyl) adipamide or N,N'-bis(3-hydroxyphenyl)glutaramide, with an epihalohydrin as described in U.S. Patent No. 5,134,218.

The amide- and hydroxymethyl-functionalized polyethers represented by Formula III can be prepared, for example, by reacting the diglycidyl ethers, such as the diglycidyl ether of bisphenol A, with a dihydric phenol having pendant amido, N-substituted amido and/or hydroxyalkyl moieties, such as 2,2-bis(4-hydroxyphenyl)acetamide and 3,5-dihydroxybenzamide. These polyethers and their preparation are described in U.S. Patent Nos. 5,115,075 and 5,218,075.

The hydroxy-functional polyethers represented by Formula IV can be prepared, for example, by allowing a diglycidyl ether or combination of diglycidyl ethers to react with a dihydric phenol or a combination of dihydric phenols using the process described in U.S. Patent No. 5,164,472. Alternatively, the hydroxy-functional polyethers are obtained by allowing a dihydric phenol or combination of dihydric phenols to react with an epihalohydrin by the process described by Reinking, Barnabeo and Hale in the Journal of Applied Polymer Science, Vol. 7, p. 2135 (1963).

The hydroxy-functional poly(ether sulfonamides) represented by Formula V are prepared, for example, by polymerizing an N,N'-dialkyl or N,N'-diaryldisulfonamide with a diglycidyl ether as described in U.S. Patent No. 5,149,768.

The poly(hydroxy ester ethers) represented by Formula VI are prepared by reacting diglycidyl ethers of aliphatic or aromatic diacids, such as diglycidyl terephthalate, or

diglycidyl ethers of dihydric phenols with, aliphatic or aromatic diacids such as adipic acid or isophthalic acid. These polyesters are described in U.S. Patent No. 5,171,820.

The hydroxy-phenoxyether polymers represented by Formula VII are prepared, for example, by contacting at least one dinucleophilic monomer with at least one diglycidyl ether of a cardo bisphenol, such as 9,9-bis(4-hydroxyphenyl)fluorene, phenolphthalein, or phenolphthalimidine or a substituted cardo bisphenol, such as a substituted bis(hydroxyphenyl)fluorene, a substituted phenolphthalein or a substituted phenolphthalimidine under conditions sufficient to cause the nucleophilic moieties of the dinucleophilic monomer to react with epoxy moieties to form a polymer backbone containing pendant hydroxy moieties and ether, imino, amino, sulfonamido or ester linkages. These hydroxy-phenoxyether polymers are described in U.S. Patent No. 5,184,373.

The poly(hydroxyamino ethers) ("PHAE" or polyetheramines) represented by Formula VIII are prepared by contacting one or more of the diglycidyl ethers of a dihydric phenol with an amine having two amine hydrogens under conditions sufficient to cause the amine moieties to react with epoxy moieties to form a polymer backbone having amine linkages, ether linkages and pendant hydroxyl moieties. These compounds are described in U.S. Patent No. 5,275,853. For example, polyhydroxyaminoether copolymers can be made from resorcinol diglycidyl ether, hydroquinone diglycidyl ether, bisphenol A diglycidyl ether, or mixtures thereof. The hydroxy-phenoxyether polymers are the condensation reaction products of a dihydric polynuclear phenol, such as bisphenol A, and an epihalohydrin and have the repeating units represented by Formula IV wherein Ar is an isopropylidene diphenylene moiety. The process for preparing these is described in U.S. Patent No. 3,305,528, incorporated herein by reference in its entirety.

Generally, preferred phenoxy-type materials form relatively stable aqueous based solutions or dispersions. Preferably, the properties of the solutions/dispersions are not adversely affected by contact with water. Preferred materials range from about 10 % solids to about 50 % solids, including about 15%, 20%, 25%, 30%, 35%, 40% and 45%, and ranges encompassing such percentages, although values above and below these values are also contemplated. Preferably, the material used dissolves or disperses in polar solvents. These polar solvents include, but are not limited to, water, alcohols, and glycol ethers. See,

for example, U.S. Pat. Nos. 6,455,116, 6,180,715, and 5,834,078 which describe some preferred phenoxy-type solutions and/or dispersions.

One preferred phenoxy-type material is a polyhydroxyaminoether (PHAE), dispersion or solution. The dispersion or solution, when applied to a container or preform, greatly reduces the permeation rate of a variety of gases through the container walls in a predictable and well known manner. One dispersion or latex made thereof comprises 10-30 percent solids. A PHAE solution/dispersion may be prepared by stirring or otherwise agitating the PHAE in a solution of water with an organic acid, preferably acetic or phosphoric acid, but also including lactic, malic, citric, or glycolic acid and/or mixtures thereof. These PHAE solution/dispersions also include organic acid salts as may be produced by the reaction of the polyhydroxyaminoethers with these acids.

In some embodiments, phenoxy-type thermoplastics are mixed or blended with other materials using methods known to those of skill in the art. In some embodiments a compatibilizer may be added to the blend. When compatibilizers are used, preferably one or more properties of the blends are improved, such properties including, but not limited to, color, haze, and adhesion between a layer comprising a blend and other layers. One preferred blend comprises one or more phenoxy-type thermoplastics and one or more polyolefins. A preferred polyolefin comprises polypropylene. In one embodiment polypropylene or other polyolefins may be grafted or modified with a polar molecule, group, or monomer, including, but not limited to, maleic anhydride, glycidyl methacrylate, acryl methacrylate and/or similar compounds to increase compatibility.

The following PHAE solutions or dispersions are examples of suitable phenoxy-type solutions or dispersions which may be used if one or more layers of resin are applied as a liquid such as by dip, flow, or spray coating, such as described in WO 04/004929 and U.S. Patent No. 6,676,883. One suitable material is BLOX® experimental barrier resin, for example XU-19061.00 made with phosphoric acid manufactured by Dow Chemical Corporation. This particular PHAE dispersion is said to have the following typical characteristics: 30% percent solids, a specific gravity of 1.30, a pH of 4, a viscosity of 24 centipoise (Brookfield, 60 rpm, LVI, 22°C.), and a particle size of between 1,400 and 1,800 angstroms. Other suitable materials include BLOX® 588-29 resins based on resorcinol have also provided superior results as a barrier material. This particular dispersion is said to have the following typical characteristics: 30 % percent solids, a specific gravity of 1.2, a

pH of 4.0, a viscosity of 20 centipoise (Brookfield, 60 rpm, LVI, 22°C.), and a particle size of between 1500 and 2000 angstroms. Other variations of the polyhydroxyaminoether chemistry may prove useful such as crystalline versions based on hydroquinone diglycidylethers. Other suitable materials include polyhydroxyaminoether solutions/dispersions by Imperial Chemical Industries ("ICI," Ohio, USA) available under the name OXYBLOK. In one embodiment, PHAE solutions or dispersions can be crosslinked partially (semi-cross linked), fully, or to the desired degree as appropriate for an application including by using a formulation that includes cross linking material. The benefits of cross linking include, but are not limited to, one or more of the following: improved chemical resistance, improved abrasion resistance, lower blushing, and lower surface tension. Examples of cross linker materials include, but are not limited to, formaldehyde, acetaldehyde or other members of the aldehyde family of materials. Suitable cross linkers can also enable changes to the T_g of the material, which can facilitate formation of certain containers. Other suitable materials include BLOX® 5000 resin dispersion intermediate, BLOX® XUR 588-29, BLOX® 0000 and 4000 series resins. The solvents used to dissolve these materials include, but are not limited to, polar solvents such as alcohols, water, glycol ethers or blends thereof. Other suitable materials include, but are not limited to, BLOX® R1.

In one embodiment, preferred phenoxy-type thermoplastics are soluble in aqueous acid. A polymer solution/dispersion may be prepared by stirring or otherwise agitating the thermoplastic epoxy in a solution of water with an organic acid, preferably acetic or phosphoric acid, but also including lactic, malic, citric, or glycolic acid and/or mixtures thereof. In a preferred embodiment, the acid concentration in the polymer solution is preferably in the range of about 5% - 20%, including about 5% - 10% by weight based on total weight. In other preferred embodiments, the acid concentration may be below about 5% or above about 20%; and may vary depending on factors such as the type of polymer and its molecular weight. In other preferred embodiments, the acid concentration ranges from about 2.5 to about 5% by weight. The amount of dissolved polymer in a preferred embodiment ranges from about 0.1% to about 40%. A uniform and free flowing polymer solution is preferred. In one embodiment a 10% polymer solution is prepared by dissolving the polymer in a 10% acetic acid solution at 90° C. Then while still hot the solution is diluted with 20% distilled water to give an 8% polymer solution. At higher concentrations

of polymer, the polymer solution tends to be more viscous. One preferred non-limiting hydroxy-phenoxyether polymer, PAPHEN 25068-38-6, is commercially available from Phenoxy Associates, Inc.. Other preferred phenoxy resins are available from InChem® (Rock Hill, South Carolina), these materials include, but are not limited to, the
5 INCHEMREZtm PKHH and PKHW product lines.

Other suitable coating materials include preferred copolyester materials as described in U.S. Patent No. 4,578,295 to Jabarin. They are generally prepared by heating a mixture of at least one reactant selected from isophthalic acid, terephthalic acid and their C₁ to C₄ alkyl esters with 1,3 bis(2-hydroxyethoxy)benzene and ethylene glycol. Optionally, the
10 mixture may further comprise one or more ester-forming dihydroxy hydrocarbon and/or bis(4-β-hydroxyethoxyphenyl)sulfone. Especially preferred copolyester materials are available from Mitsui Petrochemical Ind. Ltd. (Japan) as B-010, B-030 and others of this family.

Examples of preferred polyamide materials include MXD-6 from Mitsubishi Gas
15 Chemical (Japan). Other preferred polyamide materials include Nylon 6, and Nylon 66. Other preferred polyamide materials are blends of polyamide and polyester, including those comprising about 1-20% polyester by weight, including about 1-10% polyester by weight, where the polyester is preferably PET or a modified PET, including PET ionomer. In another embodiment, preferred polyamide materials are blends of polyamide and polyester,
20 including those comprising about 1-20% polyamide by weight, and 1-10% polyamide by weight, where the polyester is preferably PET or a modified PET, including PET ionomer. The blends may be ordinary blends or they may be compatibilized with one or more antioxidants or other materials. Examples of such materials include those described in U.S. Patent Publication No. 2004/0013833, filed March 21, 2003, which is hereby incorporated
25 by reference in its entirety. Other preferred polyesters include, but are not limited to, PEN and PET/PEN copolymers.

Certain coating materials are preferably applied as part of a top coat or layer that provides chemical resistance such as to caustic or acidic materials, than the layer immediately beneath the top coat. In certain embodiments, these top coats or layers are
30 aqueous based or non-aqueous based polyesters, polyolefins, and blends thereof which are optionally partially or fully cross linked. One preferred aqueous based polyester is polyethylene terephthalate, however other polyesters may also be used.

One suitable aqueous based polyester resin is described in U.S. Pat. No. 4,977,191 (Salsman), incorporated herein by reference. More specifically, U.S. Pat. No. 4,977,191 describes an aqueous based polyester resin, comprising a reaction product of 20-50% by weight of terephthalate polymer, 10-40% by weight of at least one glycol and 5-25% by weight of at least one oxyalkylated polyol.

Another suitable aqueous based polymer is a sulfonated aqueous based polyester resin composition as described in U.S. Pat. No. 5,281,630 (Salsman), herein incorporated by reference. Specifically, U.S. Pat. No. 5,281,630 describes an aqueous suspension of a sulfonated water-soluble or water dispersible polyester resin comprising a reaction product of 20-50% by weight terephthalate polymer, 10-40% by weight at least one glycol and 5-25% by weight of at least one oxyalkylated polyol to produce a prepolymer resin having hydroxyalkyl functionality where the prepolymer resin is further reacted with about 0.10 mole to about 0.50 mole of alpha, beta-ethylenically unsaturated dicarboxylic acid per 100 g of prepolymer resin and a thus produced resin, terminated by a residue of an alpha, beta-ethylenically unsaturated dicarboxylic acid, is reacted with about 0.5 mole to about 1.5 mole of a sulfite per mole of alpha, beta-ethylenically unsaturated dicarboxylic acid residue to produce a sulfonated-terminated resin.

Yet another suitable aqueous based polymer is the coating described in U.S. Pat. No. 5,726,277 (Salsman), incorporated herein by reference. Specifically, U.S. Pat. No. 5,726,277 describes coating compositions comprising a reaction product of at least 50% by weight of waste terephthalate polymer and a mixture of glycols including an oxyalkylated polyol in the presence of a glycolysis catalyst wherein the reaction product is further reacted with a difunctional, organic acid and wherein the weight ratio of acid to glycols in is the range of 6:1 to 1:2.

While the above examples are provided as preferred aqueous based polymer coating compositions, other aqueous based polymers are suitable for use in the products and methods describe herein. By way of example only, and not meant to be limiting, further suitable aqueous based compositions are described in U.S. Pat. No. 4,104,222 (Date, et al.), incorporated herein by reference. U.S. Pat. No. 4,104,222 describes a dispersion of a linear polyester resin obtained by mixing a linear polyester resin with a higher alcohol/ethylene oxide addition type surface-active agent, melting the mixture and dispersing the resulting melt by pouring it into an aqueous solution of an alkali under stirring. Specifically, this

dispersion is obtained by mixing a linear polyester resin with a surface-active agent of the higher alcohol/ethylene oxide addition type, melting the mixture, and dispersing the resulting melt by pouring it into an aqueous solution of an alkanolamine under stirring at a temperature of 70-95° C, said alkanolamine being selected from the group consisting of

5 monoethanolamine, diethanolamine, triethanolamine, monomethylethanolamine, monoethylethanolamine, diethylethanolamine, propanolamine, butanolamine, pentanolamine, N-phenylethanolamine, and an alkanolamine of glycerin, said alkanolamine being present in the aqueous solution in an amount of 0.2 to 5 weight percent, said surface-active agent of the higher alcohol/ethylene oxide addition type being an ethylene oxide

10 addition product of a higher alcohol having an alkyl group of at least 8 carbon atoms, an alkyl-substituted phenol or a sorbitan monoacylate and wherein said surface-active agent has an HLB value of at least 12.

Likewise, by example, U.S. Pat. No. 4,528,321 (Allen) discloses a dispersion in a water immiscible liquid of water soluble or water swellable polymer particles and which

15 has been made by reverse phase polymerization in the water immiscible liquid and which includes a non-ionic compound selected from C₄₋₁₂ alkylene glycol monoethers, their C₁₋₄ alkanoates, C₆₋₁₂ polyalkylene glycol monoethers and their C₁₋₄ alkanoates.

In some embodiments, a coating material may also be used as a base preform material.

20 2. Additives to Enhance Coating Materials

An advantage of preferred methods disclosed herein are their flexibility allowing for the use of multiple functional additives in various combinations and/or in one or more layers. Additives known by those of ordinary skill in the art for their ability to provide enhanced CO₂ barriers, O₂ barriers, UV protection, scuff resistance, blush resistance,

25 impact resistance, and/or chemical resistance are among those that may be used. For additives listed herein, the percentages given are percent by weight of the materials in the coating solution exclusive of solvent, sometimes referred to as the "solids" although not all non-solvent materials are solid.

Preferred additives may be prepared by methods known to those of skill in the art.

30 For example, the additives may be mixed directly with a particular material, they may be dissolved/dispersed separately and then added to a particular material, or they may be combined with a particular material to addition of the solvent that forms the material

solution/dispersion. In addition, in some embodiments, preferred additives may be used alone as a single layer or as part of a single layer.

In preferred embodiments, the barrier properties of a layer may be enhanced by the use of additives. Additives are preferably present in an amount up to about 40% of the material, also including up to about 30%, 20%, 10%, 5%, 2% and 1% by weight of the material. In other embodiments, additives are preferably present in an amount less than or equal to 1% by weight, preferred ranges of materials include, but are not limited to, about 0.01% to about 1%, about 0.01% to about 0.1%, and about 0.1% to about 1% by weight. In some embodiments additives are preferably stable in aqueous conditions.

Derivatives of resorcinol (m-dihydroxybenzene) may be used in conjunction with various preferred materials as blends or as additives or monomers in the formation of the material. The higher the resorcinol content the greater the barrier properties of the material. For example, resorcinol diglycidyl ether can be used in PHAE and hydroxyethyl ether resorcinol can be used in PET and other polyesters and Copolyester Barrier Materials.

Another type of additive that may be used are "nanoparticles" or "nanoparticulate material." For convenience the term nanoparticles will be used herein to refer to both nanoparticles and nanoparticulate material. These nanoparticles are tiny, micron or sub-micron size (diameter), particles of materials including inorganic materials such as clay, ceramics, zeolites, elements, metals and metal compounds such as aluminum, aluminum oxide, iron oxide, and silica, which enhance the barrier properties of a material usually by creating a more tortuous path for migrating gas molecules, e.g. oxygen or carbon dioxide, to take as they permeate a material. In preferred embodiments nanoparticulate material is present in amounts ranging from 0.05 to 1% by weight, including 0.1%, 0.5% by weight and ranges encompassing these amounts.

One preferred type of nanoparticulate material is a microparticulate clay based product available from Southern Clay Products. One preferred line of products available from Southern Clay products is Cloisite® nanoparticles. In one embodiment preferred nanoparticles comprise monmorillonite modified with a quaternary ammonium salt. In other embodiments nanoparticles comprise monmorillonite modified with a ternary ammonium salt. In other embodiments nanoparticles comprise natural monmorillonite. In further embodiments, nanoparticles comprise organoclays as described in U.S. Patent No. 5,780,376, the entire disclosure of which is hereby incorporated by reference and forms part

of the disclosure of this application. Other suitable organic and inorganic microparticulate clay based products may also be used. Both man-made and natural products are also suitable.

Another type of preferred nanoparticulate material comprises a composite material of a metal. For example, one suitable composite is a water based dispersion of aluminum oxide in nanoparticulate form available from BYK Chemie (Germany). It is believed that this type of nanoparticulate material may provide one or more of the following advantages: increased abrasion resistance, increased scratch resistance, increased T_g , and thermal stability.

Another type of preferred nanoparticulate material comprises a polymer-silicate composite. In preferred embodiments the silicate comprises montmorillonite. Suitable polymer-silicate nanoparticulate materials are available from Nanocor and RTP Company. Other preferred nanoparticle materials include fumed silica, such as Cab-O-Sil.

In preferred embodiments, the UV protection properties of the material may be enhanced by the addition of different additives. In a preferred embodiment, the UV protection material used provides UV protection up to about 350 nm or lower, including about 370 nm or lower, and about 400 nm or lower. The UV protection material may be used as an additive with layers providing additional functionality or applied separately from other functional materials or additives in one or more layers. Preferably additives providing enhanced UV protection are present in the material from about 0.05 to 20% by weight, but also including about 0.1%, 0.5%, 1%, 2%, 3%, 5%, 10%, and 15% by weight, and ranges encompassing these amounts. Preferably the UV protection material is added in a form that is compatible with the other materials. For example, a preferred UV protection material is Milliken UV390A ClearShield®. UV390A is an oily liquid for which mixing is aided by first blending the liquid with water, preferably in roughly equal parts by volume. This blend is then added to the material solution, for example, BLOX® 599-29, and agitated. The resulting solution contains about 10% UV390A and provides UV protection up to 390 nm when applied to a PET preform. As previously described, in another embodiment the UV390A solution is applied as a single layer. In other embodiments, a preferred UV protection material comprises a polymer grafted or modified with a UV absorber that is added as a concentrate. Other preferred UV protection materials include, but are not limited to, benzotriazoles, phenothiazines, and azaphenothiazines. UV protection materials

may be added during the melt phase process prior to use, e.g. prior to injection molding extrusion, or palletizing, or added directly to a coating material that is in the form of a solution or dispersion. Suitable UV protection materials include those available from Milliken, Ciba and Clariant.

5 Carbon dioxide (CO₂) scavenging properties can be added to one or more materials and/or layers. In one preferred embodiment such properties are achieved by including one or more scavengers, such as an active amine reacts with CO₂ to form a high gas barrier salt. This salt then acts as a passive CO₂ barrier. The active amine may be an additive or it may be one or more moieties in the resin material of one or more layers. Suitable carbon
10 dioxide scavenger materials other than amines may also be used.

 Oxygen (O₂) scavenging properties can be added to preferred materials by including one or more O₂ scavengers such as anthroquinone and others known in the art. In another embodiment, one suitable O₂ scavenger is AMOSORB[®] O₂ scavenger available from BP Amoco Corporation and ColorMatrix Corporation which is disclosed in U.S. Patent No.
15 6,083,585 to Cahill et al., the disclosure of which is hereby incorporated in its entirety. In one embodiment, O₂ scavenging properties are added to preferred phenoxy-type materials, or other materials, by including O₂ scavengers in the phenoxy-type material, with different activating mechanisms. Preferred O₂ scavengers can act spontaneously, gradually or with delayed action, e.g. not acting until being initiated by a specific trigger. In some
20 embodiments the O₂ scavengers are activated via exposure to UV or water (e.g., present in the contents of the container), or a combination of both. The O₂ scavenger, when present, is preferably present in an amount of from about 0.1 to about 20 percent by weight, more preferably in an amount of from about 0.5 to about 10 percent by weight, and, most preferably, in an amount of from about 1 to about 5 percent by weight, based on the total
25 weight of the coating layer.

 The materials of certain embodiments may be cross-linked to enhance thermal stability for various applications, for example hot fill applications. In one embodiment, inner layers may comprise low-cross linking materials while outer layers may comprise high crosslinking materials or other suitable combinations. For example, an inner coating
30 on a PET surface may utilize non crosslinked or low cross-linked material, such as the BLOX[®] 588-29, and the outer coat may utilize another material, such as EXP 12468-4B from ICI, capable of cross linking such as to provide greater adhesion to the underlying

layer, such as a PET or PP layer. Suitable additives capable of cross linking may be added to one or more layers. Suitable cross linkers can be chosen depending upon the chemistry and functionality of the resin or material to which they are added. For example, amine cross linkers may be useful for crosslinking resins comprising epoxide groups. Preferably cross linking additives, if present, are present in an amount of about 1% to 10% by weight of the coating solution/dispersion, preferably about 1% to 5%, more preferably about 0.01% to 0.1% by weight, also including 2%, 3%, 4%, 6%, 7%, 8%, and 9% by weight. Optionally, a thermoplastic epoxy (TPE) can be used with one or more crosslinking agents. In some embodiments, agents (e.g. carbon black) may also be coated onto or incorporated into a layer material, including TPE material. The TPE material can form part of the articles disclosed herein. It is contemplated that carbon black or similar additives can be employed in other polymers to enhance material properties.

The materials of certain embodiments may optionally comprise a curing enhancer. As used herein, the term "curing enhancer" is a broad term and is used in its ordinary meaning and includes, without limitation, chemical cross-linking catalyst, thermal enhancer, and the like. As used herein, the term "thermal enhancer" is a broad term and is used in its ordinary meaning and includes, without limitation, materials that, when included in a polymer layer, increase the rate at which that polymer layer absorbs thermal energy and/or increases in temperature as compared to a layer without the thermal enhancer. Preferred thermal enhancers include, but are not limited to, transition metals, transition metal compounds, radiation absorbing additives (e.g., carbon black). An effective amount of thermal enhancers can be utilized to enhance the curing process. Suitable transition metals include, but are not limited to, cobalt, rhodium, and copper. Suitable transition metal compounds include, but are not limited to, metal carboxylates. Preferred carboxylates include, but are not limited to, neodecanoate, octoate, and acetate. Thermal enhancers may be used alone or in combination with one or more other thermal enhancers.

The thermal enhancer can be added to a material and may significantly increase the temperature of the material that can be achieved during a given curing process, as compared to the material without the thermal enhancer. For example, in some embodiments, the thermal enhancer (e.g., carbon black) can be added to a polymer so that the rate of heating or final temperature of the polymer subjected to a heating or curing process (e.g., IR radiation) is significantly greater than the polymer without the thermal enhancer when

subjected to the same or similar process. The increased heating rate of the polymer caused by the thermal enhancer can increase the rate of curing or drying and therefore increase production rates because less time is required for the process.

5 In some embodiments, the thermal enhancer is present in an amount of about 5 to 800 ppm, preferably about 20 to about 150 ppm, preferably about 50 to 125 ppm, preferably about 75 to 100 ppm, also including about 10, 20, 30, 40, 50, 75, 100, 125, 150, 175, 200, 300, 400, 500, 600, and 700 ppm and ranges encompassing these amounts. The amount of thermal enhancer may be calculated based on the weight of layer which comprises the thermal enhancer or the total weight of all layers comprising the article.

10 In some embodiments, a preferred thermal enhancer comprises carbon black. In one embodiment, carbon black can be applied as a component of a coating material in order to enhance the curing of the coating material. When used as a component of a coating material, carbon black is added to one or more of the coating materials before, during, and/or after the coating material is applied (e.g., impregnated, coated, etc.) to the article.

15 Preferably carbon black is added to the coating material and agitated to ensure thorough mixing. The thermal enhancer may comprise additional materials to achieve the desired material properties of the article. In another embodiment wherein carbon black is used in an injection molding process, the carbon black may be added to the polymer blend in the melt phase process.

20 In some embodiments, the polymer includes about 5 to 800 ppm, preferably about 20 to about 150 ppm, preferably about 50 to 125 ppm, preferably about 75 to 100 ppm, also including about 10, 20, 30, 40, 50, 75, 100, 125, 150, 175, 200, 300, 400, 500, 600, and 700 ppm thermal enhancer and ranges encompassing these amounts. In a further embodiment, the coating material is cured using radiation, such as infrared (IR) heating. In preferred

25 embodiments, the IR heating provides a more effective coating than curing using other methods. Other thermal and curing enhancers and methods of using same are disclosed in U.S. Patent Application Ser. No. 10/983,150, filed November 5, 2004, entitled "Catalyzed Process for Forming Coated Articles," the disclosure of which is hereby incorporated by reference in its entirety.

30 In some embodiments the addition of anti-foam/bubble agents is desirable. In some embodiments utilizing solutions or dispersion the solutions or dispersions form foam and/or bubbles which can interfere with preferred processes. One way to avoid this interference, is

to add anti-foam/bubble agents to the solution/dispersion. Suitable anti-foam agents include, but are not limited to, nonionic surfactants, alkylene oxide based materials, siloxane based materials, and ionic surfactants. Preferably anti-foam agents, if present, are present in an amount of about 0.01% to about 0.3% of the solution/dispersion, preferably
5 about 0.01% to about 0.2%, but also including about 0.02%, 0.03%, 0.04%, 0.05%, 0.06%, 0.07%, 0.08%, 0.09%, 0.1%, 0.25%, and ranges encompassing these amounts.

In another embodiment foaming agents may be added to the coating materials in order to foam the coating layer. In a further embodiment a reaction product of a foaming agent is used. Useful foaming agents include, but are not limited to azobisformamide,
10 azobisisobutyronitrile, diazoaminobenzene, N,N-dimethyl-N,N-dinitroso terephthalamide, N,N-dinitrosopentamethylene-tetramine, benzenesulfonyl-hydrazide, benzene-1,3-disulfonyl hydrazide, diphenylsulfon-3-3, disulfonyl hydrazide, 4,4'-oxybis benzene sulfonyl hydrazide, p-toluene sulfonyl semicarbazide, barium azodicarboxylate, butylamine nitrile, nitroureas, trihydrazino triazine, phenyl-methyl-urethane,
15 p-sulfonhydrazide, peroxides, ammonium bicarbonate, and sodium bicarbonate. As presently contemplated, commercially available foaming agents include, but are not limited to, EXPANCEL[®], CELOGEN[®], HYDROCEROL[®], MIKROFINE[®], CEL-SPAN[®], and PLASTRON[®] FOAM. Foaming agents and foamed layers are described in greater detail below.

20 The foaming agent is preferably present in the coating material in an amount from about 1 up to about 20 percent by weight, more preferably from about 1 to about 10 percent by weight, and, most preferably, from about 1 to about 5 percent by weight, based on the weight of the coating layer (i.e. solvents are excluded). Newer foaming technologies known to those of skill in the art using compressed gas could also be used as an alternate
25 means to generate foam in place of conventional blowing agents listed above.

3. Examples of Preferred Articles

In certain preferred embodiments, the finished article is formed from a process which comprises two or more coating layers applied sequentially upon a base article, which may be in the form of a preform, or a bottle, or any other type of container. The base article
30 may be manufactured from a thermoplastic material that has a lesser gas barrier performance and/or other functional performance than one or more of the coating layers to be applied subsequently, and may comprise PET, but in other embodiments may also be

PEN, PLA, PP, polycarbonate or other materials as described hereinabove. In another embodiment the the base preform or article may incorporate an oxygen scavenger, preferably one that is benign to the subsequent recycling stream after the finished article has been discarded.

5 A coating layer to be applied onto the base article preferably comprises a thermoplastic material that, when applied in a layer having a low thickness as compared to the base substrate, imparts improved gas and/or aroma barrier properties over the base article alone. Suitable materials to be used in a first coating layer include thermoplastic epoxy, PHAE, Phenoxy-type thermoplastics, blends including phenoxy-type thermoplastics,
10 MXD6, Nylon, nanoparticles or nanocomposites and blends thereof, PGA, PVDC, or other materials disclosed herein. The material is preferably applied in the form of a water based solution or dispersion, but can also be applied as a solvent based solution or dispersion, preferably exhibiting low VOCs. Materials are preferably those approved by the FDA for direct food contact, but such approval is not necessary. Additives to a first coating layer
15 may include UV absorbers, coloring agents and adhesion promoters to enhance adhesion of the coating to the substrate. To achieve desired properties, suitable materials may be partially heat cured and/or crosslinked to various degrees dependant on the application. The coating layer material is preferably applied by dip, spray or flow coating as described herein, followed by drying and/or curing as necessary, preferably with IR. If the coating
20 material is applied in the form of a solution, dispersion, or the like, the coated substrate is preferably completely dry before the second or top coating layer is applied.

 One or more further coating layers may be applied. In one embodiment, a further coating layer preferably comprises a thermoplastic material that imparts chemical resistance and/or abrasion resistance over the base article alone. To achieve desired properties,
25 suitable materials may be partially heat cured and/or crosslinked to various degrees dependant on the application. The material is preferably applied in the form of an aqueous or solvent based solution or dispersion, preferably exhibiting low VOCs. Additives to a further coating layer may include lubricants, thermal enhancers, UV absorbers and adhesion promoters. The application is preferably effected by dip, spray or flow coating on to a hot
30 preform, followed by drying and curing, preferably with IR.

E. Preferred Foam Materials

In some embodiments, a foam material may be used in a substrate (base article or preform) or in a coating layer. As used herein, the term "foam material" is a broad term and is used in accordance with its ordinary meaning and may include, without limitation, a foaming agent, a mixture of foaming agent and a binder or carrier material, an expandable cellular material, and/or a material having voids. The terms "foam material" and "expandable material" are used interchangeably herein. Preferred foam materials may exhibit one or more physical characteristics that improve the thermal and/or structural characteristics of articles (e.g., containers) and may enable the preferred embodiments to be able to withstand processing and physical stresses typically experienced by containers. In one embodiment, the foam material provides structural support to the container. In another embodiment, the foam material forms a protective layer that can reduce damage to the container during processing. For example, the foam material can provide abrasion resistance which can reduce damage to the container during transport. In one embodiment, a protective layer of foam may increase the shock or impact resistance of the container and thus prevent or reduce breakage of the container. Furthermore, in another embodiment foam can provide a comfortable gripping surface and/or enhance the aesthetics or appeal of the container.

In one embodiment, foam material comprises a foaming or blowing agent and a carrier material. In one preferred embodiment, the foaming agent comprises expandable structures (e.g., microspheres) that can be expanded and cooperate with the carrier material to produce foam. For example, the foaming agent can be thermoplastic microspheres, such as EXPANCEL® microspheres sold by Akzo Nobel. In one embodiment, microspheres can be thermoplastic hollow spheres comprising thermoplastic shells that encapsulate gas. Preferably, when the microspheres are heated, the thermoplastic shell softens and the gas increases its pressure causing the expansion of the microspheres from an initial position to an expanded position. The expanded microspheres and at least a portion of the carrier material can form the foam portion of the articles described herein. The foam material can form a layer that comprises a single material (e.g., a generally homogenous mixture of the foaming agent and the carrier material), a mix or blend of materials, a matrix formed of two or more materials, two or more layers, or a plurality of microlayers (lamellae) preferably

including at least two different materials. Alternatively, the microspheres can be any other suitable controllably expandable material. For example, the microspheres can be structures comprising materials that can produce gas within or from the structures. In one embodiment, the microspheres are hollow structures containing chemicals which produce or contain gas wherein an increase in gas pressure causes the structures to expand and/or burst. In another embodiment, the microspheres are structures made from and/or containing one or more materials which decompose or react to produce gas thereby expanding and/or bursting the microspheres. Optionally, the microsphere may be generally solid structures. Optionally, the microspheres can be shells filled with solids, liquids, and/or gases. The microspheres can have any configuration and shape suitable for forming foam. For example, the microspheres can be generally spherical. Optionally, the microspheres can be elongated or oblique spheroids. Optionally, the microspheres can comprise any gas or blends of gases suitable for expanding the microspheres. In one embodiment, the gas can comprise an inert gas, such as nitrogen. In one embodiment, the gas is generally non-flammable. However, in certain embodiments non-inert gas and/or flammable gas can fill the shells of the microspheres. In some embodiments, the foam material may comprise foaming or blowing agents as are known in the art. Additionally, the foam material may be mostly or entirely foaming agent.

Although some preferred embodiments contain microspheres that generally do not break or burst, other embodiments comprise microspheres that may break, burst, fracture, and/or the like. Optionally, a portion of the microspheres may break while the remaining portion of the microspheres do not break. In some embodiments up to about 0.5%, 1%, 2%, 3%, 4%, 5%, 10%, 20%, 30%, 40%, 50%, 60% 70%, 80%, 90% by weight of microspheres, and ranges encompassing these amounts, break. In one embodiment, for example, a substantial portion of the microspheres may burst and/or fracture when they are expanded. Additionally, various blends and mixtures of microspheres can be used to form foam material.

The microspheres can be formed of any material suitable for causing expansion. In one embodiment, the microspheres can have a shell comprising a polymer, resin, thermoplastic, thermoset, or the like as described herein. The microsphere shell may comprise a single material or a blend of two or more different materials. For example, the microspheres can have an outer shell comprising ethylene vinyl acetate ("EVA"),

polyethylene terephthalate ("PET"), polyamides (e.g. Nylon 6 and Nylon 66) polyethylene terephthalate glycol (PETG), PEN, PET copolymers, and combinations thereof. In one embodiment a PET copolymer comprises CHDM comonomer at a level between what is commonly called PETG and PET. In another embodiment, comonomers such as DEG and
5 IPA are added to PET to form microsphere shells. The appropriate combination of material type, size, and inner gas can be selected to achieve the desired expansion of the microspheres. In one embodiment, the microspheres comprise shells formed of a high temperature material (e.g., PETG or similar material) that is capable of expanding when subject to high temperatures, preferably without causing the microspheres to burst. If the
10 microspheres have a shell made of low temperature material (e.g., as EVA), the microspheres may break when subjected to high temperatures that are suitable for processing certain carrier materials (e.g., PET or polypropylene having a high melt point). In some circumstances, for example, EXPANCEL® microspheres may be break when processed at relatively high temperatures. Advantageously, mid or high temperature
15 microspheres can be used with a carrier material having a relatively high melt point to produce controllably, expandable foam material without breaking the microspheres. For example, microspheres can comprise a mid temperature material (e.g., PETG) or a high temperature material (e.g., acrylonitrile) and may be suitable for relatively high temperature applications. Thus, a blowing agent for foaming polymers can be selected based on the
20 processing temperatures employed.

The foam material can be a matrix comprising a carrier material, preferably a material that can be mixed with a blowing agent (e.g., microspheres) to form an expandable material. The carrier material can be a thermoplastic, thermoset, or polymeric material, such as ethylene vinyl acetate ("EVA"), linear low density polyethylene ("LLDPE"),
25 polyethylene terephthalate glycol (PETG), poly(hydroxyamino ethers) ("PHAE"), PET, polyethylene, polypropylene, polystyrene ("PS"), pulp (e.g., wood or paper pulp or fibers, or pulp mixed with one or more polymers), mixtures thereof, and the like. However, other materials suitable for carrying the foaming agent can be used to achieve one or more of the desired thermal, structural, optical, and/or other characteristics of the foam. In some
30 embodiments, the carrier material has properties (e.g., a high melt index) for easier and rapid expansion of the microspheres, thus reducing cycle time thereby resulting in increased production.

In preferred embodiments, the formable material may comprise two or more components including a plurality of components each having different processing windows and/or physical properties. The components can be combined such that the formable material has one or more desired characteristics. The proportion of components can be varied to produce a desired processing window and/or physical properties. For example, the first material may have a processing window that is similar to or different than the processing window of the second material. The processing window may be based on, for example, pressure, temperature, viscosity, or the like. Thus, components of the formable material can be mixed to achieve a desired, for example, pressure or temperature range for shaping the material.

In one embodiment, the combination of a first material and a second material may result in a material having a processing window that is more desirable than the processing window of the second material. For example, the first material may be suitable for processing over a wide range of temperatures, and the second material may be suitable for processing over a narrow range of temperatures. A material having a portion formed of the first material and another portion formed of the second material may be suitable for processing over a range of temperatures that is wider than the narrow range of processing temperatures of the second material. In one embodiment, the processing window of a multi-component material is similar to the processing window of the first material. In one embodiment, the formable material comprises a multilayer sheet or tube comprising a layer comprising PET and a layer comprising polypropylene. The material formed from both PET and polypropylene can be processed (e.g., extruded) within a wide temperature range similar to the processing temperature range suitable for PET. The processing window may be for one or more parameters, such as pressure, temperature, viscosity, and/or the like.

Optionally, the amount of each component of the material can be varied to achieve the desired processing window. Optionally, the materials can be combined to produce a formable material suitable for processing over a desired range of pressure, temperature, viscosity, and/or the like. For example, the proportion of the material having a more desirable processing window can be increased and the proportion of material having a less undesirable processing window can be decreased to result in a material having a processing window that is very similar to or is substantially the same as the processing window of the first material. Of course, if the more desired processing window is between a first

processing window of a first material and the second processing window of a second material, the proportion of the first and the second material can be chosen to achieve a desired processing window of the formable material.

Optionally, a plurality of materials each having similar or different processing
5 windows can be combined to obtain a desired processing window for the resultant material.

In one embodiment, the rheological characteristics of a formable material can be altered by varying one or more of its components having different rheological characteristics. For example, a substrate (e.g., PP) may have a high melt strength and is amenable to extrusion. PP can be combined with another material, such as PET which has
10 a low melt strength making it difficult to extrude, to form a material suitable for extrusion processes. For example, a layer of PP or other strong material may support a layer of PET during co-extrusion (e.g., horizontal or vertical co-extrusion). Thus, formable material formed of PET and polypropylene can be processed, e.g., extruded, in a temperature range generally suitable for PP and not generally suitable for PET.

15 In some embodiments, the composition of the formable material may be selected to affect one or more properties of the articles. For example, the thermal properties, structural properties, barrier properties, optical properties, rheology properties, favorable flavor properties, and/or other properties or characteristics disclosed herein can be obtained by using formable materials described herein.

20 F. Preferred Articles

Generally, preferred articles herein include preforms or containers having one or more coating layers. The coating layer or layers preferably provide some functionality such as barrier protection, UV protection, impact resistance, scuff resistance, blush resistance, chemical resistance, antimicrobial properties, and the like. The layers may be applied as
25 multiple layers, each layer having one or more functional characteristics, or as a single layer containing one or more functional components. The layers are applied sequentially with each coating layer being partially or fully dried/cured prior to the next coating layer being applied.

A preferred substrate is a PET preform or container as described above. However,
30 other substrate materials may also be utilized. Other suitable substrate materials include, but are not limited to, polyesters, polypropylene, polyethylene, polycarbonate, polyamides and acrylics.

For example, in one multiple layer article, the inner layer is a primer or base coat having functional properties for enhanced adhesion to PET, O₂ scavenging, UV resistance and passive barrier and the one or more outer coatings provide passive barrier and scuff resistance. In the descriptions herein with regard to coating layers, inner is taken as being
5 closer to the substrate and outer is taken as closer to the exterior surface of the container. Any layers between inner and outer layers are generally described as “intermediate” or “middle.” In other embodiments, multiple coated articles comprise an inner coating layer comprising an O₂ scavenger, an intermediate active UV protection layer, followed by an outer layer of the partially or highly cross-linked material. In another embodiment, multiple
10 coated preforms comprise an inner coating layer comprising an O₂ scavenger, an intermediate CO₂ scavenger layer, an intermediate active UV protection layer, followed by an outer layer of partially or highly cross-linked material. These combinations provide a hard increased cross linked coating that is suitable for carbonated beverages such as beer. In another embodiment useful for carbonated soft drinks, the inner coating layer is a UV
15 protection layer followed by an outer layer of cross linked material. Although the above embodiments have been described in connection with particular beverages, they may be used for other purposes and other layer configurations may be used for the referenced beverages.

In a related embodiment, the final coating and drying of the preform provides scuff
20 resistance to the surface of the preform and finished container in that the solution or dispersion contains diluted or suspended paraffin or wax, slipping agent, polysilane or low molecular weight polyethylene to reduce the surface tension of the container.

G. Methods and Apparatus for Preparation of Coated Articles

Once suitable coating materials are chosen, the preform is preferably coated in a manner that promotes adhesion between the two materials. Although the discussion which follows is in terms of preforms, such discussion should not be taken as limiting, in that the methods and apparatus described may be applied or adapted for containers and other articles. Generally, adherence between coating materials and the preform substrate increases as the surface temperature of the preform increases. Therefore it is preferable to perform coating on a heated preform, although preferred coating materials will adhere to the preform at room temperature.

Plastics generally, and PET preforms specifically, have static electricity that results in the preforms attracting dust and getting dirty quickly. In a preferred embodiment the preforms are taken directly from the injection-molding machine and coated, including while still warm. By coating the preforms immediately after they are removed from the injection-molding machine, not only is the dust problem avoided, it is believed that the warm preforms enhance the coating process. However, the methods also allow for coating of preforms that are stored prior to coating. Preferably, the preforms are substantially clean, however cleaning is not necessary.

In a preferred embodiment an automated system is used. A preferred method involves entry of the preform into the system, dip, spray, or flow coating of the preform, optional removal of excess material, drying/curing, cooling, and ejection from the system. The system may also optionally include a recycle step. In one embodiment the apparatus is a single integrated processing line that contains two or more dip, flow, or spray coating units and two or more curing/drying units that produce a preform with multiple coatings. In another embodiment, the system comprises one or more coating modules. Each coating module comprises a self-contained processing line with one or more dip, flow, or spray coating units and one or more curing/drying units. Depending on the module configuration, a preform may receive one or more coatings. For example, one configuration may comprise three coating modules wherein the preform is transferred from one module to the next, in another configuration, the same three modules may be in place but the preform is transferred from the first to the third module skipping the second. This ability to switch between different module configurations allows for flexibility. In a further preferred embodiment either the modular or the integrated systems may be connected directly to a

preform injection-molding machine and/or a blow-molding machine. The injection molding machine prepares preforms for use in the present invention.

The following describes a preferred embodiment of a coating system that is fully automated. This system is described in terms of currently preferred materials, but it is understood by one of ordinary skill in the art that certain parameters will vary depending on the materials used and the particular physical structure of the desired end-product preform. This method is described in terms of producing coated 24 gram preforms having about 0.05 to about 0.75 total grams of coating material deposited thereon, including about 0.07, 0.09, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45, 0.50, 0.55, 0.60, 0.65, and 0.70 grams. In the method described below, the coating solution/dispersion is at a suitable temperature and viscosity to deposit about 0.06 to about 0.20 grams of coating material per coating layer on a 24 gram preform, also including about 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, and 0.19 grams per coating layer on a 24 gram preform. Preferred deposition amounts for articles of varying sizes may be scaled according to the increase or decrease in surface area as compared to a 24 gram preform. Accordingly, articles other than 24 gram preforms may fall outside of the ranges stated above. Furthermore, in some embodiments, it may be desired to have a single layer or total coating amount on a 24 gram preform that lies outside of the ranges stated above.

The apparatus and methods may also be used for other similarly sized preforms and containers, or may adapted for other sizes of articles as will be evident to those skilled in the art in view of the discussion which follows. Currently preferred coating materials include, TPEs, preferably phenoxy type resins, more preferably PHAEs, including the BLOX resins noted supra. These materials and methods are given by way of example only and are not intended to limit the scope of the invention in any way.

1. Entry into the System

The preforms are first brought into the system. An advantage of one preferred method is that ordinary preforms such as those normally used by those of skill in the art may be used. For example, 24 gram monolayer preforms of the type in common use to make 16 ounce bottles can be used without any alteration prior to entry into the system. In one embodiment the system is connected directly to a preform injection molding machine providing warm preforms to the system. In another embodiment stored preforms are added to the system by methods well known to those skilled in the art including those which load

preforms into an apparatus for additional processing. Preferably the stored preforms are pre-warmed to about 100 °F to about 130 °F, including about 120 °F, prior to entry into the system. The stored preforms are preferably clean, although cleaning is not necessary. PET preforms are preferred, however other preform and container substrates can be used. Other
5 suitable article substrates include, but are not limited to, various polymers such as polyesters, polyolefins, including polypropylene and polyethylene, polycarbonate, polyamides, including nylons, or acrylics.

2. Dip, Spray, or Flow Coating

Once a suitable coating material is chosen, it can be prepared and used for either
10 dip, spray, or flow coating. The material preparation is essentially the same for dip, spray, and flow coating. The coating material comprises a solution/dispersion made from one or more solvents into which the resin of the coating material is dissolved and/or suspended.

The temperature of the coating solution/dispersion can have a drastic effect on the viscosity of the solution/dispersion. As temperature increases, viscosity decreases and vice
15 versa. In addition, as viscosity increases the rate of material deposition also increases. Therefore temperature can be used as a mechanism to control deposition. In one embodiment using flow coating, the temperature of the solution/dispersion is maintained in a range cool enough to minimize curing of the coating material but warm enough to maintain a suitable viscosity. In one embodiment, the temperature is about 60°F - 80°F,
20 including about 70°F. In some cases, solutions/dispersions that may be too viscous to use in spray or flow coating may be used in dip coating. Similarly, because the coating material may spend less time at an elevated temperature in spray coating, higher temperatures than would be recommended for dip or flow coating because of curing problems may be utilized in spray coating. In any case, a solution or dispersion may be used at any temperature
25 wherein it exhibits suitable properties for the application. In preferred embodiments, a temperature control system is used to ensure constant temperature of the coating solution/dispersion during the application process. In certain embodiments, as the viscosity increases, the addition of water may decrease the viscosity of the solution/dispersion. Other embodiments may also include a water content monitor and/or a viscosity monitor that
30 provides a signal when viscosity falls outside a desired range and/or which automatically adds water or other solvent to achieve viscosity within a desired range.

In a preferred embodiment, the solution/dispersion is at a suitable temperature and viscosity to deposit about 0.06 to about 0.2 grams per coat on a 24 gram preform, also including about 0.07, 0.08, 0.09, 0.1, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, and 0.19 grams per coating layer on a 24 gram preform. Preferred deposition amounts for articles of varying sizes may be scaled according to the increase or decrease in surface area as compared to a 24 gram preform. Accordingly, articles other than 24 gram preforms may fall outside of the ranges stated above. Furthermore, in some embodiments, it may be desired to have a single layer on a 24 gram preform that lies outside of the ranges stated above.

In one embodiment, coated preforms produced from dip, spray, or flow coating are of the type seen in FIG. 3. The coating 22 is disposed on the body portion 4 of the preform and does not coat the neck portion 2. The interior of the coated preform 16 is preferably not coated. In a preferred embodiment this is accomplished through the use of a holding mechanism comprising an expandable collet or grip mechanism that is inserted into the preform combined with a housing surrounding the outside of the neck portion of the preform. The collet expands thereby holding the preform in place between the collet and the housing. The housing covers the outside of the neck including the threading, thereby protecting the inside of the preform as well as the neck portion from coating.

In preferred embodiments, coated preforms produced from dip, spray, or flow coating produce a finished product with substantially no distinction between layers. Further, in dip and flow coating procedures, it has been found that the amount of coating material deposited on the preform decreases slightly with each successive layer.

a. Dip Coating

In a preferred embodiment, the coating is applied through a dip coating process. The preforms are dipped into a tank or other suitable container that contains the coating material. The dipping of the preforms into the coating material can be done manually by the use of a retaining rack or the like, or it may be done by a fully automated process. Although the apparatus shown in Fig. 14 depicts one embodiment of an automated flow coating unit, in certain embodiments utilizing automated dip coating, the position of the flow coater 86 would represent the positioning of the dip coating tank or other suitable container containing the coating material.

In a preferred embodiment, the preforms are rotating while being dipped into the coating material. The preform preferably rotates at a speed of about 30 - 80 RPM, more preferably about 40 RPM, but also including 50, 60, and 70 RPM. This allows for thorough coating of the preform. Other speeds may be used, but preferably not so high as to cause
5 loss of coating material due to centrifugal forces.

The preform is preferably dipped for a period of time sufficient to allow for thorough coverage of the preform. Generally, this ranges from about 0.25 to about 5 seconds although times above and below this range are also included. Without wishing to be bound to any theory, it appears that longer residence time does not provide any added
10 coating benefit.

In determining the dipping time and therefore speed, the turbidity of the coating material should also be considered. If the speed is too high the coating material may become wavelike and splatter causing coating defects. Another consideration is that many coating material solutions or dispersions form foam and/or bubbles which can interfere with
15 the coating process. To avoid this interference, the dipping speed is preferably chosen to avoid excessive agitation of the coating material. If necessary anti-foam/bubble agents may be added to the coating solution/dispersion.

b. Spray Coating

In a preferred embodiment, the coating is applied through a spray coating process.
20 The preforms are sprayed with a coating material that is in fluid connection with a tank or other suitable container that contains the coating material. The spraying of the preforms with the coating material can be done manually with the use of a retaining rack or the like, or it may be done by a fully automated process. Although the apparatus shown in Fig. 14 depicts one embodiment of an automated flow coating unit, in certain embodiments
25 utilizing automated spray coating, the position of the flow coater 86 would represent the positioning of the spray coating apparatus.

In a preferred embodiment, the preforms are rotating while being sprayed with the coating material. The preform preferably rotates at a speed of about 30 - 80 RPM, more preferably about 40 RPM, but also including about 50, 60, and 70 RPM. Preferably, the
30 preform rotates at least about 360° while proceeding through the coating spray. This allows for thorough coating of the preform. The preform may, however, remain stationary while spray is directed at the preform.

The preform is preferably sprayed for a period of time sufficient to allow for thorough coverage of the preform. The amount of time required for spraying depends upon several factors, which may include the spraying rate (volume of spray per unit time), the area encompassed by the spray, and the like.

5 The coating material is contained in a tank or other suitable container in fluid communication with the production line. Preferably a closed system is used in which unused coating material is recycled. In one embodiment, this may be accomplished by collecting any unused coating material in a coating material collector which is in fluid communication with the coating material tank. Many coating material solutions or
10 dispersions form foam and/or bubbles which can interfere with the coating process. To avoid this interference, the coating material is preferably removed from the bottom or middle of the tank. Additionally, it is preferable to decelerate the material flow prior to returning to the coating tank to further reduce foam and/or bubbles. This can be done by means known to those of skill in the art. If necessary anti-foam/bubble agents may be
15 added to the coating solution/dispersion.

In determining the spraying time and associated parameters such as nozzle size and configuration, the properties of the coating material should also be considered. If the speed is too high and/or the nozzle size incorrect, the coating material may splatter causing coating defects. If the speed is too slow or the nozzle size incorrect, the coating material
20 may be applied in a manner thicker than desired. Suitable spray apparatus include those sold by Nordson Corporation (Westlake, Ohio). Another consideration is that many coating material solutions or dispersions form foam and/or bubbles which can interfere with the coating process. To avoid this interference, the spraying speed, nozzle used and fluid connections are preferably chosen to avoid excessive agitation of the coating material. If
25 necessary anti-foam/bubble agents may be added to the coating solution/dispersion.

c. Flow Coating

In a preferred embodiment, the coating is applied through a flow coating process. The object of flow coating is to provide a sheet of material, similar to a falling shower curtain or waterfall, that the preform passes through for thorough coating. Advantageously,
30 preferred methods of flow coating allow for a short residence time of the preform in the coating material. The preform need only pass through the sheet a period of time sufficient

to coat the surface of the preform. Without wishing to be bound to any theory, it appears that longer residence time does not provide any added coating benefit.

Referring to FIGS. 14, 15, and 16 there are shown alternate views of non-limiting diagrams of one embodiment of a preferred flow coating process. In this embodiment, the top view of a system comprising a single flow coater 86 is shown. The preform enters the system 84 and then proceeds to the flow coater 86 wherein the preform 1 passes through the coating material waterfall (not illustrated). The coating material proceeds from the tank or vat 150 through the gap 155 in the tank down the angled fluid guide 160 where it forms a waterfall as it passes onto the preforms. Other embodiments may have fluid guides that are substantially horizontal. The gap 155 in the tank 150 may be widened or narrowed to adjust the flow of the material. The material is pumped from the reservoir (not illustrated) into the vat or tank 150 at a rate that maintains the coating material level above that of the gap 155. Advantageously, this configuration ensures a constant flow of coating material. The excess amount of material also dampens any fluid fluctuations due to the cycling of the pump.

In order to provide an even coating the preform is preferably rotating while it proceeds through the sheet of coating material. The preform preferably rotates at a speed of about 30 - 80 RPM, more preferably about 40 RPM, but also including 50, 60, and 70 RPM. Preferably, the preform rotates at least about two full rotations or 720° while being proceeding through the sheet of coating material. In one preferred embodiment, the preform is rotating and placed at an angle while it proceeds through the coating material sheet. The angle of the preform is preferably acute to the plane of the coating material sheet. This advantageously allows for thorough coating of the preform without coating the neck portion or inside of the preform. In another preferred embodiment, the preform 1 as shown in Fig. 16 is vertical, or perpendicular to the floor, while it proceeds through the coating material sheet. It has been found that as the coating material sheet comes into contact with the preform the sheet tends to creep up the wall of the preform from the initial point of contact. One of skill in the art can control this creep effect by adjusting parameters such as the flow rate, coating material viscosity, and physical placement of the coating sheet material relative to the preform. For example, as the flow increases the creep effect may also increase and possibly cause the coating material to coat more of the preform than is desirable. As another example, by decreasing the angle of the preform relative to the

coating material sheet, coating thickness may be adjusted to retain more material at the center or body of the preform as the angle adjustment decreases the amount of material removed or displaced to the bottom of the preform by gravity. The ability to manipulate this creep effect advantageously allows for thorough coating of the preform without coating the neck portion or inside of the preform.

The coating material is contained in a tank or other suitable container in fluid communication with the production line in a closed system. It is preferable to recycle any unused coating material. In one embodiment, this may be accomplished by collecting the returning waterfall flow stream in a coating material collector which is in fluid communication with the coating material tank. Many coating material solutions or dispersions form foam and/or bubbles which can interfere with the coating process. To avoid this interference, the coating material is preferably removed from the bottom or middle of the tank. Additionally, it is preferable to decelerate the material flow prior to returning to the coating tank to further reduce foam and/or bubbles. This can be done by means known to those of skill in the art. If necessary, anti-foam/bubble agents may be added to the coating solution/dispersion.

In choosing the proper flow rate of coating materials, several variables should be considered to provide proper sheeting, including coating material viscosity, flow rate velocity, length and diameter of the preform, line speed and preform spacing.

The flow rate velocity determines the accuracy of the sheet of material. If the flow rate is too fast or too slow, the material may not accurately coat the preforms. When the flow rate is too fast, the material may splatter and overshoot the production line causing incomplete coating of the preform, waste of the coating material, and increased foam and/or bubble problems. If the flow rate is too slow the coating material may only partially coat the preform.

The length and the diameter of the preform to be coated should also be considered when choosing a flow rate. The sheet of material should thoroughly cover the entire preform, therefore flow rate adjustments may be necessary when the length and diameter of preforms are changed.

Another factor to consider is the spacing of the preforms on the line. As the preforms are run through the sheet of material a so-called wake effect may be observed. If the next preform passes through the sheet in the wake of the prior preform it may not

receive a proper coating. Therefore it is important to monitor the speed and center line of the preforms. The speed of the preforms will be dependant on the throughput of the specific equipment used.

3. Removal of Excess Material

5 Advantageously preferred methods provide such efficient deposition that virtually all of the coating on the preform is utilized (i.e. there is virtually no excess material to remove). However there are situations where it is necessary to remove excess coating material after the preform is coated by dip, spray or flow methods. Preferably, the rotation speed and gravity will work together to normalize the sheet on the preform and remove any
10 excess material. Preferably, preforms are allowed to normalize for about 5 to about 15 seconds, more preferably about 10 seconds. If the tank holding the coating material is positioned in a manner that allows the preform to pass over the tank after coating, the rotation of the preform and gravity may cause some excess material to drip off of the preform back into the coating material tank. This allows the excess material to be recycled
15 without any additional effort. If the tank is situated in a manner where the excess material does not drip back into the tank, other suitable means of catching the excess material and returning it to be reused, such as a coating material collector or reservoir in fluid communication with the coating tank or vat, may be employed.

Where the above methods are impractical due to production circumstances or
20 insufficient, various methods and apparatus, such as a drip remover 88 may be used to remove excess material. See e.g. FIGS. 14, 15, and 16. For example, suitable drip removers include one or more of the following: a wiper, brush, sponge roller, air knife or air flow, which may be used alone or in conjunction with each other. Further, any of these methods may be combined with the rotation and gravity method described above. Preferably any
25 excess material removed by these methods is recycled for further use.

4. Drying and Curing

After the preform 1 has been coated and any excess material removed 88, the coated preform is then dried and cured 90. The drying and curing process is preferably performed by infrared (IR) heating 90. See FIGS. 14, 15, 17A, and 17B. In one embodiment, a 1000
30 W quartz IR lamp 200 is used as the source. A preferred source is a General Electric Q1500 T3/CL Quartzline Tungsten-Halogen lamp. This particular source and equivalent sources may be purchased commercially from any of a number of sources including General

Electric and Phillips. The source may be used at full capacity, or it may be used at partial capacity such as at about 50%, about 65%, about 75% and the like. Preferred embodiments may use a single lamp or a combination of multiple lamps. For example, six IR lamps may be used at 70% capacity.

5 Preferred embodiments may also use lamps whose physical orientation with respect to the preform is adjustable. As shown in FIGS. 17A and 17B, the lamp position 200 may be adjusted 220 to position the lamp closer to or farther away from the preform. For example, in one embodiment with multiple lamps, it may be desirable to move one or more of the lamps located below the bottom of the preform closer to the preform. This
10 advantageously allows for thorough curing of the bottom of the preform. Embodiments with adjustable lamps may also be used with preforms of varying widths. For example, if a preform is wider at the top than at the bottom, the lamps may be positioned closer to the preform at the bottom of the preform to ensure even curing. The lamps are preferably oriented so as to provide relatively even illumination of all surfaces of the coating.

15 In other embodiments reflectors are used in combination with IR lamps to provide thorough curing. In preferred embodiments lamps 200 are positioned on one side of the processing line while one or more reflectors 210 230 are located on the opposite side of or below the processing line. This advantageously reflects the lamp output back onto the preform allowing for a more thorough cure. More preferably an additional reflector 210 is
20 located below the preform to reflect heat from the lamps upwards towards the bottom of the preform. This advantageously allows for thorough curing of the bottom of the preform. In other preferred embodiments various combinations of reflectors may be used depending on the characteristics of the articles and the IR lamps used. More preferably reflectors are used in combination with the adjustable IR lamps described above.

25 FIG. 17 depicts a view of one non-limiting embodiment of a preferred IR drying/curing unit. On one side of the processing line there is shown a series of lamps 200. Below the preforms there is shown an angled reflector 210 which reflects heat towards the bottom of the preforms for more thorough curing. Opposite to the lamps is a semicircular reflector 230 which reflects the IR heat back onto the preforms allowing for a more
30 thorough and efficient cure. FIG. 17B is an enlarged section of the lamp which demonstrates an embodiment where the lamp placement is adjustable 220. The lamps may

be moved closer to or farther away from the preform allowing for maximum drying/curing flexibility.

In addition, the use of infrared heating allows for the thermoplastic epoxy (for example PHAE) coating to dry without overheating the PET substrate and can be used during preform heating prior to blow molding, thus making for an energy efficient system. Also, it has been found that use of IR heating can reduce blushing and improve chemical resistance.

Although this process may be performed without additional air, it is preferred that IR heating be combined with forced air. The air used may be hot, cold, or ambient. The combination of IR and air curing provides the unique attributes of superior chemical, blush, and scuff resistance of preferred embodiments. Further, without wishing to be bound to any particular theory, it is believed that the coating's chemical resistance is a function of crosslinking and curing. The more thorough the curing, the greater the chemical resistance.

In determining the length of time necessary to thoroughly dry and cure the coating several factors such as coating material, thickness of deposition, and preform substrate should be considered. Different coating materials cure faster or slower than others. Additionally, as the degree of solids increases, the cure rate decreases. Generally, for IR curing, 24 gram preforms with about 0.05 to about 0.75 grams of coating material the curing time is about 5 to 60 seconds, although times above and below this range may also be used.

Another factor to consider is the surface temperature of the preform as it relates to the glass transition temperature (T_g) of the substrate and coating materials. Preferably the surface temperature of the coating exceeds the T_g of the coating materials without heating the substrate above the substrate T_g during the curing/drying process. This provides the desired film formation and/or crosslinking without distorting the preform shape due to overheating the substrate. For example, where the coating material has a higher T_g than the preform substrate material, the preform surface is preferably heated to a temperature above the T_g of the coating while keeping the substrate temperature at or below the substrate T_g . One way of regulating the drying/curing process to achieve this balance is to combine IR heating and air cooling, although other methods may also be used.

An advantage of using air in addition to IR heating is that the air regulates the surface temperature of the preform thereby allowing flexibility in controlling the

penetration of the radiant heat. If a particular embodiment requires a slower cure rate or a deeper IR penetration, this can be controlled with air alone, time spent in the IR unit, or the IR lamp frequency. These may be used alone or in combination.

Preferably, the preform rotates while proceeding through the IR heater. The
5 preform preferably rotates at a speed of about 30 - 80 RPM, more preferably about 40 RPM. If the rotation speed is too high, the coating will spatter causing uneven coating of the preform. If the rotation speed is too low, the preform dries unevenly. More preferably, the preform rotates at least about 360° while proceeding through the IR heater. This advantageously allows for thorough curing and drying.

10 In other preferred embodiments, Electron Beam Processing may be employed in lieu of IR heating or other methods. Electron Beam Processing (EBP) has not been used for curing of polymers used for and in conjunction with injection molded preforms and containers primarily due to its large size and relatively high cost. However recent advances in this technology, are expected to give rise to smaller less expensive machines. EBP
15 accelerators are typically described in terms of their energy and power. For example, for curing and crosslinking of food film coatings, accelerators with energies of 150-500 keV are typically used.

EBP polymerization is a process in which several individual groups of molecules combine together to form one large group (polymer). When a substrate or coating is
20 exposed to highly accelerated electrons, a reaction occurs in which the chemical bonds in the material are broken and a new, modified molecular structure is formed. This polymerization causes significant physical changes in the product, and may result in desirable characteristics such as high gloss and abrasion resistance. EBP can be a very efficient way to initiate the polymerization process in many materials.

25 Similar to EBP polymerization, EBP crosslinking is a chemical reaction, which alters and enhances the physical characteristics of the material being treated. It is the process by which an interconnected network of chemical bonds or links develop between large polymer chains to form a stronger molecular structure. EBP may be used to improve thermal, chemical, barrier, impact, wear and other properties of inexpensive commodity
30 thermoplastics. EBP of crosslinkable plastics can yield materials with improved dimensional stability, reduced stress cracking, higher set temperatures, reduced solvent and water permeability and improved thermomechanical properties.

The effect of the ionizing radiation on polymeric material is manifested in one of three ways: (1) those that are molecular weight-increasing in nature (crosslinking); (2) those that are molecular weight-reducing in nature (scissioning); or (3), in the case of radiation resistant polymers, those in which no significant change in molecular weight is observed.

5 Certain polymers may undergo a combination of (1) and (2). During irradiation, chain scissioning occurs simultaneously and competitively with crosslinking, the final result being determined by the ratio of the yields of these reactions. Polymers containing a hydrogen atom at each carbon atom predominantly undergo crosslinking, while for those polymers containing quaternary carbon atoms and polymers of the $-CX_2-CX_2-$ type (when

10 $X = \text{halogen}$), chain scissioning predominates. Aromatic polystyrene and polycarbonate are relatively resistant to EBP.

For polyvinylchloride, polypropylene and PET, both directions of transformation are possible; certain conditions exist for the predominance of each one. The ratio of crosslinking to scissioning may depend on several factors, including total irradiation dose,

15 dose rate, the presence of oxygen, stabilizers, radical scavengers, and/or hindrances derived from structural crystalline forces.

Overall property effects of crosslinking can be conflicting and contrary, especially in copolymers and blends. For example, after EBP, highly crystalline polymers like HDPE may not show significant change in tensile strength, a property derived from the crystalline

20 structure, but may demonstrate a significant improvement in properties associated with the behavior of the amorphous structure, such as impact and stress crack resistance.

Aromatic polyamides (Nylons) are considerably responsive to ionizing radiation. After exposure the tensile strength of aromatic polyamides does not improve, but for a blend of aromatic polyamides with linear aliphatic polyamides, an increase in tensile

25 strength is derived together with a substantial decrease in elongation.

EBP may be used as an alternative to IR for more precise and rapid curing of TPE coatings applied to preforms and containers.

It is believed that when used in conjunction with dip, spray, or flow coating, EBP may have the potential to provide lower cost, improved speed and/or improved control of crosslinking when compared to IR curing. EBP may also be beneficial in that the changes it

30 brings about occur in solid state as opposed to alternative chemical and thermal reactions carried out with melted polymer.

In other preferred embodiments, gas heaters, UV radiation, and flame may be employed in addition to or in lieu of IR or EPB curing. Preferably the drying/curing unit is placed at a sufficient distance or isolated from the coating material tank and/or the flow coating sheet as to avoid unwanted curing of unused coating material.

5

5. Cooling

The preform is then cooled. The cooling process combines with the curing process to provide enhanced chemical, blush and scuff resistance. It is believed that this is due to the removal of solvents and volatiles after a single coating and between sequential coatings.

In one embodiment the cooling process occurs at ambient temperature. In another
10 embodiment, the cooling process is accelerated by the use of forced ambient or cool air.

There are several factors to consider during the cooling process. It is preferable that the surface temperature of the preform is below the T_g of the lower of the T_g of the preform substrate or coating. For example, some coating materials have a lower T_g than the preform substrate material, in this example the preform should be cooled to a temperature
15 below the T_g of the coating. Where the preform substrate has the lower T_g the preform should be cooled below the T_g of the preform substrate.

Cooling time is also affected by where in the process the cooling occurs. In a preferred embodiment multiple coatings are applied to each preform. When the cooling step is prior to a subsequent coating, cooling times may be reduced as elevated preform
20 temperature is believed to enhance the coating process. Although cooling times vary, they are generally about 5 to 40 seconds for 24 gram preforms with about 0.05 to about 0.75 grams of coating material.

6. Ejection from System

In one embodiment, once the preform has cooled it will be ejected from the system
25 and prepared for packaging. In another embodiment the preform will be ejected from the coating system and sent to a blow-molding machine for further processing. In yet another embodiment, the coated preform is handed off to another coating module where a further coat or coats are applied. This further system may or may not be connected to further coating modules or a blow molding-machine.

30

7. Recycle

Advantageously, bottles made by, or resulting from, a preferred process described above may be easily recycled. Using current recycling processes, the coating can be easily

removed from the recovered PET. For example, a polyhydroxyaminoether based coating applied by dip coating and cured by IR heating can be removed in 30 seconds when exposed to an 80° C aqueous solution with a pH of 12. Additionally, aqueous solutions with a pH equal to or lower than 4 can be used to remove the coating. Variations in acid salts made from the polyhydroxyaminoethers may change the conditions needed for coating removal. For example, the acid salt resulting from the acetic solution of a polyhydroxyaminoether resin can be removed with the use of an 80° C aqueous solution at a neutral pH. Alternatively, the recycle methods set forth in U.S. Pat. No. 6,528,546, entitled Recycling of Articles Comprising Hydroxy-phenoxyether Polymers, may also be used. The methods disclosed in this application are herein incorporated by reference.

8. Example I

A lab scale flow coating system was used to coat 24 gram PET preforms. A system, as illustrated in Figs 14 through 16 was used, and comprised a single flow coating unit with an IR curing/drying unit. The preforms were manually loaded onto the processing line. The collets used to hold the 24 gram preforms were spaced 1.5" on center from each other. It was found that this distance provided the proper spacing to avoid any wake effect while the preforms passed through the coating waterfall or sheet. The coating material was pumped into a tank using a non-shearing pump. The coating material then flowed out of the tank forming a waterfall or sheet that coated the preforms as they passed through the sheet. The preforms moved along the line at a rate of three inches per second in order to ensure two full rotations while passing through the coating sheet. Once through the sheet the line speed allowed the preforms to drip for approximately 10 seconds before passing over a sponge roller to remove an excess coating material from the bottom of the preform. The preforms then moved into the IR curing/drying unit. Five 1000 W General Electric Q1500 T3/CL Quartzline Tungsten-Halogen lamps at 60 % capacity were used as the source. The lamps were positioned at 0.6 inches on the centerline. The preforms remained in the IR curing/drying unit for about 10 seconds. As the preforms moved out of the curing/drying unit they were cooled for about 10 seconds with forced ambient air before being removed from the system.

The coating material used in this example was a PHAE dispersion, BLOX® XUR 588-29 (from The Dow Chemical Company), having 30% solids. The average deposition (single layer on a 24 gram preform) was about 97 mg.

9. Example II

FIG. 18 is a schematic illustration of one embodiment of a coating system. The coating system 300 is preferably an automated system for rapidly coating preforms. The illustrated coating system 300 comprises a transfer system 310, a conveyor system or carousel system 312, a coating unit 316 (e.g., a delivery system, flow coating unit, etc.), a material removal system 318, a temperature control system 320, and a preform removal system 346. In the illustrated embodiment, the temperature control system 320 comprises a pair of curing units 330, 332 and a cooling system 336.

The coating system 300 can be used to coat substrate articles, such as containers, preforms, and the like. For the sake of simplicity, the embodiments disclosed below are described with respect to preforms which can be blow molded into containers. Generally, the transfer system 310 can feed preforms to the carousel system 312. The carousel system 312 can move the preforms along a processing line such that the preforms are coated by the coating unit 316, treated by the removal system 318, and then passed through the temperature control system 320 to cure the coating layer. The coated preforms are then cooled by the cooling system 336 and discharged from the carousel system 312.

In some embodiments, the coating system 300 can receive warm preforms to aid in the curing process. In the illustrated embodiment of FIG. 18, the coating system 300 can receive warm preforms from a substrate producing system 340. The illustrated substrate producing system 340 is an injection molding machine, such as a Gaylord injection molding machine or other injection molding machine. The preforms manufactured by the injection molding machine can be quickly transported to the coating system 300 via a delivery system 342. The delivery system 342 can be a typical system used to transport preforms away from injection molding machines and therefore will not be discussed in further detail.

The inherent heat of the warm preforms may provide one or more of the following: reduce curing time, result in generally completely cured coating layers, minimize the number of blisters formed in the coating layer, promote coherent coating layers, and/or the like. In one non-limiting embodiment, the temperatures of the warm preforms are in the range of about 30° C to 70° C when the preforms are coated by the coating unit 316. The temperatures of the preforms are preferably generally greater than about 30° C when the preforms are coated by the coating unit 316. Advantageously, there may be less contamination (e.g., dust) on the surfaces of the preforms due to the rapid transfer between

the injection molding machine 340 and the coating system 300. The reduced levels of contamination may promote adhesive between the coating layers and the injection molded preforms. The preforms outputted from the injection molding machine can be cooled to a desired temperature before being processed by the coating system 300.

5 The substrate producing system 340 can be any suitable system for producing substrates. In some embodiments, the substrate producing system 340 is an extrusion blow molding machine. Extruded blow molded containers can be outputted from the substrate producing system 340 and delivered to the coating system 300 for applying a coating layer. Alternatively, the substrate producing system 340 can be a compression molding system or
10 other type of apparatus for producing substrate articles.

 In other embodiments, the preforms can be indirectly fed from a substrate article producing system, such as an injection machine, to the coating system 300. For example, preforms can be manufactured and stored for an extended period of time before the preforms are processed by the coating system. If the preforms are dirty or otherwise
15 contaminated, the preforms can be cleaned by, for example, a washing process. Any suitable cleaner can be used to clean the preforms. For example, cleaning agents, water, chemicals, surfactants, combinations thereof, and the like can be used to clean the preforms to ensure that the surfaces of the preforms are suitable for receiving coating layers. The preforms can be washed before and/or after they enter the coating system 300. A washing
20 unit (not shown) can be located along the processing line between the transfer system 310 and the coating unit 316. It is contemplated that the preforms can be washed at any point along the processing line. Preferably any excess liquid from the cleaning process is removed prior to the preforms entering the flow coating system 312. Of course, the preforms can be coated by the coating system 300 with or without cleaning, or other types
25 of preparation processes.

 Optionally, a temperature control unit can be located along the processing line for heating the preforms before coating material is deposited on the preforms. The temperature control unit (not shown) can be positioned along the processing line between the transfer system 310 and the flow coating unit 316. The temperature control unit can comprise an
30 oven, an energy delivery system (e.g., one or more heat lamps), or other suitable device for controllably heating and/or cooling preforms. In some embodiments, the temperature

control unit can preheat the preforms immediately before the preforms are coated by the coating unit 316.

With reference to FIGS. 18 and 19, the transfer system 310 can receive and then feed preforms to the carousel system 312 at any desired feed rate. In some embodiments, the transfer system 310 can batch feed and/or continuously feed preforms to the carousel system 312. Additionally, a plurality of transfer systems 310 can be used to receive and deliver preforms to the carousel system 312.

The illustrated transfer system 310 continuously feeds preforms to the carousel system 312. The transfer system 310 can deliver preforms at a generally fixed or variable rate, preferably one preform at a time. However, multiple preforms can be simultaneously and continuously delivered to the carousel system 312. Advantageously, the preforms can be passed through the coating unit 316, preferably at a somewhat constant line speed, without stopping the movement of the carousel system 312. Fluctuations of the line speed can cause an undesirable distribution of coating material on the preforms. Additionally, the continuous feeding of preforms can increase the output of the coating system 300 and may ensure that coating material flowing from the coating unit 316 is efficiently used.

In the illustrated embodiment of FIG. 19, the transfer system 310 comprises one or more gates 348, a starwheel 350 attached to a drive shaft 352, and an outer guide member 354. Preforms can be passed through the gate 348 and delivered to the starwheel 350. The starwheel 350 and the guide member 354 can cooperate to carry the preforms to the carousel system 312.

The gate 348 is configured to inhibit or permit delivery of preforms to the starwheel 350. The gate 348 has a rod 360 movable between an open position to allow delivery of preforms to the starwheel 350 and a closed position in which preforms are not delivered to the starwheel 350. When the rod 360 occupies the closed position, the end of the rod stops the preforms from being delivered to the starwheel 350. When the rod 360 occupies an open position, preforms can be delivered to the starwheel 350. Air lines can provide pressurized air that is used to actuate the gate 348. In some embodiments, the gate 348 can be actuated manually, electrically, mechanically, pneumatically (illustrated), and/or by any other suitable means.

The starwheel 350 can have slots or pockets 362 configured to engage preforms, as shown in FIG. 20. The starwheel 350 can have several pockets 362 positioned about its

periphery. Each pocket 362 is configured to surround at least a portion of a body of a preform. In the illustrated embodiment of FIGS. 18-20, the pockets 362 are curved segments having a radius of curvature similar to the radius of the upper portion of the body 4 of the preform 1. The preform 1 within the pocket 362 is captured between the outer guide member 354 and the starwheel 350, as shown in FIG. 20. As shown in FIGS. 20 and 21, the bottom surface 363 of the support ring 6 can slidably engage the upper surface 364 of the starwheel 350 and an upper surface 368 of the outer member 354.

The drive shaft 352 can rotate at a generally constant rotational speed for continuous feeding of preforms to the carousel system 312. In some embodiments, the shaft 352 rotates at fixed and/or variable speeds during the production cycle. When the shaft 352 rotates, each of the pockets 362 and the corresponding preform it captures rotate in unison. As the preforms move, the support rings 6 of the preforms slide along the stationary upper surface 368 of the outer member 354. The preforms can therefore travel along a curved path extending from, e.g., the delivery system 342 to the carousel system 312.

The rotational speed of the starwheel 350 can be determined by the desired output of the coating system 300, and the size and configuration of the starwheel 350. For example, a starwheel having a large radius may be rotated at a lower speed than a starwheel 350 having a small radius. In one non-limiting embodiment, the starwheel 350 can deliver 5,000 to 15,000 preforms/hour to the coating system 300. In another non-limiting embodiment, the starwheel 350 can deliver up to about 40,000 preforms/hour to the coating system 300. In one non-limiting embodiment, the starwheel 350 can deliver more than about 45,000 preforms/hour to the coating system 300. Optionally, the rotational speed of the starwheel 350 can be based on the output capacity of the injection molding machine 340 (FIG. 18) to optimize preform production.

The starwheel 350 can have any number of pockets 362 disposed along its periphery. The number of pockets 362 can be selected by the size and configuration of the uncoated preforms 1. Preferably, the transfer system 310 is toleranced so that preforms of various sizes can be transferred by the transfer system 310 without any adjustment or modification.

FIG. 22 illustrates another embodiment of a transfer system that can be utilized with the coating system 300. The transfer system 370 can batch feed preforms to the carousel system 312. For example, a set number of preforms can be simultaneously delivered to the

carousel system 312. The carousel system 312 can then receive and carry the preforms along the processing line. After a period of time, another batch can be delivered to the carousel system 312.

5 The transfer system 370 can have grippers 372, each configured to hold an uncoated preform 1. The grippers can be any suitable gripping mechanisms or devices that can selectively hold and release preforms. The delivery system 342 (FIG. 18) can feed one or more preforms to the transfer system 370 at a single time. After the transfer system 370 receives the preforms 1, the transfer system 370 can move the preforms to any desired position. For example, the transfer system 370 can move the preforms in the horizontal
10 direction and vertical direction indicated by the arrows 374, 376, respectively. The transfer system 370 can also move the preforms in the transverse direction depending on the configuration of the carousel system 312.

The transfer systems, such as the transfer systems describe above, can carry and deliver the preforms 1 to a loading system 377 (FIG. 24A) that is configured to load the
15 preforms onto the carousel system 312. In some embodiments, the transfer system can simultaneously deliver a plurality of prefoms 1 to the loading system 377. However, the transfer system can sequentially deliver preforms to the loading system 377 in other embodiments.

With respect to FIG. 18, the carousel system 312 can comprise one or more carriers
20 374 that are configured to receive preforms from the transfer system 310. The carriers 374 move along the carousel system 312 while carrying one or more preforms. In one embodiment, each carrier 374 holds and transports a single preform. In another embodiment, including the illustrated embodiment, each carrier 374 holds and transports more than one preform, preferably at least two preforms. The carousel system 312 can have
25 a motor (not shown) that drives the carriers 374 around the carousel system 312. Optionally, the carriers 374 can rotate the preforms as the carriers move along the periphery of the carousel system 312. For example, each carrier 374 can continuously rotate one or more preforms as the carrier 374 moves along the processing line. Optionally, the carriers 374 can move or rotate the preforms in the outwardly and/or inwardly direction relative to
30 the carousel system 312.

With respect to FIG. 24A, the loading system 377 of the carousal system 312 can be utilized to place preforms on the carriers 374. The illustrated loading system 377 comprises

one or more loaders 376 that are located below the carriers 374. The illustrated loaders 376 are axially movable in the vertical direction between a loading position and an unloading position. In one embodiment, the loader 376 receives one or more preforms 1 delivered by the transfer system 310 when the loader 376 occupies the loading position. The loader 376
5 can be vertically displaced towards the unloading position in order to lift the preforms to the movable carrier 374. The carrier 374 can receive the raised preform. The carrier 374 can then retain and carry the preforms along the processing line.

Each loader 376 and corresponding carrier 374 preferably travel in unison along at least a portion of the processing line. Each loader 376 can comprise a cam riser, follower,
10 or other suitable mechanism for delivering a preform to the carrier 374.

A curved guide member 380 (FIG. 24B shown in phantom) can contact the uncoated preform 1 held within the pocket 362 of the starwheel 350 to position the preform 1 between a pair of holding members or prongs 386 of the loaders 376. The support ring 6 of the preform 1 can rest on the upper surface 389 of the loader 376 and is subsequently
15 elevated to a corresponding carrier 374. As the loader 376 reaches the unloading position, the preform is handed off to the carrier 374.

In this manner, one or more preforms 1 can be transferred from the starwheel 350 to the carriers 374. The loader 376 can be adapted to carry any number of preforms 1. In one embodiment, for example, the loaders 376 are configured to carry only one preform 1. In
20 another embodiment, the loaders 376 are configured to carry a plurality of preforms 1.

With continued reference to FIG. 24B, the loaders 376 can move in the direction indicated by arrow 388 and the starwheel 350 can rotate in the direction indicated by the arrow 390. The loaders 376 and the starwheel 350 can be synchronized so that each pair of prongs 386 matches with a corresponding pocket 362 of the starwheel 350. Preferably, the
25 member 380 is positioned above and stationary relative to the loader 376 and the starwheel 350.

With reference again to FIG. 24A, the loaders 376 can carry and lift up the preforms to a corresponding carrier 374. The carriers 374 can then receive and hold the preforms for further transport along the carousel system. In some embodiments, each loader 376
30 comprises a rail 400, a carriage 402, and an elongated member 404 connected to the carriage 402. The end of the elongated member 404 includes a roller 408 configured to pass along a slot or cam 412. The loader 376 can travel along the carousel system 312 and

may be moved vertically as the roller 408 rolls along the curved slot 412. After the loader 376 holds a preform 1, the carriage 402 of the loader 376 can slide vertically upwards along the rail 400 to lift the preform towards the carrier 374. When the carriage 402 reaches an elevated position (e.g., the unloading position), the carrier 374 can receive and hold the neck 2 of the preform 1. The carriage 402 can then be moved vertically downward so that the prongs 386 move away from the preform 1.

After the carriers 374 have received the preforms, the carriers 374 can transport those preforms about the periphery of the carousel system 312 in the direction indicated by the arrows 375 of FIGS. 18 and 23. The carriers 374 can be connected to each other in order to have the carriers 374 move together. Any suitable means, such as belt, linkage, tie rod, or the like can be used to interconnect the carriers 374. In one embodiment, all or a substantial number of the carriers 374 of the coating system 300 are coupled to adjacent carriers 374 on either side. To hold the preforms, the carriers 374 engage the inner portions (e.g., the interior surface 16) of the preforms. In another embodiment, the carriers 374 can engage both the inner portions and the outer portions of the preforms. For example, each carrier 374 can engage the interior surface 16 and the outer surface threads 8 of the neck 2. In yet another embodiment, each carrier 374 can engage only an outer portion (e.g., the outer portion of the neck 2) of a preform. Preferably, each carrier 374 does not extend downwardly past the outer portion of the support ring 6 so that the body 4 can be completely coated with material.

With respect to FIGS. 24A and 25, the carriers 374 can have one or more gripping mechanisms 420 configured to fit within and extend into the interior of the preform, as shown in FIG. 42. The gripping mechanisms can comprise a mandrel or other suitable device for securely holding a preform. The illustrated gripping mechanisms are in the form of mandrels. As used herein, the term "mandrel" is a broad term and is used in its ordinary meaning and may include, without limitation, a collet, spindle, preform holder, and the like. The mandrel can be used to retain selectively a preform. In some embodiments, the mandrel is moveable between a holding position and a release position. The mandrel can hold a preform when occupying the holding position and can release or receive a preform when occupying the release position. In some embodiments, the mandrel 420 is a generally cylindrical elongated body sized to fit into the opening of a preform. Optionally, the mandrel 420 can extend into and along a substantial portion of the neck of the preform. In

another embodiment, the mandrel 420 can extend most of the way into the interior of the preform and can terminate along the body 4 of the preform. Preferably, at least a portion of the mandrel 420 is configured to engage the interior surface of a preform.

5 In some embodiments, at least a portion of the mandrel 420 can be moved to hold and/or release a preform. Preferably, at least a portion of the mandrel 420 can be moved radially inward and/or outward as desired. For example, the mandrel 420 can move radially outwardly to engage and hold the interior surface 16 of a preform. The mandrel 420 can be moved radially inwardly to release the preform from the mandrel 420.

10 With continued reference to FIG. 24A, the mandrel 420 can have an expandable ring, such as a split, slip ring 424. In one embodiment, the ring 424 is an annular body having a gap so that the ring can be conveniently expanded in the radial direction. The slip ring 424 can be biased inwardly to surround tightly the body of the mandrel 420.

15 With reference to FIG. 25, the mandrel 420 can have an upper lip 430, a body 432, and a groove 436. The upper lip 430 can have a lower surface 431 suitable for contacting the upper edge of a preform such that the preform can securely sit against the upper lip 430. When the loader 376 delivers a preform to the carrier 374, the loader 376 can lift the preform until the preform contacts, or is adjacent to, the lower surface 431.

20 The groove 436 is adapted to receive at least a portion of the ring 424 (shown in cross section). One or more openings 440 along the groove 436 can cooperate with one or more protrusions 444 for selectively actuating the ring 424. The protrusions 444 are generally spherical bodies that can extend from an associated circular opening 440. When the protrusions 444 extend from the openings 440, the protrusions 444 push the ring 424 in the outwardly direction so that the outer surface of the ring 424 can apply sufficient pressure to the interior surface to hold a preform. The protrusions 444 can be retracted into
25 the body 432 of the mandrel 420 so that the protrusions 444 generally do not apply a force to the ring 424, thus allowing the ring 424 to bias inwardly to surround tightly the body 432. When the protrusions 444 are retracted, the preforms can be easily loaded onto the mandrels 420, or released from the mandrels 420. Thus, the protrusions 444 can be moved between the extended position and retracted position in order to hold and release,
30 respectively, a preform. The protrusions 444 can have any shape suitable for engaging the inner surface of the ring 424. In the illustrated embodiment, the mandrel 420 has four

openings 440 and four corresponding protrusions 444. However, any suitable number of protrusions 444 and openings 440 can be employed.

With respect to FIGS. 26A and 26B, each carrier 374 can have a lever 374 system 450 adapted to control selectively the movement of the ring 424. The mandrels are not
5 shown.

The lever system 450 can be articulated to cause the mandrel 420 (not shown) to either tightly grip a preform or to release the preform. For example, when the mandrel 420 occupies a first position, the mandrel 420 can tightly grip a preform. When the mandrel 420 occupies a second position, the mandrel 420 can release and/or receive a preform. The
10 mandrel 420 can be actuated between as many positions as desired. The illustrated lever system 450 is attached to the body 452 of the carrier 374, and preferably comprises a lever 454, a base 455, and rods 456, 458.

As shown in FIG. 26B, the lever 454 extends from a pivot 462 and is rotatable in the direction indicated by the arrows 460. The end of the lever 374 can have a roller 464
15 for engaging a first track of the carousel system 312. Contact pads 468, 470 of the lever 454 (FIG. 26A) can contact the upper ends of the rods 456, 458, respectively.

The base 455 can be rotated in the direction indicated by the arrows 478 and extends from a pivot 482, as shown in FIG. 26B. The end of the base 455 can have a roller 484 for engaging a second track of the carousel system 312. In the illustrated embodiment of FIGS.
20 26A and 26B, each of the rods 456, 458 extends through a hole in the base 455.

With reference again to FIG. 26A, the upper ends 490, 492 of the rods 456, 458 can contact the contact pads 468, 470, respectively, to cause movement of the rods 456, 458 relative to the base 455. Springs 494, 496 disposed about a portion of the rods 456, 458, respectively, bias the ends 490, 492 toward the lever 454. When the carrier 374 travels
25 along the carousel system 312, each of the rollers 464, 484 can be disposed in a corresponding track of the carousel system 312. As the carrier 374 moves along the tracks, the distance between the tracks can be increased or decreased to move the rollers 464, 484 away from or towards each other. When the rollers 464, 484 are sufficiently close together, the lever 454 applies a force to the rods 456, 458 sufficient to overcome the bias of the
30 springs 494, 496, thereby pushing the rods 456, 458 out of the ends of the cylindrical housings 500, 502, respectively. Each of the cylindrical housings 500, 502 can be disposed

through a cylindrical passage 515 (FIG. 25) in a corresponding mandrel 420. In operation, mandrels can be mounted to each cylindrical housing 500, 502.

The diameters of the rods 456, 458 are varied such that, at different positions relative to the housings 500, 502, the protrusions 444 (not shown) are extended or retracted.

5 With respect to FIGS. 26A and 26B, the carrier 374 can have a drive mechanism to engage a portion of the carousel system 312 to cause rotation of the mandrels. In the illustrated embodiment, a drive mechanism 503 (FIG. 26B) has a drive gear 505 that can mate with teeth, a gear, a chain, brush and/or other structure of the carousel system 312. As a carousel motor moves all of the carriers 374 along the carousel system 312, the drive gear
10 505 of the drive mechanism 503 can cause rotation of the rods 456, 458 which, in turn, rotate corresponding mandrels. Optionally, the rods 456, 458 can be interconnected by a belt. Alternatively, the rods can be independently driven by one or more drive mechanisms. For example, each rod 456, 458 can be drive by a brush gear.

As shown in FIG. 24A, the mandrels 420 can be disposed about the housings 500,
15 502 so that the rods 456, 458 can extend out of the lower ends of the mandrels 420. For example, the housing 500 can be disposed within the passage 515 (shown in phantom in FIG. 25) of the mandrel 420. Preferably, the housing 500 and the mandrel 420 are aligned so that one or more of the openings 510 of the housing 500 are aligned with the openings 440 of the mandrel 420. The protrusions 444 can therefore pass out of the openings 440,
20 510. The housing 502 can be similarly aligned with another mandrel 420.

With continued reference to FIG. 26A, the body 452 of the carrier 374 can have mounting holes 516, 518 configured to receive fasteners for attaching the carrier 374 to a movable portion the carousel system 312.

With reference to FIGS. 18 and 27, the coating system 300 can have one or more
25 coating units 316. The illustrated coating unit 316 is in the form of a flow coating system. It is understood that flow coating system 316 can be substitution with a dip or spray system depending on the application.

As illustrated in FIGS. 27 and 28, the flow coating system 316 can comprise a tank or vat 550 that is preferably in fluid communication with a fluid source. The fluid within
30 the tank 550 can be delivered by the flow coating system 316 onto the preforms 1 passing by. The fluid in the tank 550 can comprise, but is not limited to, barrier materials (e.g., a gas barrier material, such as phenoxy thermoplastics), additives (e.g., anti-foaming agents),

colorants, thermoplastics, polymers, and the like. Any desired fluid can be held within the tank 550.

In the illustrated embodiment of FIG. 28, the tank 550 comprises a housing 552 and a flow control system 558. The housing 552 has walls 556 that define a chamber 554 adapted to hold coating material (e.g., a fluid coating material). Embodiments of the housing 552 can have any shape suitable for containing coating material. The chamber 554 can be sized to hold any desired amount of coating material, preferably in a liquid state. It is contemplated that the size of the chamber 554 can be selected depending on, for example, the output of the coating system 300, the size and configuration of the preforms, the properties of the coating material, the amount of coating material to be applied, and/or the like.

The fluid control system 558 can be used to control selectively the flow rate of the coating material delivered out of the flow coating system 316. The fluid control system 558 can provide coating material at a generally constant or variable flow rate during a production cycle. In one embodiment, the fluid control system 558 comprises a movable gate 562 and a gate positioning assembly 564 (FIG. 27) configured to move selectively the gate 562 relative to a fluid guide 566. As shown in FIG. 29, an edge 568 of the gate 562 and the fluid guide 566 define a gap or passage 570. The edge 568 of the gate 562 can be generally straight along the length of the gate 562. In another embodiment, the edge 568 can be curved or have any other suitable shape for providing one or more gaps between the gate 562 and the fluid guide 566. Optionally, the edge 568 may advantageously promote laminar flow of the coating material flowing along the surface of the fluid guide 566 and onto the preforms. The tank 550 can have other means for reducing the turbulence of the coating material.

The edge 568 has a surface 574 that is generally parallel with the surface of the fluid guide 566. In other embodiments, the gap 570 can have a height that varies along its length and/or width. Additionally, the surface 574 can be curved and/or oriented at any angle to the fluid guide 566. The size of the gap 570 can be increased or decreased to increase or decrease, respectively, the amount of fluid that flows down the fluid guide 566 and onto the preform. As coating material flows out of the flow coating system 316, the top surface of the coating material in the tank 550 is preferably higher than the gap 570. If the coating material has bubbles or foam, the bubbles or foam can reside at the upper surface of the

coating material. Advantageously, the coating material flowing through the gap 570 may be substantially free of bubbles, foam, or other contaminants that have a tendency to float in the coating material.

The gate positioning assembly 564 of FIGS. 27 and 30 can selectively position the gate 562 to obtain any desired sized gap 570. The gate positioning assembly 564 can have one or more nuts 580 that threadably engage one or more bolts 581. As the nuts 580 are rotated they move a bracket 582, which is attached to the gate 562, in the vertical direction. The gate positioning assembly 564 may be supported by a member 560 that is coupled to the housing 552 of the tank 550. In other embodiments, the gate positioning assembly 564 can rotate and/or provide transverse movement of the gate 562. Also, the gate positioning assembly 564 can move the gate 562 continuously and/or incrementally. In certain embodiments, the gate positioning assembly 564 can comprise one or more motors (e.g., stepper motors), solenoids, screw driven actuators, and/or the like that can be used to move the gate 562. It is contemplated that the gate positioning assembly 564 can be manually or automatically controlled. For example, the gate positioning assembly 564 can be numerically controlled by a control system (e.g., a digital control system).

Optionally, at least one of the gate 562 and the fluid guide 566 can have a means for producing laminar flow. For example, the gate 562 and the fluid guide 566 can have fins, coatings, surface treatment, or other structures for reducing turbulence of the coating material delivered by the flow coating system 316.

With continued reference to FIG. 28, the tank 550 can optionally comprise a lid or top 593 that covers the tank 550 to limit or prevent contamination of the coating material within the chamber 554. The lid 593 can be removably coupled to the housing 552 for convenient removal and access to the chamber 554. In some embodiments, fasteners can be used to permanently or temporarily couple the lid 593 to the housing 552.

In some embodiments, the tank 550 comprises an overflow system 592 to regulate the amount of material in the tank 550. The overflow system 592 maintains a desirable amount of coating material within the tank 550. If the level of coating material rises above an opening 594 of the overflow system 592, preferably comprising a tube 591, the coating material flows into the opening 594 and through the tube 591 out of the tank 550, thereby reducing the amount of the coating material in the tank 550. In the illustrated embodiment, the tube 591 extends upwardly from the bottom of the tank 550 and into the chamber 554.

Optionally, the tank 550 can also include a level sensor 596 that can be used to determine the level of the coating material in the tank 550. The overflow sensor 596 can be in communication with one or more pumps, valves, and/or other devices that maintain a desired level of coating material. For example, a valve can be actuated to let coating material flow out of the tank 550 based directly or indirectly on a signal from the sensor 596.

With respect to FIG. 31, a fluid system 530 can be in fluid communication with the tank 550. The fluid system 530 is a closed system that recycles coating material to efficiently reuse unused coating material. However, the fluid system 530 can be an open system. Additionally, the fluid system 530 can be both a closed system for one or more portions of a production cycle and an open system for one or more portions of the production cycle.

With continued reference to FIG. 31, the fluid system 530 may comprise one or more lines, tanks, pumps, and/or filtration systems. In the illustrated embodiment, the fluid system 530 comprises a tank system 600. An overflow line 604 and a drain line 606 extend between the tank 550 and a reservoir or tank 610. A pump 614 is located along an output line 612 that extends between the reservoir 610 and the tank 550.

In one embodiment, the tank system 600 comprises a collection tank 620 that receives unused material from the flow coating system 316. As shown in FIG. 33, the collection tank 620 can be disposed underneath preforms that are being coated and/or underneath the end of the guide 566. The collection tank can be in the form of a trough, catch tank, or other type of structure configured to receive unused coating material.

Optionally, the collection tank 620 can have a means for reducing the formation of foam and/or bubbles in the collected coating material. Foam or bubbles in the coating material may result in uneven coating or imperfections of the resulting multilayer preform. The coating material collected in the tank 620 can be reused to coat preforms. Thus, it may be advantageous to limit or prevent the formation of foam and/or bubbles in the coating material within the tank 620.

As shown in FIG. 32, the collection tank 620 has a baffle 622 for reducing or preventing the formation of foam and/or bubbles. The unused portion of the curtain of coating material 624 (i.e., coating material that does not remain on the preforms) can flow onto and along the baffle without producing substantial turbulence. In another

embodiment, a plurality of baffles reduces foaming of the coating material. Although not illustrated, other structures can be used to limit the formation of foam/bubbles in the coating material. For example, various sloped surfaces, fins, channels, and/or other suitable structures can be used to reduce foaming. It is contemplated that the position and type of anti-foaming structures can be selected to achieve a desirable flow out of the collection tank 620 and into a collection tank line 630. Additionally, the tank 620 can have structures, which also may be anti-foaming structures, that promote a vortex to accelerate the flow of unused coating material into the line 630. The tank 620 may not have any means for reducing the formation of foam/bubbles. Of course, the configuration of the tank 620 can be selected based on the properties of the coating material.

The distance between the tank 550 and the collection tank 620 can be determined by the desired sheeting action of the coating material, properties of the coating material (e.g., foaming characteristics, viscosity, etc.), flow rate, line speed of the carousel system 312, preform spacing, and/or other processing parameters.

The collection tank line 630 can extend between the collection tank 620 and the reservoir 610. Material collected by the collection tank 620 can be delivered to the reservoir 610 via the collection tank line 630.

With continued reference to FIG. 31, the overflow line 604 can extend from the tank 550 to the reservoir 610. Fluid that passes through the overflow tube 591 can be subsequently passed through the overflow line 604 and into the reservoir 610. In some embodiments, material from the collection tank 620 may not be delivered to the reservoir 610. For example, the overflow line 604 can deliver coating material to an off-line storage tank.

Optionally, the fluid system 530 can have a drain line 606 extending from the tank 550 to the reservoir 610. In some embodiments, the drain line 606 is used to drain the tank 550 to prevent curing of coating material in the tank 550 when pumps are not operating. Additionally, the tank 550 may be drained for cleaning the inner surfaces of the tank 550, or to perform other maintenance. A flow regulator (e.g., a valve system) can be positioned along the drain line 606. The flow regulator can be used to inhibit or permit the flow of fluid out of the tank 550 through the drain line 606.

The reservoir 610 can store the coating material, especially for extended periods of time, and can have any suitable size or configuration for holding coating material. For

example, the reservoir 610 can be a container having a capacity of more than about 5 gallons, 10 gallons, 15 gallons, 20 gallons, 30 gallons, and ranges encompassing such volumes. In some embodiments, the reservoir 610 can have a capacity greater than about 15 gallons, 25 gallons, or 35 gallons. In one embodiment, the coating system 300 can
5 comprise a plurality of reservoirs 610. One of the reservoirs 610 can be on-line while another reservoir is off-line. After a certain amount of coating material from the on-line tank 610 has been used, the on-line reservoir 610 can be replaced with the off-line reservoir 610, preferably full of coating material. The emptied reservoir 610 can then be filled, preferably filled off-line. In this manner, coating material can be rapidly added to the
10 coating system 300, thereby increasing the output of preforms.

With continued reference to FIG. 31, the pump 614 is disposed at some point along the output line 612. The pump 614 can draw coating material from the reservoir 610 and pressurize the coating material so that the coating material flows through the output line 612 and into the tank 550. The pump 614 can be any suitable device for sufficiently
15 pressurizing the coating material. For example, the pump 614 can be a diaphragm pump, screw type pump, or the like and may have a fixed or variable displacement. In one embodiment, for example, the pump 614 is a diaphragm pump which preferably produces little or no shearing. Advantageously, this diaphragm pump 614 can be used with shear sensitive coating materials and can comprise one or more diaphragms. In one non-limiting
20 embodiment, the pump 614 is a double diaphragm pump. Optionally, a plurality of pumps can be utilized at various locations along the fluid system 530 to pressurize the coating material.

As shown in FIGS. 31 and 34, the inlet 632 of the output line 612 is connected to a lower portion of the reservoir 610. The illustrated inlet 632 is connected to the bottom half
25 of the reservoir 610. In one non-limiting embodiment, the inlet 632 is less than 2 inches from the bottom of the reservoir 610. In one non-limiting embodiment, the inlet 632 is disposed along the bottom of the reservoir 610. Advantageously, the inlet 632 can be positioned below the surface of the coating material in the reservoir 610 so as to draw in coating material with a minimal amount of foam or bubbles. However, the inlet 632 can be
30 connected at any point along the reservoir 610 suitable for receiving coating material.

Optionally, the fluid system 530 can have a filtration system. With respect to FIG. 31, a filtration system 650 is configured to remove undesired substances that may be

present in the coating material circulating through the fluid system 530. For example, the filtration system 650 can capture selected impurities, such as cured portions of the coating material, contaminants (e.g., dust that was present on the surface of the preforms and in the unused coating material captured by the collection tank 620), and/or any other substances.

- 5 The filtration system 650 can comprise one or more filters that are suitable for removing a variety of undesirable substances.

The illustrated filtration system 650 comprises an input line 652, a pump 654, a pump line 656, a filtration unit 660, and an output line 666. The input line 652 extends from the reservoir 610 to the pump 654. The pump 654 can be similar to or different from
10 the pump 614. The pump line 656 extends between the pump 654 and the filtration unit 660. Fluid in the reservoir 610 can pass through the lines 652, 656, the filtration unit 660 and then through the output line 666 and back into the reservoir 610.

The filtration system 650 can be positioned at other points in the fluid system 530. For example, rather than drawing fluid from the tank 610, the filtration system 650 can be
15 positioned along the output line 614. The filtration system 650 can be positioned at any other suitable location for effectively filtering the coating material.

The filtration unit 660 can have one or more filters. The illustrated filtration unit 660 comprises a pair of filters 662, 664 that can have similar or different filter ratings. In some non-limiting embodiments, the filter 662 can have a rating (e.g., a micron rating) in
20 the range of about 30 to 70 microns. In one preferred embodiment, the filter 662 has a micron rating of about 50 microns. The filter 664 can have a micron rating of less than 10 microns. In one non-limiting embodiment, the filter 664 may have micron rating of about 5 microns. The upstream filter 662 can filter out relatively large contaminants so that the filter 664 can filter out smaller contaminants without being clogged with large particles.
25 The filters 662, 664 can have bags, cartridges, and/or other filtering structures that can be periodically replaced or cleaned (e.g., particulate can be removed from the filtering structures).

The flow of the coating material through the filtration system 650 can be reduce, preferably stop, in order change the filters off-line. Optionally, valves can be disposed
30 along the lines 652, 656 to control the flow rate through the filtration system 650. Advantageously, the coating system 300 can bypass the filtration system 650 to continue

coating preforms while the filtration system 650 is being serviced. However, the coating system 300 also can be completely shut off when the filtration system 650 is being serviced.

In operation, coating material can flow from the tank 610 and into the input line 652. The pump 654 can draw the coating material through the input line 652 and can cause
5 the material to flow through both the pump line 656 and the filtration unit 660. The filtration unit 660 can remove undesirable substances from the coating material. The filtered coating material is then passed through the output line 666 and returned to the reservoir 610.

With reference again to FIG. 18, after the preforms are coated by the flow coating
10 system 316, the carousel system 312 can move the preforms to the material removal system 318 configured to remove excess coating material on the preforms. Typically, the coating material is still a liquid when the coated preforms reach the removal system 318.

The coating system 300 may provide such efficient deposition that virtually all of the coating material on the preform is utilized (i.e., there is generally no excess material to
15 remove) to form the resulting multilayer preform. In some embodiments, most or all of the coating material deposited on each preform is cured to form the resulting multilayer preform. However, there are situations where it may be desirable to remove excess coating material after the preform is coated. In one embodiment, the rotation of the preforms and gravity will work together to generally normalize the sheet of coating material on the
20 preforms and remove at least a portion of the excess material.

In some embodiments, the removal system 318 may be used to remove additional undesirable material. If the preforms have excess material, the excess material may blister, burn, or otherwise produce substantial imperfections, whereby the preforms may be unsuitable for subsequent blow molding and use.

FIG. 35 is a perspective view of one embodiment of the removal system 318. The
25 removal system 318 can remove at least a portion of the coating layer on the preforms in order to produce preforms with a somewhat uniform coating. Preferably, the coating layers are uncured when the coated preforms reach the removal system 318. The illustrated removal system 318 is a de-tear device that has a surface 700 adapted to contact and
30 remove material from the preforms. The removal system 318 can have an absorbent component that draws off coating material from the preform as the preform passes by. The absorbent component can rotate to further enhance the removal of coating material.

With respect to FIGS. 36 and 37, the surface 700 is defined by a sponge roller or belt 702 that engages a drive wheel 704 (FIG. 37) driven by a motor 706. One or more wheels 710 can tension the belt 702. The surface 700 of the belt 702 preferably comprises an absorbent material, such as an open celled foam (e.g., open celled polyurethane foam). In other embodiments, the belt 702 comprises a non-absorbent material. The material forming the belt 702 can be selected based on the desired amount of material absorbed by the belt 702.

The illustrated removal system 318 includes a removal system cleaner 711 configured to extract material from the removal system 318. The removal system cleaner 711 includes a wheel 712 that can compress the belt 702 between the wheel 704 to remove coating material from the belt 702. In the illustrated embodiment, the belt 702 is compressed between the wheels 704, 712 to squeeze out liquid coating material. Such removal system cleaner can be employed to prevent saturation of the belt 702.

In operation, after the flow coating system 316 coats preforms, the coated preforms move along the processing line in the direction indicated by the arrow 720 shown in FIG. 35. As the preforms move and engage the removal system 318, the motor 706 can rotate the drive wheel 704 which, in turn, causes movement of the belt 702 and its surface 700. The surface 700 can have the same or different linear speed as the line speed of the carousel system 312. The surface 700 can be pressed against one or more preforms to remove material from the preforms. In the illustrated embodiment, the removal system 318 can simultaneously remove at least a portion of the coating material on the bodies of several preforms.

A fluid can be fed onto the belt 702 to further enhance the removal of coating material. In some embodiments, including the illustrated embodiment of FIG. 36, a line 715 delivers liquid, e.g., water, solvent, coating material, and the like onto the surface 700 of the belt 702. Any number of lines can be used to deliver liquid to the removal system 318. The liquid can help clean the belt 702 and may improve the efficacy of the belt 702.

Optionally, the surface 700 may be a stationary surface that engages and removes excess material from the preforms. The preforms can be dragged across the stationary surface 700.

The removal system 318 can remove material from at least a portion of each preform. A substantial portion of the coating, preferably in a liquid state, on the surface of

the rounded end cap can be removed by the removal system 318. In some embodiments, the removal system 318 can remove most or all of the coating material on the rounded end cap. The removal system 318 can leave a thin film of coating material disposed on the surface of the end cap. The removal system 318 can also be used to remove coating material from other portions of the preforms.

The removal system 318 can be moved relative to the preforms to adjust the amount of material removed from the coated preforms. As shown in FIGS. 35 and 38, the removal system 318 can remove material from the end portion 716 a preform having a length L_1 . The end portion 716 is the section of the preform where the removal system 318 has drawn off material. The preform can have an overall length L_2 . In some non-limiting embodiments, the end portion 716 has a length L_1 that is generally less than the radius, r , of the end cap 10. In some non-limiting embodiments, the end portion 716 has a length L_1 that is generally equal to the radius of the end cap 10. In some non-limiting embodiments, the end portion 716 has a length L_1 that is generally less than about $\frac{1}{2}$ of the length L_2 . In another non-limiting embodiment, the length L_1 is in the range of about 5% to 30% of the length L_2 . In yet another non-limiting embodiment, the length L_1 is in the range of about 10% to 40% of the length L_2 . In some non-limiting embodiments, the length L_1 is about 5%, 10%, 20%, 30%, 40%, 50% of the length L_2 and ranges encompassing such percentages. In some non-limiting embodiments, the removal system 318 removes about 2.5 %, 5%, 10%, 15%, 20%, 30%, 40%, 50% by weight of the coating material on the preforms, and ranges encompassing such percentages. It is contemplated that any percentage of the material 714 can be removed by the removal system 318.

Any number of removal systems 318 can be utilized to remove material from the preforms. For example, a first removal system 318 can remove a first amount of material from each of the preforms moving along the processing line. A second removal system 318 can subsequently remove a second amount of material from each of the preforms. The first amount of material may be generally the same as or different from the second amount of material. In one embodiment, the first amount of material is greater than the second amount of material. Each removal system 318 can remove material from the same and/or different portions of the preform. In one embodiment, a first removal system 318 can remove material from a first portion of each preform. A second removal system 318 can remove material from a second portion of each preform. In one embodiment, the first

portion has a length generally greater than the length of the second portion. It is understood that any number of removal systems 318 can be used, and orientated at various suitable positions, to remove material from the preforms held by the carriers 374.

It is contemplated that the particular position of the removal system 318 can be
5 selected based on, e.g., the viscosity of the coating material, rotational speed of the preforms, line speed, settings of the temperature control system 320, the desired quality of the coated preforms, and/or the like. For example, if an undesirable number of blisters are formed by the coating material during the curing process, the removal system 318 can remove excess material that may contribute to blistering. For example, if blisters form on
10 the end cap 10 during curing, material can be removed from the end cap 10 before the coated preform enters the temperature control system 320. The coating material on the preform can then recoat the end cap to form a relatively thin layer of material over the end cap 10. The thin layer can preferably cure without forming an undesirable number of blisters.

15 When the coated preform enters the temperature control system 320, the temperature control system 320 may heat the coated preform, thereby causing the viscosity of the coating material to decrease, thus causing the coating material 714 to spread towards the end of the preform. The removal system 318 can be positioned relative to the preform to compensate for these changes in viscosity of the coating material. In some embodiments,
20 the coating material 714 can cover the portion 716 before and/or during the curing process so that the cured coating layer covers the end cap 10.

The preforms can be vertically oriented, or at an angle to a vertical axis. In the illustrated embodiment, the preforms are passed along the removal system 318 while they are angled from the vertical axis such that a portion of the end cap 10 contacts the removal
25 system 318. In some non-limiting embodiments, the longitudinal axis 722 (Fig. 38) of the preform forms an angle of less than 90° with the vertical axis. In one non-limiting embodiment, the longitudinal axis 722 of the preform forms an angle in the range of about 20° to about 70° with the vertical axis. In one non-limiting embodiment, the longitudinal axis 722 of the preform forms an angle in the range of about 40° to about 60° with the
30 vertical axis. In some embodiments, generally vertically oriented preforms pass through the sheet of coating material produced by the coating system 316, and then the orientation of the preforms is changed before the preforms reach the removal system 318, as shown in

FIG. 35. Additionally, the preforms can be rotated about their longitudinal axes 722 as they proceed along the removal system 318 to enhance the distribution and/or removal of material on the surfaces of the preforms. For example, the preforms can be angled and rotated to retain more coating material on their body portions. In one embodiment, for example, the orientation and rotation of the preforms result in retention of coating material in the upper and/or central portions of the preforms' bodies 4, and may also promote the formation of a uniform layer of coating material. However, in other embodiments, the preforms may not be rotated about their longitudinal axes 722 as they move down the processing line. In some embodiments, the preforms may continuously or periodically rotate as they pass along one or more removal systems 318.

The surface 700 of the removal system 318 can have any size and configuration suitable for removing material from the preforms conveyed along the carousel system 312. With reference to FIG. 39A, the surface 700 can have a surface treatment or structure(s) 730. The surface structure(s) 730 can comprise one or more serrations, ridges, protuberances, grooves, channels, and/or any other structure that may facilitate the removal and/or spreading of the coating material.

With reference to FIG. 39B, the surface 700 can have one or more channels 730 to enhance the removal of coating material on the preforms. Coating material can be received within and passed along the channel 730 away from the preform. In some embodiments, the channel 730 can be parallel or transverse to the arrow 720 shown in FIG. 35. Optionally, the removal system 318 can have one or more lines 715 that can feed fluid (e.g., water, solvent, thinner, coating material, surfactants, combinations thereof, or the like) to the surface 700. The combination of structures 730 and liquid may rapidly draw off excess coating material on the preforms.

The surface 700 can also be a generally smooth surface. Preferably, a flow of fluid is provided by the line 715 to draw the uncured coating material from the preforms and onto the smooth surface 700. It is contemplated that any amount of liquid (e.g., droplets, pools, and/or stream of liquid) can be used to remove excess material from the preforms.

The preforms may or may not contact the surface 700. In one embodiment, the fluid on the surface 700 contacts the preforms, but the surface 700 is spaced from the preform. Of course, the surface 700 can contact the preforms during the removal process.

The removal system 318 can extend along a row of preforms on the carousel system 312 to simultaneously remove coating material from multiple preforms. However, the removal system 318 can be sized and configured to remove material from one preform at a time.

5 The line 715 can optionally deliver coating material to the removal system 318. The coating material can be used to draw a similar or different coating material off of the preforms. For example, coating material can be delivered by the line 715 to the surface 700. As the coating material flows along at least a portion of the surface 700, it can remove material, preferably material in a liquid state, disposed on the preform. In one
10 embodiment, the coating material can both ensure that excess material is removed from the preform while leaving a thin layer of coating material on the preform.

With reference to FIG. 39C, the removal system 318 can direct a fluid flow to remove and/or redistribute coating material 714 on the preform 20. The illustrated removal system 318 comprises a fluid source 750 that outputs a directed high velocity stream of
15 fluid towards one or more preforms. The fluid can be a gas, such as air, nitrogen, oxygen, and/or the like. In some embodiments, the fluid source 750 can extend along the row of preforms on the carousel system 312 to simultaneously remove coating material on each of the preforms.

The illustrated fluid source 750 is an air knife. A line 752 can deliver air to the air
20 knife 750 which, in turn, delivers the air out of nozzle 756 towards the preform to blow off excess material from the preform. Although not illustrated, the fluid source 750 can comprise a plurality of fluid sources, such as air knives. Optionally, the fluid source 750 can spray liquid to remove coating material from the preform.

With reference to FIG. 39D, the removal system 318 can use energy, such a
25 potential energy, to remove coating material from the coated preform. In the illustrated embodiment, the removal system 318 comprises an energy source 760 that can produce an electrical charge. The electrical charge can draw off the uncured material from the preform. The electrical line 762 can provide power to the energy source 760. Although not illustrated, the energy source 760 can comprise a plurality of energy sources.

30 With reference to FIG. 39E, the removal system 318 is a bath 764 that can comprise one or more of the following liquids: water, coating material, surfactants, mixtures thereof, and the like. At least a portion of the coated preform 20 can be dragged through the bath

764 in a tank 766 in order to remove material from the preform. For example, the preform can be positioned so that the end cap of the preform is dipped into the liquid, such that at least a portion of the coating on the end cap is removed. Alternatively, the bath 764 can be used to deposit coating material onto the preform.

5 It is contemplated that one or more of the removal systems 318 described herein can be disposed at any point along the processing line. For example, one or more of the removal systems 318 can be disposed between the curing units 330, 332 of the temperature control system 320.-

10 The removal system 318 may have a removal fluid system for recycling fluid removed from the preforms. In the illustrated embodiment of FIG. 40, a removal fluid system 800 can be in fluid communication with the fluid system 530 described herein. The fluid system 800 comprises a collection tray 802, an output line 804, and a tank 806. The tray 802 can collect excess fluid that is removed by the removal system 318. Preferably, the tray 802 is sized and configured to catch fluid (e.g., water, solvents, thinners, coating
15 materials, surfactants, combinations thereof, or the like) that falls from the preforms and/or the removal system 318. If the removal system 318 uses coating material to remove material from the preforms, the material can be recycled and subsequently used by the flow coating system 316 and/or the removal system 318. The tray 802 can be positioned underneath any portion the process line. The collection tray 802 can be positioned down-
20 line of the flow coating system 316 underneath the removal system 318.

 The output line 804 extends between the tray 802 and the tank 806. Fluid captured in the tray 802 can flow through the line 804 and into the tank 806. A pump 810, which can be similar to or different from the pump 614, can draw fluid from the tank 806 and into the line 715. The pump 806 can pressurize the fluid so that the fluid passes through and out
25 of the line 715.

 The tank 806 can optionally have an agitator 811 to agitate and mix the fluid contained in the tank 806. The agitator 811 can promote mixing of the material contained within the tank 806 to minimize curing of the coating material, enhance homogeneity of the mixture, and the like.

30 With continued reference to FIG. 40, the removal fluid system 800 can be in fluid communication with the fluid system 530. In one embodiment, fluid can pass between the systems 530, 800 to ensure a proper amount of fluid is within one and/or both of the fluid

systems 530, 800. In one embodiment, a fluid line 814 provides fluid communication between the tank 806 and the reservoir 610. A filtration unit 660 may optionally be disposed along the line 814 to remove contaminants from the fluid passing therethrough. A pump 614 may be disposed along the line 814 to pressurize the fluid flowing between the tank 610 and the tank 806. In one embodiment, at least one of the tanks 610, 806 can have one or more sensors 816 for determining the amount of fluid in the tanks. If the amount of fluid in one of the tanks reaches an undesirable level, the pump 614 can be used to allocate the fluid between the tanks 610, 806 as desired.

The sensor 816 can be configured to detect and send a signal indicative of the components of the working fluid. The signals from the sensors 816 can be used to adjust the percentage of the components of the material. Additives can be added to the working fluid based on the signals to obtain a desired mixture. For example, the sensors 816 can be configured to measure the properties (e.g., viscosity, density, amount of bubbles, optical characteristics, refractive index, etc.) of the coating material to determine whether additives should be added to the fluid. For example, if the sensor 816 detects a low amount of anti-foaming agent in the fluid, anti-foaming agent can be added, e.g., manually or automatically. In some embodiments, the sensors 816 can comprise an optical analysis system (e.g., a spectrometer system, colorimetric analysis system, etc.), refractometer, the like suitable for determining the concentration of the various components of the coating material. In some embodiments, one or more sensors 816 can send a signal to a controller. The controller can be used to control selective the amount of constituents of the fluid. The devices and methods described in U.S. Patent Nos. 6,067,151 and 5,309,288, which are incorporated herein by reference in their entireties, can be utilized. The sensors 816 can also be configured to measure other parameters of the coating material. The sensors 816 can measure the parameters of the working fluid continuously or intermittently depending on the particular application. In some non-limiting embodiments, the sensors 816 can be configured to measure the temperature, viscosity, concentration, amount of constituents, etc. of the coating material.

In some embodiments, the fluid system 530 has a fluid temperature control system 817 for selectively controlling the temperature of the coating material. The fluid temperature control system 817 can be at any position along the fluid system 530. For example, one or more fluid temperature control systems 817 can be positioned along fluid

lines, within tanks, or at other suitable locations for changing the temperature of the coating material. In some embodiments, including the illustrated embodiment of FIG. 40, the fluid temperature control system 817 is a heat exchanger that can rapidly change the temperature of the fluid material in the tank 610. The fluid temperature control system 817 can operate to ensure that the temperature of the coating material is maintained within a desired temperature range to minimize, e.g., material breakdown, curing, and the like. Any suitable type of heat exchanger can be employed.

With reference again to FIG. 18, after coating material has been removed from the preforms, the preforms can be passed through the temperature control system 320 to cure the coating layer. The temperature control system 320 can cure at least a portion of the coating material disposed on the outer surfaces of the preforms. The temperature control system 320 preferably cures a substantial portion of the coating material on each preform.

The physical orientation of the temperature control system 320 can be adjustable relative to the preforms. As shown in FIG. 41, one or more lamps 736 may be moved relative to the preform being held by the mandrel 420. In the illustrated embodiment, each lamp 736 can be individually moved towards and/or away from the preform. It may be desirable to position one or more of the lamps 736 near to the end cap 10, as shown in FIG. 41. This advantageously allows for thorough curing of the bottom of the preform. For example, gravity may cause coating material 714 (FIG. 38) to spread down the body 4 towards the end cap 10. The coating material may accumulate at the end cap 10. This accumulated coating material can be thoroughly cured due to the spacing between the lower lamps of the curing unit 330 and the preform. Embodiments with adjustable lamps may also be used with preforms of varying widths. For example, if a preform is wider at the top than at the bottom, the lamps may be positioned closer to the bottom of the preform to ensure even curing. The lamps are preferably oriented so as to provide relatively even illumination of all surfaces of the coating. One or more lamps 736 can be generally equally spaced from the coated preform. Additionally, the preforms can be vertically orientated or angled from a vertical axis. The preforms can be rotated about their longitudinal axes 722, as they pass by the lamps 736, to achieve generally even curing of the coating material.

In some embodiments, the coating material on the substrate article can comprise a curing enhancer. For example, the coating material can comprise carbon black and/or other curing enhancer that can facilitate cross-linking of the coating material. An effective

amount of a curing enhancer can be added to the coating material based on the coating material, design of the curing unit, desired production time, and the like. Any suitable cross-linking agent can be employed to enhance the curing process.

5 With continued reference to FIG. 41, the curing units 330, 332 can have one or more reflectors 740 that can reflect the output from the lamps 736 towards the preforms. The reflector 740 can be used with infrared (IR) lamps 736 to maximize curing of the preforms. The lamps 736 are positioned on one side of the processing line while a reflector 740 is located on the opposite side of the processing line. This design advantageously reflects the output from the lamps 736 back onto the preform allowing for a more rapid and
10 thorough cure, and efficient use of the output of the lamps 736. Although not illustrated, additional reflectors can be located at any suitable position relative to the preform to reflect IR rays from the lamps toward the preform. The reflector 740 may be generally flat, curved, have a surface treatment, and/or the like to achieve the desired amount of reflected energy.

15 The temperature control system 320 can use one or more of the following: conduction, convection, and radiation to control the temperature of the preforms. Any mode of heating and cooling can be employed for controlling the temperatures of the preforms. For example, convection can be used to regulate selectively the surface temperatures of the preforms, thereby providing flexibility in controlling the penetration of
20 the radiant heat. In some embodiments, the temperature control system 320 can have a flow system for providing a fluid flow (e.g., a gas flow) to control the surface temperature of the preforms. The fluid can be heated or chilled. Preferably, a chilled gas is used to form a cool boundary layer along the surface of the preform to reduce the surface temperature of the coating layer. The boundary layer can separate heated ambient air from
25 the preform for enhanced thermal isolation. This may allow for rapid and thorough curing of the coating on the preform without overheating the surface of the coated preform. The reduced surface temperature of the coating layer can desirably retard the formation of a skin on the coating layer. If a skin forms on the coating material, the skin may blister as trapped fluid (e.g., water, air, etc.) migrates out of the coating material and bursts through the skin.
30 Of course, if a particular embodiment requires a slower cure rate or a deeper IR penetration, the curing rate can be controlled with one or more of the following: chilled gas, a

temperature controlled gripping mechanism (e.g., temperature controlled mandrels), time spent in the IR unit, the IR lamp frequency, and combinations thereof.

The temperature control system 320 and carriers 374 can work alone or in combination to control the temperature of the preforms. In one embodiment, the surface temperature of the coating may exceed the coating material T_g without heating the substrate above the substrate T_g during the curing/drying process. This provides the desired film formation and/or crosslinking without distorting the preform shape due to overheating of the substrate. For example, when the coating material has a higher T_g and a cross linking temperature than the preform substrate material, the surface of the coating is preferably heated to a temperature to cause cross-linking of the coating while keeping the substrate temperature at or below the substrate T_g . One way of regulating the drying/curing process to achieve this balance is to combine IR heating and air cooling (as discussed above), although other methods may also be employed. As such, the substrate can be maintained at a desired temperature while at least a portion of the coating material can be maintained at a different temperature.

In one embodiment illustrated in FIG. 42, the mandrel 420 has a means for controlling the temperature of the preform positioned thereon. The mandrel 420 comprises one or more channels 744 for controlling the temperature of the preform, preferably the neck 2 of the preform. The body 432 of the mandrel 420 can extend through a portion of the interior chamber of the preform. Heated or chilled fluid can pass through the mandrel 420 to regulate the temperature of the preform 20 retained thereon. Chilled fluid (e.g., a refrigerant, water, air, or the like) can flow through the channels 744 to transfer heat away from the preform. The lamps 736 and the mandrel 420 can be used in combination to achieve a crystalline neck finish of the preform. Additionally, while the preform 20 and the associated mandrel 420 proceed along the processing line through the temperature control system 320, the mandrel 420 and the preform 20 can rotate about the axis 722 to further ensure a generally uniform heat distribution through the body of the preform 20.

The temperature control system 320 can have a structure to block or reduce the amount of radiant heat that penetrates the preform and/or coating layer. As shown in FIG. 43, a shield 750 may block at least a portion of the radiant heat emitted by the lamps 736. The shield 750 can block most or all of the radiation produced by one or more of the lamps 736. The shield 750 can be a piece of, e.g., metal or plastic that blocks a portion of the

radiation outputted by the lamps 736 and can be sized and configured such that it extends along the upper portion of the preform to prevent radiation from penetrating, e.g., the neck 2 of the preform. The shield 750 can extend along the entire length of the lamps 736. Optionally, the shield 750 can comprise an opaque material that permits some radiant energy produced by the lamps 736 to pass therethrough. Optionally, a plurality of shields 750 can be used to inhibit or prevent radiation from penetrating different portions of the preform. It is contemplated that one or more of the curing units (e.g., curing units 330, 332) can have one or more shields 750 depending on the application.

The curing units 330, 332 can be maintained at any suitable temperature for curing the coating layer on the preform. The temperature within the coating units is preferably decreased along the processing line. The up-line curing unit 330 can output a high amount of radiant energy that can penetrate the coating layer when a skin is not formed on the outer surface of the coating layer. As the preforms proceed down-line, the down-line curing unit or units 332 can emit a decreased amount of radiant energy as compared to up-line curing units in order to prevent blistering, or the formation of other imperfections. However, one or more curing units can output a generally constant amount of radiant heat. Optionally, the down-line lamps 736 near the end cap 10 of the preform can produce low amounts of radiant energy to minimize blistering of the coating layer.

After the preforms undergo the curing process, the preforms can be cooled. In some embodiments, the preforms are cooled after the preforms exit all of the curing units. However, the preforms can undergo a cooling process between curing units. The cooling process can comprise using ambient air, with or without forced convection. In some embodiments, the cooling process is accelerated by the use of forced chilled air. In the illustrated embodiment of FIGS. 18 and 44 the cooling system 336 comprises a channel 770 that a blower or fan (not shown) can drive ambient air (preferably chilled air) through. The air can cool the preforms which are held by the carriers 374 and carried down the length of the channel 770. Any suitable means can be employed to cool the cured coating layer on the preforms. After the preforms are cooled a desired amount, they are released from the carriers 374 and transported away by the removal system 346, which can be a conveyor system.

Optionally, the coating system 300 can have one or more temperature sensors. In one embodiment, the temperature sensors are optical pyrometers 824 that may be carefully

positioned along the processing line to measure the temperature of the preforms. Advantageously, the pyrometers 824 can determine the preform's temperature directly by measuring the light radiation emitted by the preforms. As such, pyrometers can measure the temperature of the liquid coating material without contacting and disturbing the coating material. In the illustrated embodiment, the coating system 300 has four pyrometers 824. A first pyrometer 824 is positioned between the transfer system 310 and the flow coating system 316. A second pyrometer 824 is positioned between the material removal system 318 and the temperature control system 320. A third pyrometer 824 is positioned between the temperature control system 320 and the cooling system 336. A fourth pyrometer 824 is positioned down-line of the cooling system 336. The coating system 300 can employ any number of pyrometers 824 at any point to measure the temperature of the components of the coating system or the preforms being processed. However, other temperature devices can be used to measure the temperature of the preforms and/or components of the coating system 300. For example, one or more thermocouples can be used to measure the temperature of the preforms or the components of the coating system 300.

The temperature control system 320 can be a closed loop or open loop system. For example, the temperature control system 320 can be a closed loop system, whereby the power to the lamps 736 is controlled based upon feedback signals from one or more temperature sensors (e.g., pyrometers 824) and can then adjust the amount the radiant heat produced by the lamps 736 based on those readings. Alternatively, the temperature control system 320 can be an open loop system wherein the amount of radiant heat produced by the lamps 736 is set by user input. For example, the lamps 736 may be set to a fixed power mode. Each of the lamps 736 can be set to a desired target temperature or power output. It is contemplated that the temperature control system 320 can be switched between a closed and open loop mode. In some embodiments, a controller is in communication with the plurality of sensors and the temperature control system 320. The controller can selectively control the output of temperature control system 320 in response to at least one signal from at least one of the temperature sensors.

With reference to FIG. 18, the coating system 300 can have a controller 860 that a user can operate to control one or more of the components of the system 300. The controller 860 can receive and display readings from, e.g., the pyrometers 824. The controller 860 can store and run programs and control the coating system 300 so that the

coating system 300 can coat preforms of different sizes. Each program can be used to move one or more components of the coating system 300. The various components of the coating system 300, such as the transfer system 310, the flow coating system 316, the removal system 318, and/or the temperature control system 320, can have a mechanism for positioning. For example, exemplary systems for movement can comprise linear slides and actuation systems (e.g., screw driven actuators). The controller 860 can instruct the actuation systems (e.g., one or more solenoids, motors, including drive or stepper motors, and the like) to move components of the coating system 300 to a desired position. These components may be numerically controlled by the controller 860 (e.g., a digital control system). In some embodiments, each component has one or more degrees of freedom to position the component of interest in a desired position. Thus, the components of the coating system 300 can be positioned at any desired point along the processing line. Each component may have different position based upon the size and configuration of the preforms that are being processed. The controller 860 can have stored preset programs wherein a program can be selected and run based on the configuration of the preform, type of coating material, operating conditions (e.g., ambient temperature, humidity, and the like), or other parameters known in the art. The coating system 300 can therefore be utilized to coat a variety of different types of preforms.

10. Example III

FIG. 45 depicts another embodiment of the coating system, which may be generally similar to the embodiments illustrated above, except as further detailed below. Where possible, similar elements are identified with identical reference numerals in the depiction of the embodiments described above.

The coating system 1000 includes a feed system 1002 that delivers preforms to a transfer system 1004 which, in turn, delivers preforms to the carousel system 312. As the preforms are transported along the processing line by the carousel system 312, a coating system 1010a deposits material on the preforms moving along the processing line in the direction indicated by the arrows 375.

With reference to FIGS. 45 and 46, the feed system 1002 can comprise a plurality of conveyors and slides configured to deliver preforms to the transfer system 1004. As shown in FIG. 46, the feed system 1002 includes an upper conveyor line and a lower conveyor line (not shown) that extends downwardly into the coating system 1000 to the transfer system

1004. Although not illustrated, the feed system 1002 can have a gate or other system for controlling the delivery of preforms from the system 1002 to the transfer system 1004.

The transfer system 1004 can comprise a plurality of starwheels. The illustrated transfer system 1004 includes a first starwheel 1016 and a second starwheel 1018. The starwheel 1016 has peripheral pockets 1020 configured to receive and hold preforms delivered by the feed system 1002. The starwheel 1016 can rotate to pass the preforms to the pockets 1022 of the starwheel 1018. The starwheel 1018 then rotates and delivers the preforms to the carousel system 312. Any number of starwheels can be utilized depending on the coating system design.

As described above, the carriers 374 can receive and hold the preforms delivered by the transfer system 1004. The carousel system 312 can move the carriers 374 and associated preforms past the coating system 1010a. The coating system 1010a is a flow coating system that is preferably removably attached to a housing 1023 (FIG. 46) of the carousel system 312. The housing 1023 can surround and protect the coating system 1000.

As shown in FIGS. 45 to 47, a flow coating system 1010a preferably comprises a tank system 1030 and a delivery system 1032. The tank system 1030 can have a modular construction comprising a frame 1036 and a tank 1038 positioned therein. The modular tank system 1030 is preferably capable of being transported to and away from the coating system 1000. As used herein, the term "modular" is a broad term and is used in its ordinary meaning and may include, without limitation, an independent apparatus or system. In some embodiments, the modular tank system is movable between a remote location and a delivery position. When the tank system 1030 occupies the delivery position, the modular tank system can be next to the delivery system 1032 and coating material is delivered from the tank 1038 to the delivery system when a pump 1065 of the tank system 1030 operates.

In some embodiments, the tank 1038 is mounted within the frame 1036 and is in fluid communication with the delivery system 1032. The frame 1036 can be a housing that surrounds and supports the tank 1038 for convenient transport. The tank 1038 can be generally similar to or identical to the tank or reservoir 610, and therefore will not be described in further detail.

The frame 1036 is preferably removably coupled to the housing 1023 so that the tank system 1030 can be docked and undocked. The tank system 1030 can comprise a transportation system 1039. The illustrated transportation system 1039 comprises a

plurality of wheel systems 1040 are coupled to the tank system 1030. As such, the tank system 1030 can be conveniently rolled upon a support surface. In the illustrated embodiment, the wheel systems 1040 are attached to the bottom of the frame 1036. Although not illustrated, the frame 1036 can be mounted on other suitable means for transporting the tank system 1030. For example, the frame 1036 can be mounted upon slides (e.g., a liner slide system), on a gantry system, on rollers, or other means of transportation known in the art.

With continued referenced to FIG. 46, the housing 1023 of the coating system 312 can have a dock (e.g., an opening) for receiving the tank system 1030. When the frame 1036 is mated with the housing 1023, one or more locking mechanisms 1050 may be employed to couple temporarily the tank system 1030 to the housing 1023. Optionally, alignment structures can be employed to aid in aligning the tank system 1030 to the housing 1023. The tank 1038 contains coating material that can be delivered onto preforms carried by the carousel system 312.

Advantageously, when the level of coating material within the tank 1038 reaches a preset low level, the tank system 1030 can be easily rolled away from the housing 1023 and can be replaced with another tank system 1030, preferably a tank system full of coating material. In this manner, the modular tank systems 1030 can quickly be replaced and secured to the housing 1023. When an empty tank system 1030 has been removed from the coating system 1000, the tank 1038 can be replenished with coating material so that the tank system 1030 can once again be used to deliver material to the delivery system 1032. The delivery system 1032 can comprise coating unit, including a flow coating unit, dip coating unit, spray coating unit, and combinations thereof. A skilled artisan can select the size, configuration, means of transportation the tank system 1030, and the like depending on the amount of coating material held by the tank 1038.

The tank system 1030 can comprise an upper tank 1060 positioned above the tank 1038. Material within the tank 1038 can be delivered through the fluid line 1062 to the tank 1060. Coating material from the upper tank 1060 can be poured over the preforms moving along the processing line via the coating system 1032. In some embodiments, the tank system 1030 can comprise at least some of the components of the fluid system 530 of FIG. 31. For example, the filtration unit 660 can be mounted to the tank system 1030. In some embodiments, the entire fluid system 530 is mounted to the tank system 1030. Thus,

the tank system 1030 can comprise one or more sensors 816, fluid temperature control systems 817, fluid lines, and the like.

The illustrated coating system 1000 of FIG. 45 is configured to deposit a plurality of layers on preforms while the preforms are retained on a corresponding carrier. A first layer
5 can be deposited on each preform by the coating system 1010a. A second coating system 1010b can deposit a second layer over the coated preform. The coating system 1010b can be similar to the coating system 1010a. Each of the coating systems 1010a, 1010b can comprise one or more delivery systems 1032. The modular tank systems of the coating systems can be configured to mate with a corresponding delivery system.

10 In some embodiments, preforms are coated with a first material by the coating system 1010b. The coated preforms can be passed by the material removal system 318 and through a temperature control system 320. The temperature control system 320 can heat the coated preform, thereby curing at least a portion of the coating material. The coated preform can be moved along the processing line and can be delivered to the second coating
15 system 1010b. A second layer can be deposited by the second coating system 1010b onto the coated preform.

The coated preforms passed out of the temperature control system 320 can be warm. The inherent heat of the preforms can promote adhesion, curing, and/or drying of the material deposited by the second coating system 1010b. Alternatively, the coated preforms
20 delivered out of the temperature control system 320 can be cooled before delivery to the second coating system 1010b.

In some embodiments, the first and the second coating systems 1010a, 1010b can be positioned next to each other along the processing line. As such, the coating layer deposited by the coating system 1010a can be uncured when the second coating system
25 1010b deposits a second layer of material thereon. Any number of coating systems can be utilized to form a multilayer article having any number of layers.

With reference to FIG. 48, the delivery system 1032 is configured to deliver coating material onto preforms being carried by the carriers 374. The delivery system 1032 preferably comprises a fluid guide 1070 for delivering material from the tank 1060 onto the
30 preforms passing thereby. Preforms moving along the processing line through the opening 1061 are coated with the coating material 1063.

To catch coating material 1063 falling from the preforms, a catch-all tank 1074 is located underneath the newly coated preforms. The catch-all tank 1074 can then deliver the coating material to the tank 1038, an off-line tank, and/or a disposal system. The catch-all tank 1074 can be any type of collection tank.

5 The fluid guide 1070 and/or the catch-all tank 1074 can be movably mounted to a support structure 1080. A positioning system 1082 can be employed to move the fluid guide 1070 and/or the catch-all tank 1074. The positioning system 1082 can comprise a drive screw system, liner actuator, motors, controller, and/or other suitable means for positioning the fluid guide 1070 and/or catch-all tank 1074. In the illustrated embodiment,
10 the support structure 1080 is a linear slide that extends in the vertical direction to provide for vertical movement of the fluid guide 1070 and the catch-all tank 1074. The positioning system 1082 can be operated to move the fluid guide 1070 and/or the catch-all tank 1074 to a desired position.

 With reference again to FIG. 47, a collection tray 1086a in the form of a trough can
15 be positioned to catch coating material falling from the preforms. The trough 1086a can be an elongated tank underneath the coated preforms, and preferably extends from the catch-all tank 1074 down line along the processing line. As shown in FIG. 45, the trough 1086a extends toward the removal system 318. Preferably, the trough 1086a extends at least half-way between the flow coating system 1010a and the removal system 318. In some non-
20 limiting embodiments, the trough 1086a has a length greater than about two feet, three feet, four feet, six feet, and ranges encompassing such lengths. In some embodiments, the trough 1086a has a length that is more than half the distance between the flow coating system 1010a and the removal system 318. Optionally, a fluid line can be connected to the trough 1086 to deliver the coating material contained therein to the tank 1038, or a reservoir
25 tank. Thus, the coating material that falls from the preforms and into the trough 1086 can be recycled and used to coat preforms for efficient use of the coating material.

 With respect to FIG. 49, the carriers described above can have a gripping mechanism in the form of a mandrel 1100 configured to hold a preform. The mandrel 1100 has an elongated body 1102 that can be controllably operated to hold selectively a preform
30 1103. The illustrated mandrel 1100 is in a first position. The elongated body 1102 can have a plurality of portions movable relative to one another. The illustrated elongated body 1102 is segmented into a first portion 1106 and a second portion 1108. As shown in FIG.

49, the preform 1103 can be moved vertically (indicated by the arrows 1120) over the elongated body 1102. Once the elongated body 1102 is positioned in the preform 1103, the first portion 1106 and the second portion 1108 can be moved away from each other to engage the interior surface of the preform 1103 in order to hold securely a preform. Thus, the mandrel 1100 in the first position (FIG. 49) can receive the preform 1103. To hold the preform 1103, the mandrel 1100 can be moved (FIG. 50) to a second position.

With respect to FIG. 50, the mandrel 1100 can have one or more actuators 1130 to move the first portion 1106 and the second portion 1108 away from each other. Optionally, the mandrel 1100 can have a lead-in 1136 to facilitate the sliding and advancing of the preform 1103 over the mandrel 1100.

FIG. 51 illustrates another embodiment of a mandrel 1150. The mandrel 1150 includes an elongated body 1152 that houses a mechanism 1154 for engaging and holding a preform. The mechanism 1154 is moveable between a holding position and a release position. The illustrated elongated body 1152 comprises a groove 1156 that is configured to receive at least a portion of a movable member 1161 (e.g., a split ring) of the mechanism 1154. A drive mechanism 1160 of the mechanism 1154 can selectively move the split ring 1161 outwardly and/or inwardly as desired. The split ring 1161 can be moved outwardly and can occupy a holding position for holding a preform. The split ring 1161 can be moved inwardly to occupy a release position for either receiving a preform or releasing a preform. In some embodiments, the drive mechanism 1160 comprises a push member 1162 and a spring 1164. The spring 1164 displaces the push member 1162 outwardly against the split ring 1161. Any number of drive mechanisms 1160 can be employed. When a preform is advanced over the elongated body 1152, the opening of the preform slides over the elongated body 1152 until it contacts the lower outer surface of the split ring 1161. As the preform is advanced further along the mandrel 1150, the preform overcomes the bias of the springs 1164, thereby displacing inwardly the split ring 1161 as the preform continues to proceed upwardly along the mandrel 1150.

A drive apparatus 1181 can be connected to the mandrel 1150. The illustrated drive apparatus 1181 can comprise a gear, sprocket, brush, or any other suitable apparatus for imparting rotary motion to the mandrel 1150. For example, the drive apparatus 1181 can comprise a gear that mates with a gear or chain of a carousel system. Alternatively, the drive apparatus 1181 can be a brush that engages a brush of the conveyor system. In yet

another embodiment, the drive apparatus 1181 can be a brush gear configured to rotate the mandrel 1150. The mandrel 1150 can thus rotate about its longitudinal axis as it moves along the processing line.

5 The drive apparatus 1181 can be directly or indirectly connected to the mandrel 1150. The illustrated drive apparatus 1181 is connected to a mandrel 1150 via a connecting member 1183.

10 With respect to FIG. 52, when the preform 1170 has been fully inserted over the mandrel 1150. The drive mechanism 1160 applies an outwardly directed force to a split ring 1161. The frictional interaction between the outer surface of the split ring 1061 and the interior surface of the preform 1170 is sufficient to hold the preform thereon. Advantageously, the preform 1170 can be easily slid over the mandrel 1150 and held thereon without having to employ complicated mechanisms, thereby reducing parts that can fail or that need to be maintained. To remove the preform 1170 from the mandrel 1150, the preform can be easily pulled off of the mandrel 1150. For example, as the carriers 374 move about the carousel system 312, the coated preforms can moved along a stripping mechanism that pulls downwardly on the preforms 1170. The stripping mechanism applies a force suitable for overcoming a frictional force between the mandrel 1150 and the preform. In some embodiments, the stripping mechanism can comprise a cam surface that is configured to engage the upper surface of the support ring of the preform passing by to push the preform off of the mandrel 1150.

20 With respect to FIG. 53, a gripping mechanism 1200 can hold the outside of the neck finish of the preform. The gripping mechanism 1200 is a preform holder that can have structures 1202 (e.g., protuberances, flanges, and/or the like) for engaging a portion of the preform, preferably the neck finish (e.g., the threads) of the preform. The preforms can be coupled to the mandrel or holder 1200 by vertically advancing the preform through the opening and into the holder 1200. The holder 1200 may comprise a split annular body defining the portion 1204 adapted to apply a pressure to the neck finish. To remove the preform from the holder 1200, the preform can be pulled downwardly in order to slide the preform out of the holder 1200. In some embodiments, the holder 1200 can be actuated and moved to an open position to drop the preform. Of course, the mandrel may or may not rotate the preform as the preform travels along the processing line.

The components of the coating systems can be designed to facilitate removal of coating material. Release agents can be applied to the surfaces of the coating systems to aid in cleaning of the coating system. For example, surfaces of the coating system that come into contact with the coating material can comprise a release material that permits easy removal of the coating material. The release agent can comprise one or more of the following release materials: Teflon®, polyvinyl chloride ("PVC"), polypropylene, polyethylene, polyolefins (e.g., nylon). For example, the inner surface of the collection tray 1086a can be coated with a release agent for easy removal of uncured coating material (e.g., thermoplastic materials such as phenoxy type thermoplastics) that falls from the preforms moving along the processing line. Any of the components of the coating systems can comprise a release material. For example, the collection tray 1086a can be a molded PVC tray. Any surface that contacts the coating material can be formed of a release material to aid in removal of unused coating material.

All patents and publications mentioned herein are hereby incorporated by reference in their entireties. Except as further described herein, certain embodiments, features, systems, devices, materials, methods and techniques described herein may, in some embodiments, be similar to any one or more of the embodiments, features, systems, devices, materials, methods and techniques described in U.S. Patents Nos. 6,109,006; 6,808,820; 6,528,546; 6,312,641; 6,391,408; 6,352,426; 6,676,883; U.S. Patent Application Nos. 09/745,013 (Publication No. 2002-0100566); 10/168,496 (Publication No. 2003-0220036); 09/844,820 (2003-0031814); 10/090,471 (Publication No. 2003-0012904); 10/395,899 (Publication No. 2004-0013833); 10/614,731 (Publication No. 2004-0071885), provisional application 60/563,021, filed April 16, 2004, provisional application 60/575,231, filed May 28, 2004, provisional application 60/586,399, filed July 7, 2004, provisional application 60/620,160, filed October 18, 2004, provisional application 60/621,511, filed October 22, 2004, and provisional application 60/643,008, filed January 11, 2005, U.S. Patent Application Serial No. 11/108,342 entitled MONO AND MULTI-LAYER ARTICLES AND COMPRESSION METHODS OF MAKING THE SAME, filed on April 18, 2005, U.S. Patent Application Serial No. 11/108,345 entitled MONO AND MULTI-LAYER ARTICLES AND INJECTION METHODS OF MAKING THE SAME, filed on April 18, 2005, U.S. Patent Application Serial No. 11/108,607 entitled MONO AND MULTI-LAYER ARTICLES AND EXTRUSION METHODS OF MAKING THE

SAME, filed on April 18, 2005, which are hereby incorporated by reference in their entireties. In addition, the embodiments, features, systems, devices, materials, methods and techniques described herein may, in certain embodiments, be applied to or used in connection with any one or more of the embodiments, features, systems, devices, materials, methods and techniques disclosed in the above-mentioned patents and applications.

The various methods and techniques described above provide a number of ways to carry out the invention. Of course, it is to be understood that not necessarily all objectives or advantages described may be achieved in accordance with any particular embodiment described herein.

Furthermore, the skilled artisan will recognize the interchangeability of various features from different embodiments. Similarly, the various features and steps discussed above, as well as other known equivalents for each such feature or step, can be mixed and matched by one of ordinary skill in this art to perform methods in accordance with principles described herein.

Although the invention has been disclosed in the context of certain embodiments and examples, it will be understood by those skilled in the art that the invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses and obvious modifications and equivalents thereof. Accordingly, the invention is not intended to be limited by the specific disclosures of preferred embodiments herein.

WHAT IS CLAIMED IS:

1. An apparatus for producing multilayer articles, the apparatus comprising:
a transfer system configured to receive and carry substrate articles;
a loading system comprising a plurality of loaders, the loaders being movable between a loading position and an unloading position;
a plurality of moveable carriers having gripping mechanisms configured to hold selectively substrate articles, wherein the loaders are configured to receive substrate articles from the transfer system when the loaders are in the loading position and configured to deliver the substrate articles to the moveable carriers when the loaders are in the unloading position, the plurality of moveable carriers being configured to retain and carry the substrate articles along a processing line;
and
a coating unit positioned alongside the processing line, the coating unit configured to deliver coating material onto substrate articles retained by the carriers.
2. The apparatus of Claim 1, wherein the gripping mechanisms comprise mandrels, each mandrel being dimensioned so as to fit within an interior of a corresponding substrate article, and each mandrel being movable between a first position for holding a substrate article and a second position for receiving a substrate article.
3. The apparatus of Claim 1, wherein the transfer system comprises at least one starwheel system, the starwheel system includes a plurality of peripheral pockets sized and dimensioned to receive the substrate articles, the plurality of peripheral pockets are rotatable about a drive shaft of the starwheel system.
4. The apparatus of Claim 1, wherein the transfer system comprises a plurality of starwheel systems, substrate articles are transferred between the starwheel systems when the starwheel systems operate.
5. The apparatus of Claim 1, wherein each gripping mechanism is movable between a holding position for holding a substrate article and a release position for releasing a substrate article.
6. The apparatus of Claim 1, further comprising a material removal system positioned along the processing line, the material removal system is configured to remove coating material disposed on the substrate articles when the substrate articles are carried by the carriers along the processing line past the material removal system.

7. The apparatus of Claim 6, wherein the substrate articles comprise a plurality of preforms, each preform having a neck, body, and an end cap, and the material removal system is positioned and configured to remove a substantial portion of uncured coating material on the end caps of the preforms.

8. The apparatus of Claim 1, further comprising a heat exchanger configured to effectively control the temperature of the coating material.

9. The apparatus of Claim 1, further comprising a sensor configured to continuously detect the viscosity of the coating material.

10. The apparatus of Claim 1, comprising a fluid system comprising a tank and a filtration system, the tank configured to hold coating material, the tank in fluid communication with the filtration system and the coating unit, and the filtration system configured to receive and filter coating material from the tank.

11. The apparatus of Claim 1, further comprising a movable tank assembly that is in fluid communication with the coating unit, the movable tank assembly comprises a housing that contains a tank, the tank configured to hold coating material that is delivered to the coating unit.

12. The apparatus of Claim 11, wherein the movable tank assembly is mounted on a plurality of wheel assemblies.

13. The apparatus of Claim 1, further comprising a tank in fluid communication with the coating unit, the tank is sized and configured to hold at least 10 gallons of coating material.

14. The apparatus of Claim 1, further comprising at least one temperature sensor, the at least one temperature sensor being positioned to measure temperatures of the substrate articles moving along the processing line.

15. The apparatus of Claim 14, further comprising a controller in communication with the at least one temperature sensor and a curing system configured to cure coating material on the substrate articles, the controller selectively controlling the output of the curing system in response to at least one temperature signal from the at least one temperature sensor.

16. The apparatus of Claim 14, wherein the at least one temperature sensor comprises a pyrometer.

17. A system for producing multilayer articles, the system comprising:

a conveyor system having carriers, each carrier configured to carry at least one substrate along a processing line;

a coating system positioned next to the processing line, the coating system comprising:

a delivery system configured to deliver coating material onto substrates retained on the carriers moving along the processing line;

a modular tank system movable and positionable with respect to the conveyor system, the modular tank system comprising:

a tank configured to hold coating material;

a pump in communication with the tank; and

wherein the modular tank system is movable between a remote position and a delivery position, when the modular tank system occupies the delivery position and the pump operates, the modular tank system is next to the delivery system and coating material is delivered from the tank to the delivery system.

18. The system of Claim 17, further comprising a second delivery system positioned along the processing line, the second delivery system configured to deliver coating material onto substrates retained on the carriers moving along the processing line.

19. The system of Claim 17, wherein the modular tank system comprises a transportation system configured to roll along a support surface.

20. The system of Claim 17, wherein the modular tank system further comprises a filtration system in fluid communication with coating material in the tank.

21. The system of Claim 17, further comprising a second coating system, the second coating system comprising:

a second delivery system; and

a second modular tank system movable and positionable with respect to the conveyor system, the second modular tank system configured to mate with the second delivery system, wherein coating material from the second modular tank system is deposited onto substrates via the second delivery system.

22. The system of Claim 17, further comprising:

a transfer system configured to receive and carry substrates;

a loading system comprising a plurality of loaders, the loaders being movable between a loading position and an unloading position, wherein the loaders are

configured to receive substrates from the transfer system when the loaders are in the loading position and configured to deliver the substrates to the conveyor system when the loaders are in the unloading position; and

at least one curing unit positioned along the processing line, the at least one curing unit configured to cure the coating material deposited on the substrates.

23. A method for producing multilayer articles, the method comprising:

delivering substrate articles to a transfer system;

passing the substrate articles along the transfer system to a loading system, the loading system placing the substrate articles onto carriers configured to hold the substrate articles, the carriers being movable so as to carry the substrates along a processing line;

depositing a first coating material onto at least a portion of each substrate article to form a first coating on each substrate article;

providing a material removal system positioned along the processing line;

and

the material removal system removing the first coating material from a lower section of each substrate article.

24. The method of Claim 23, further comprising applying a second coating to at least a portion of the lower section of each substrate article after the first coating material is removed from that substrate article.

25. The method of Claim 24, wherein the applying of the second coating comprises heating the first coating material to a sufficiently high temperature to promote the first coating material to flow over the lower section of each substrate article to form the second coating.

26. The method of Claim 24, wherein the applying of the second coating comprises self coating of the substrate articles due to gravity causing the first coating material to flow over the lower section of each substrate article.

27. The method of Claim 24, further comprising rotating the substrate articles as the first and second coatings are cured.

28. The method of Claim 23, wherein the substrate articles are preforms, and each lower section is at least a portion of an end cap region of one of the preforms.

29. The method of Claim 23, wherein the transfer system continuously delivers substrate articles to the loading system.

30. The method of Claim 23, wherein the transfer system batch feeds substrate articles to the loading system.

31. The method of Claim 23, wherein the loading system comprises a plurality of loaders, and each of the loaders being movable between a loading position and an unloading position.

32. The method of Claim 31, further comprising:
placing substrate articles on the loaders in the loading position;
moving the loaders to the unloading position; and
transferring the substrate articles to the loaders when the loaders are in the loading position.

33. The method of Claim 23, wherein the first coating material comprises Phenoxy-Type Thermoplastics.

34. The method of Claim 23, wherein the first coating comprises of carbon black.

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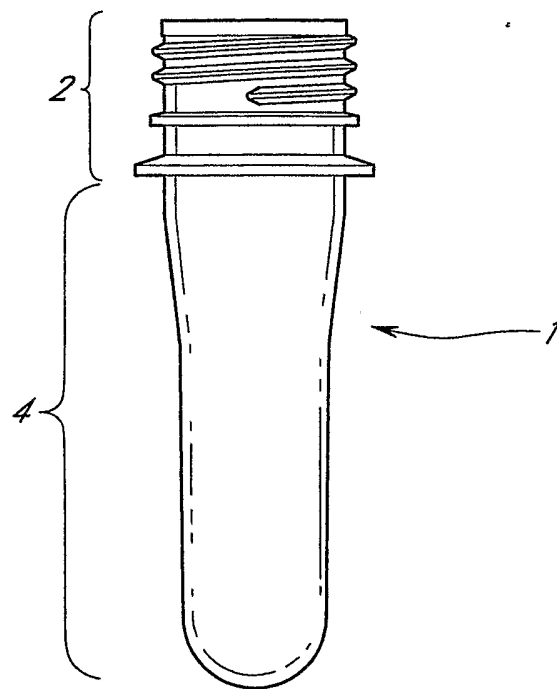
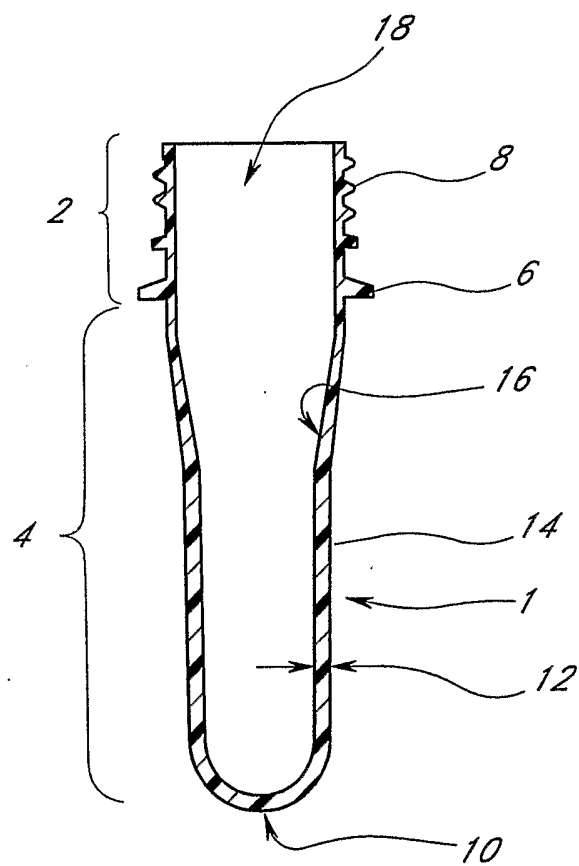
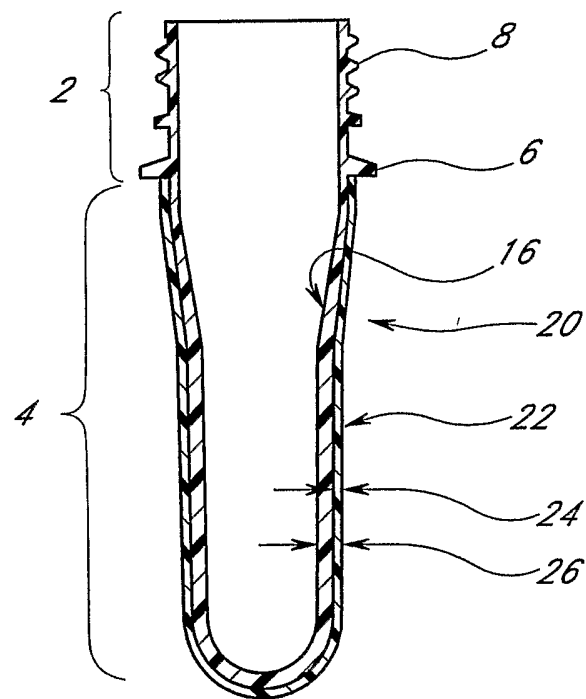


FIG. 1

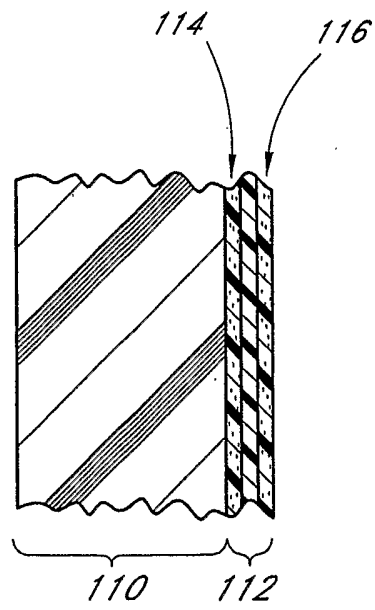
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**FIG. 2**

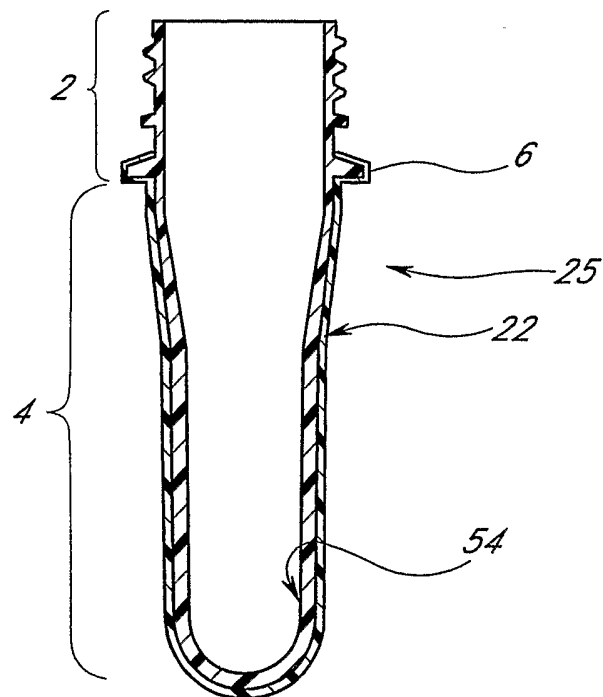
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*FIG. 3*

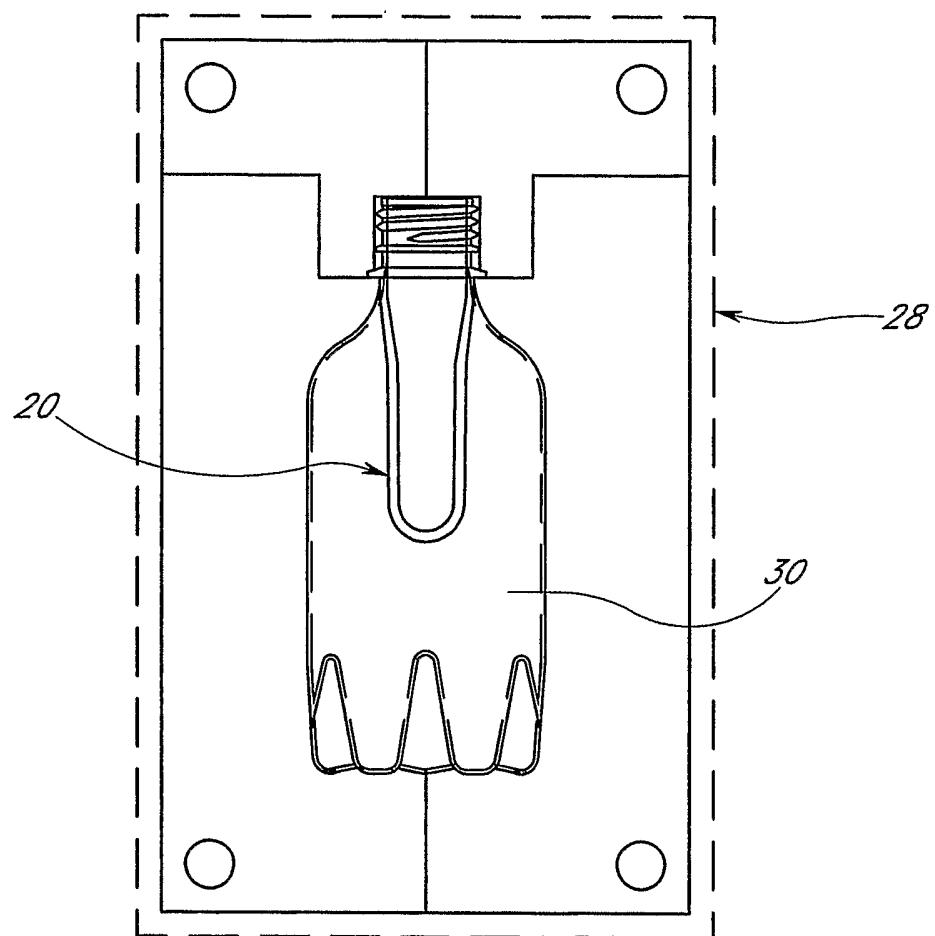
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**FIG. 4**

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*FIG. 5*

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*FIG. 6*

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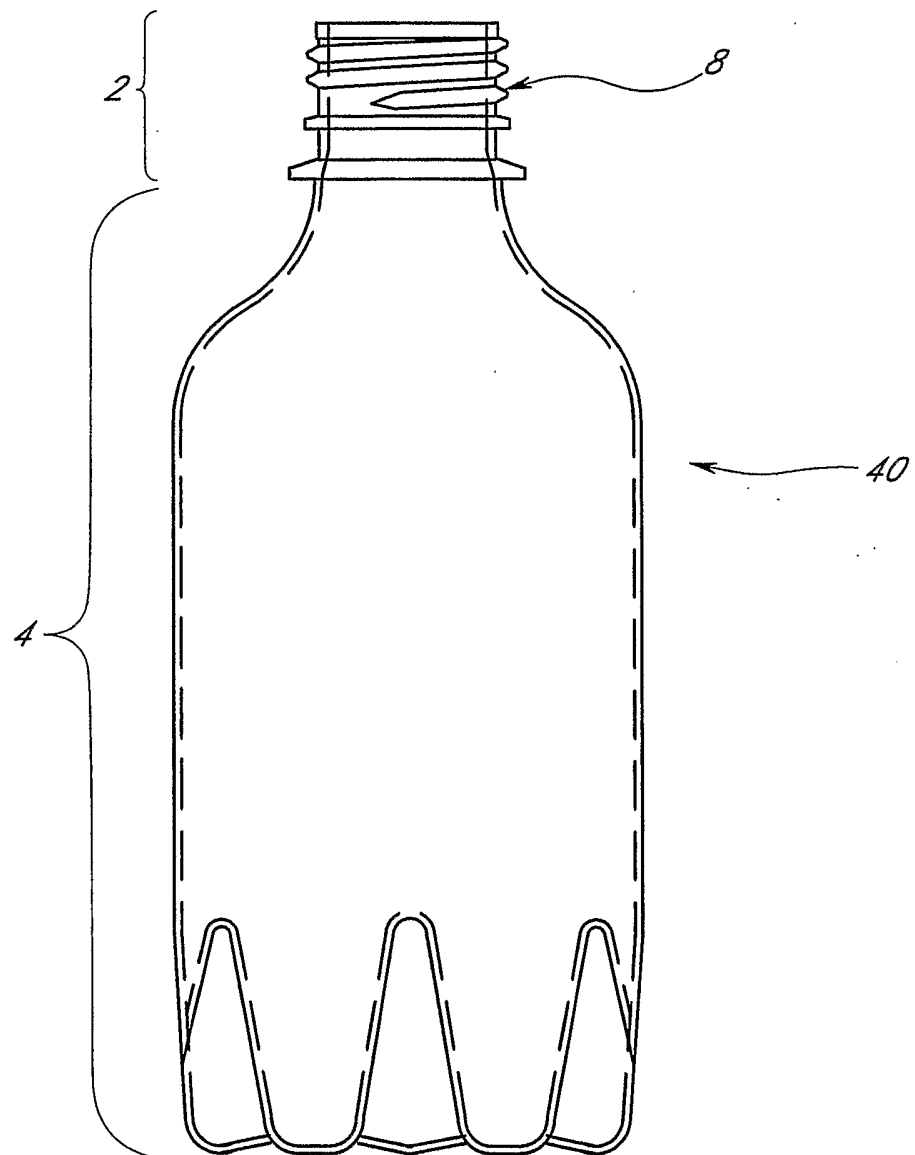
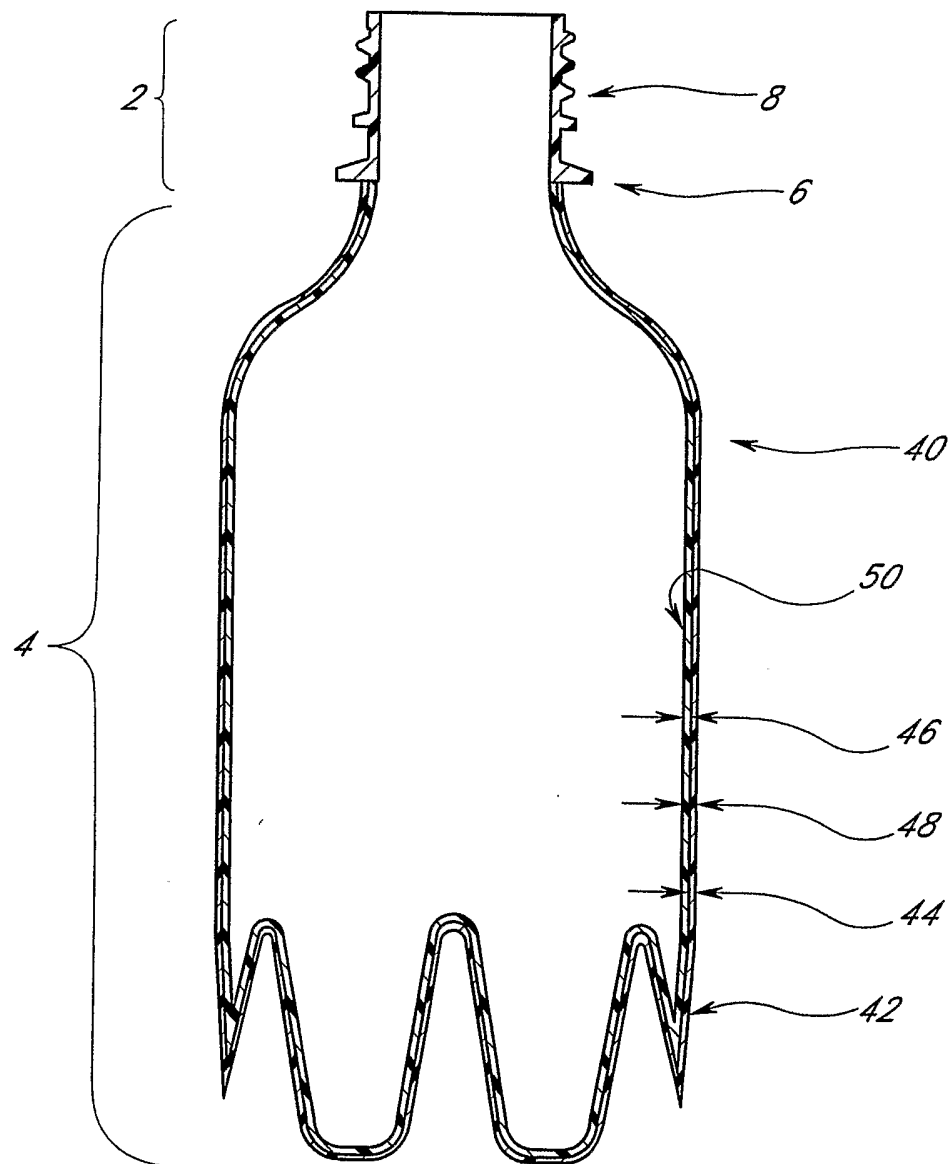


FIG. 7

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*FIG. 8*

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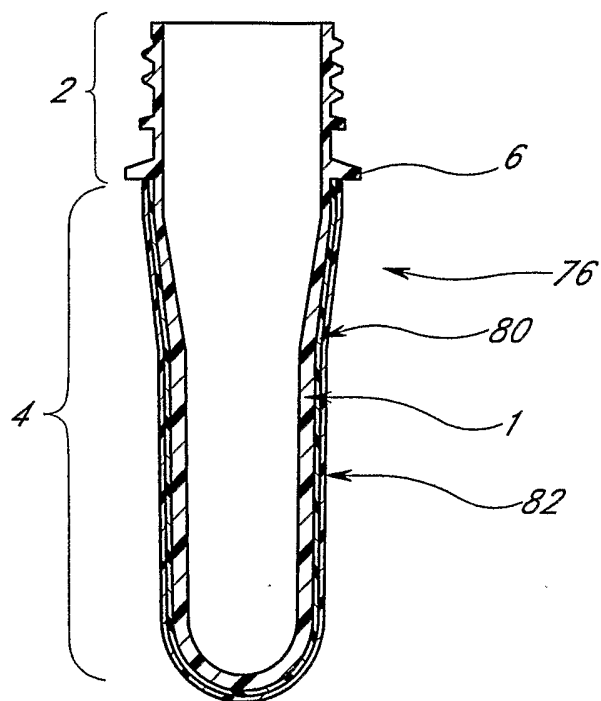
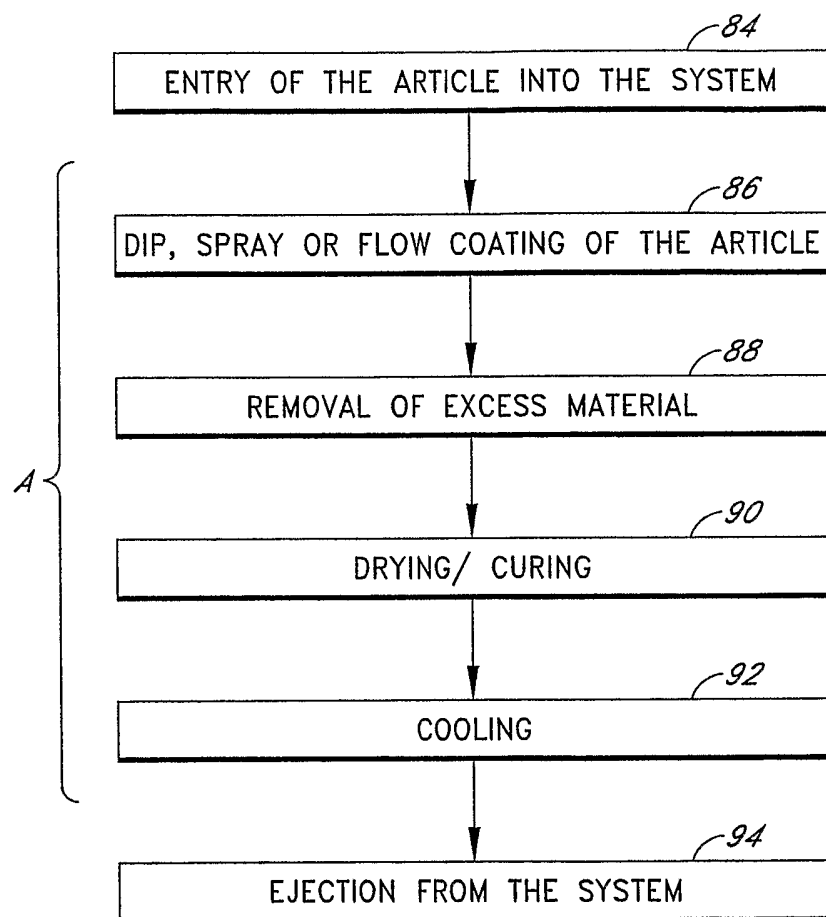
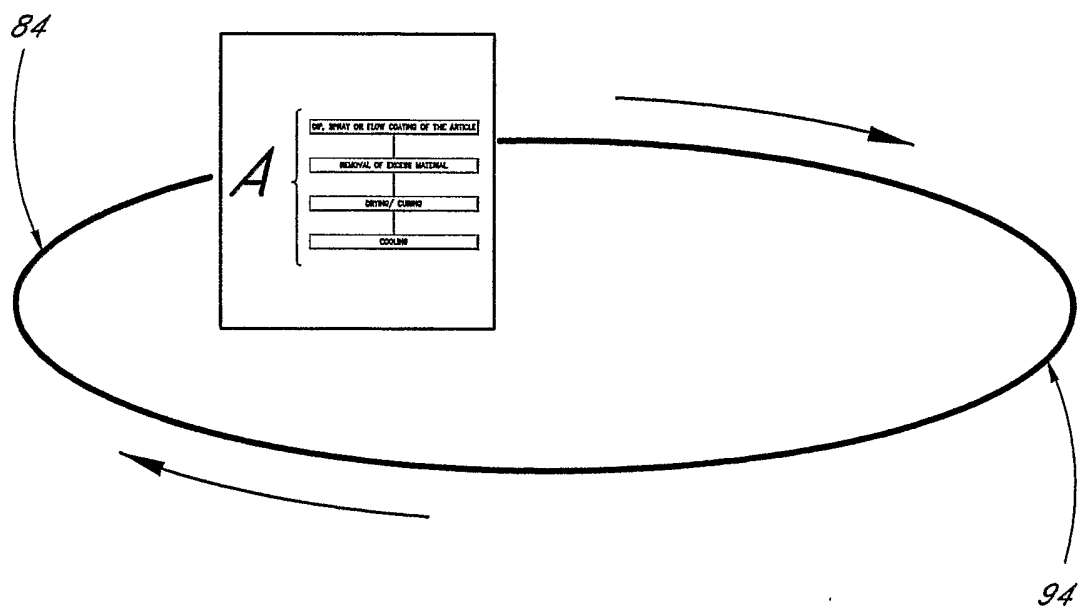


FIG. 9

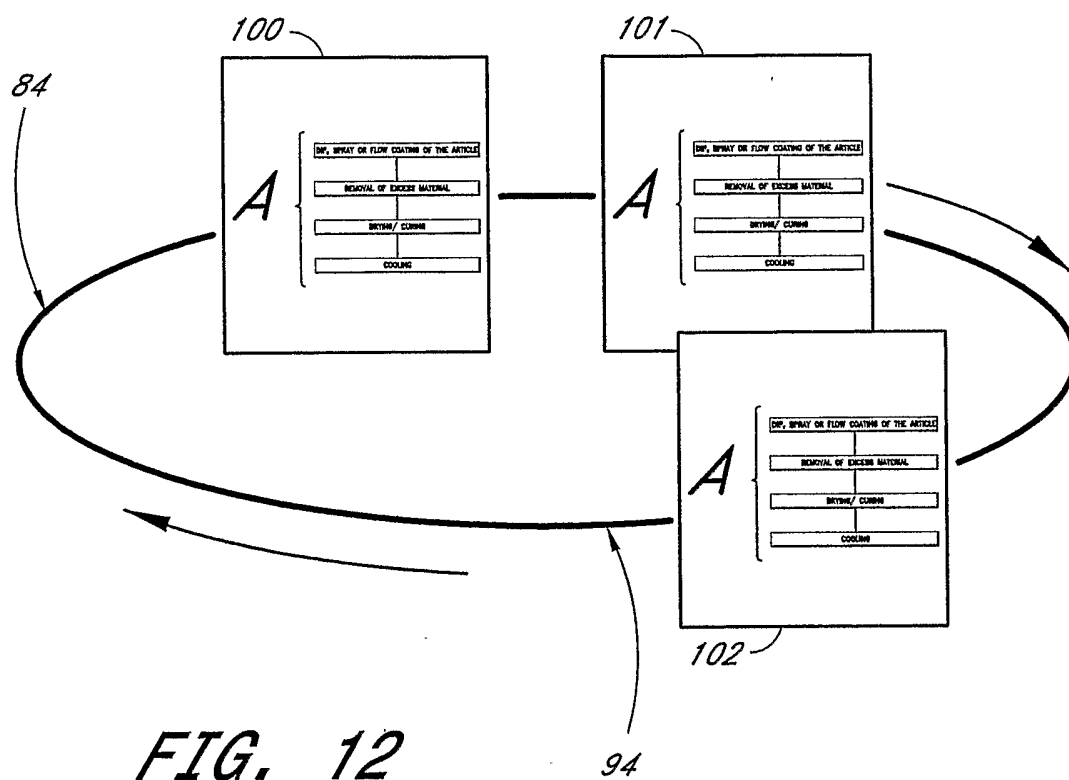
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*FIG. 10*

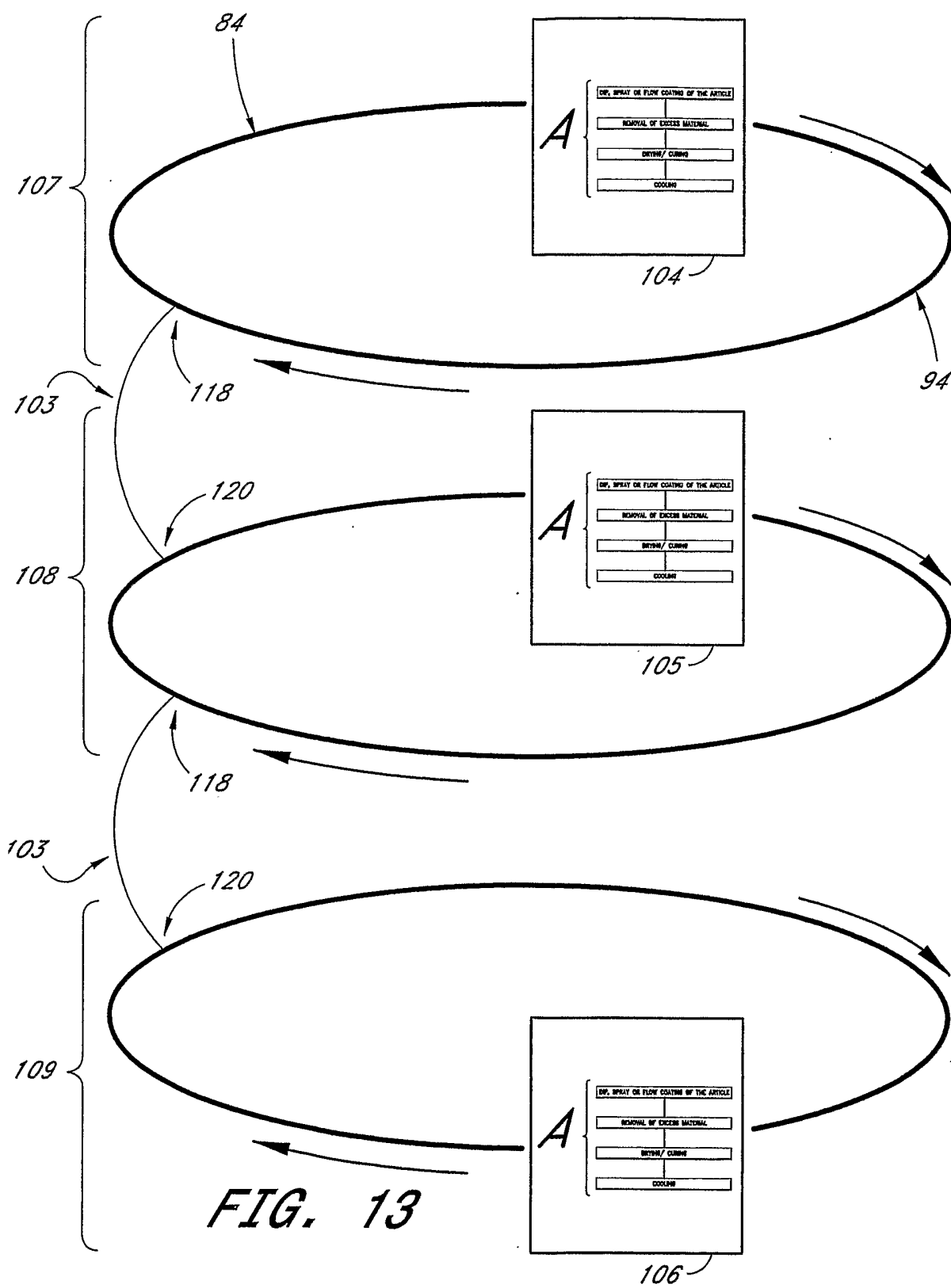
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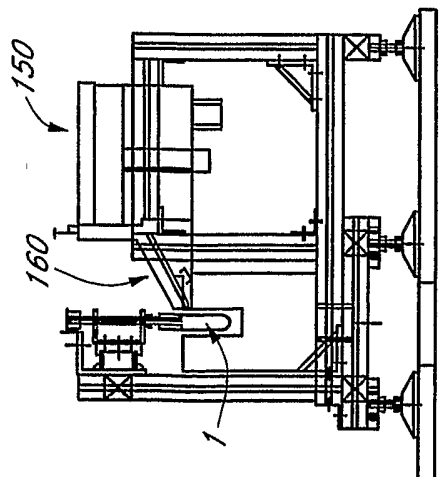
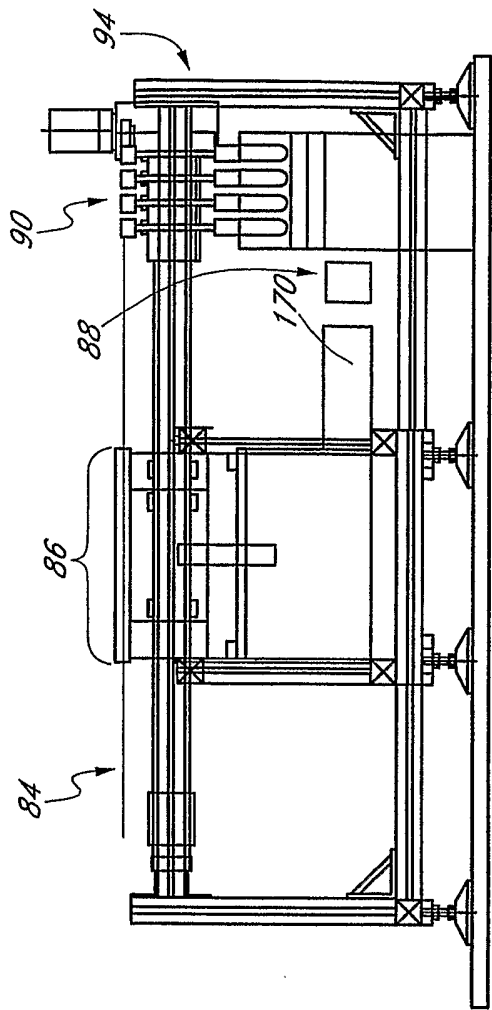
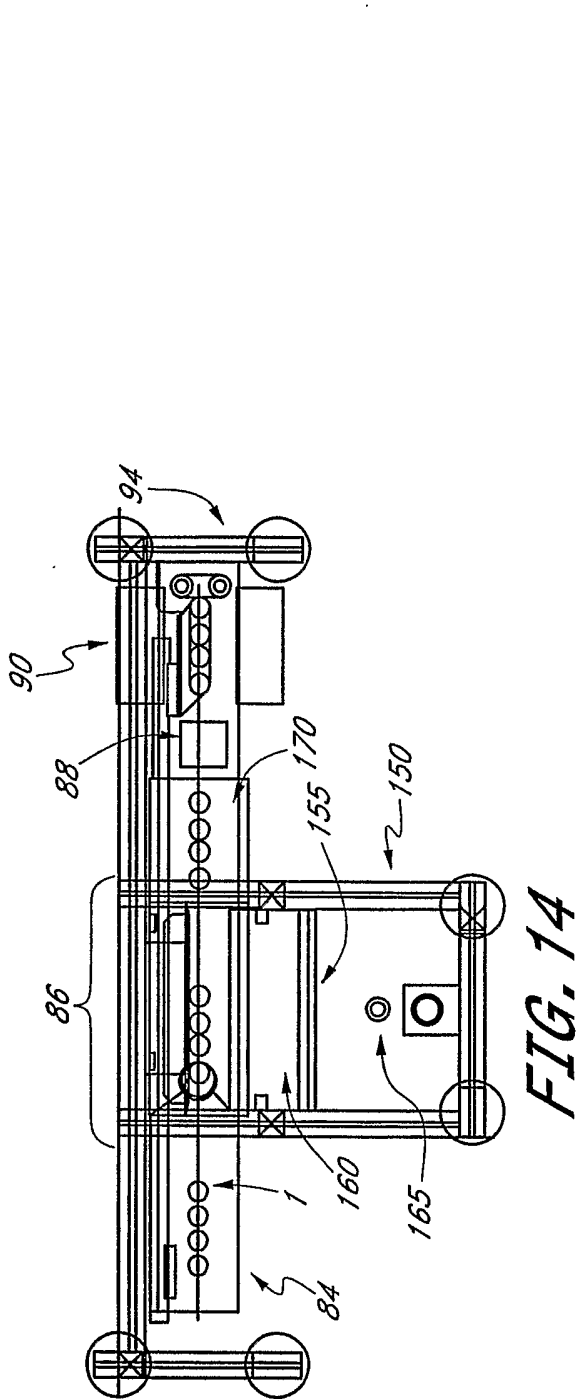
*FIG. 11*

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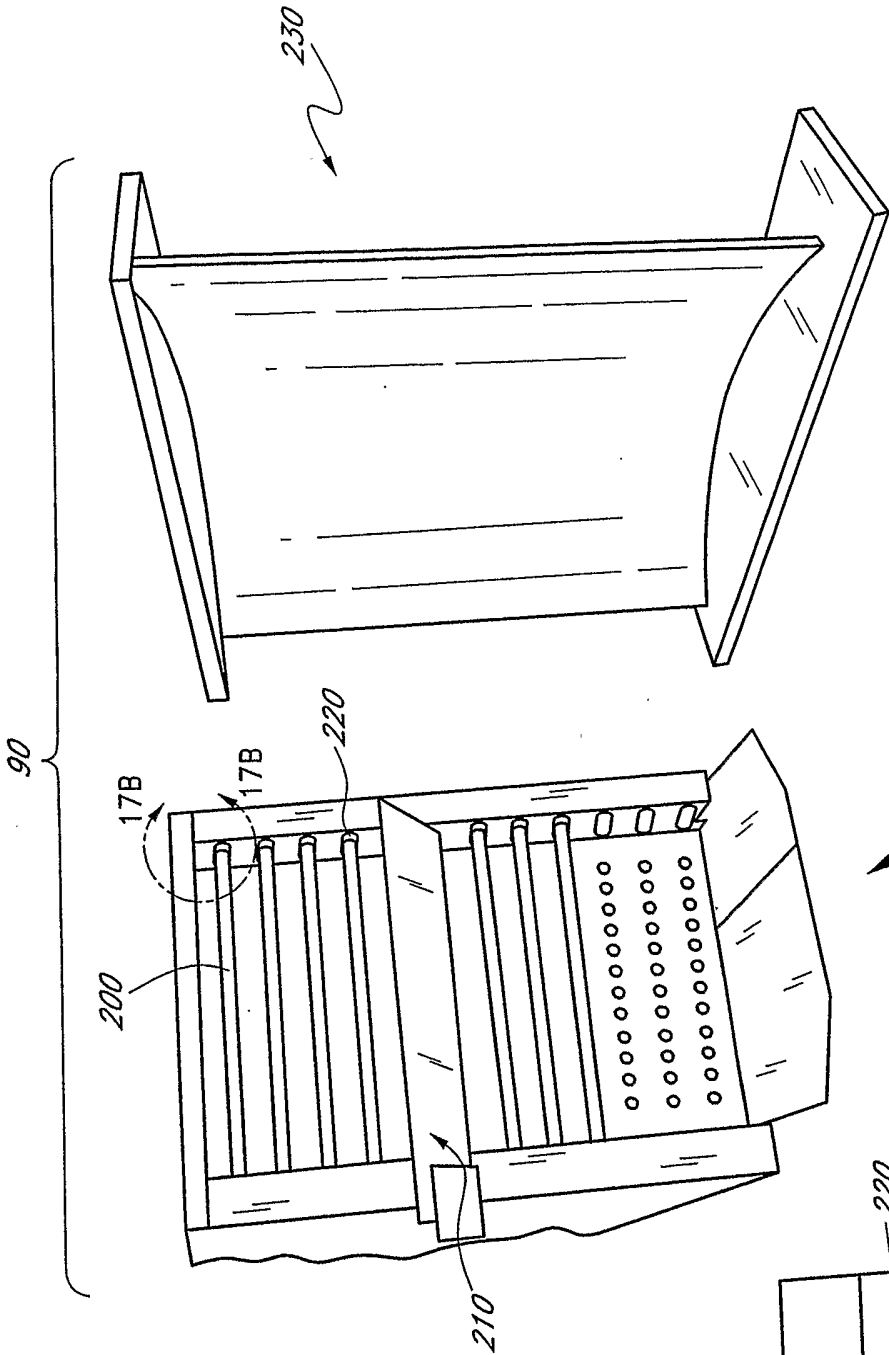


FIG. 17A

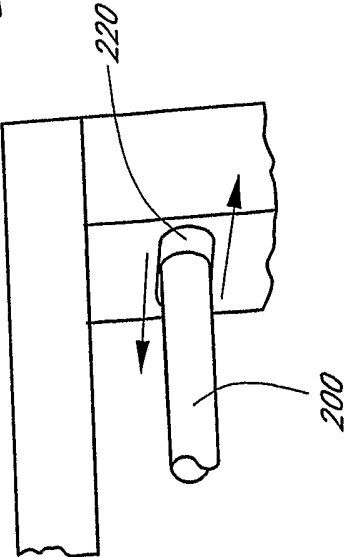


FIG. 17B

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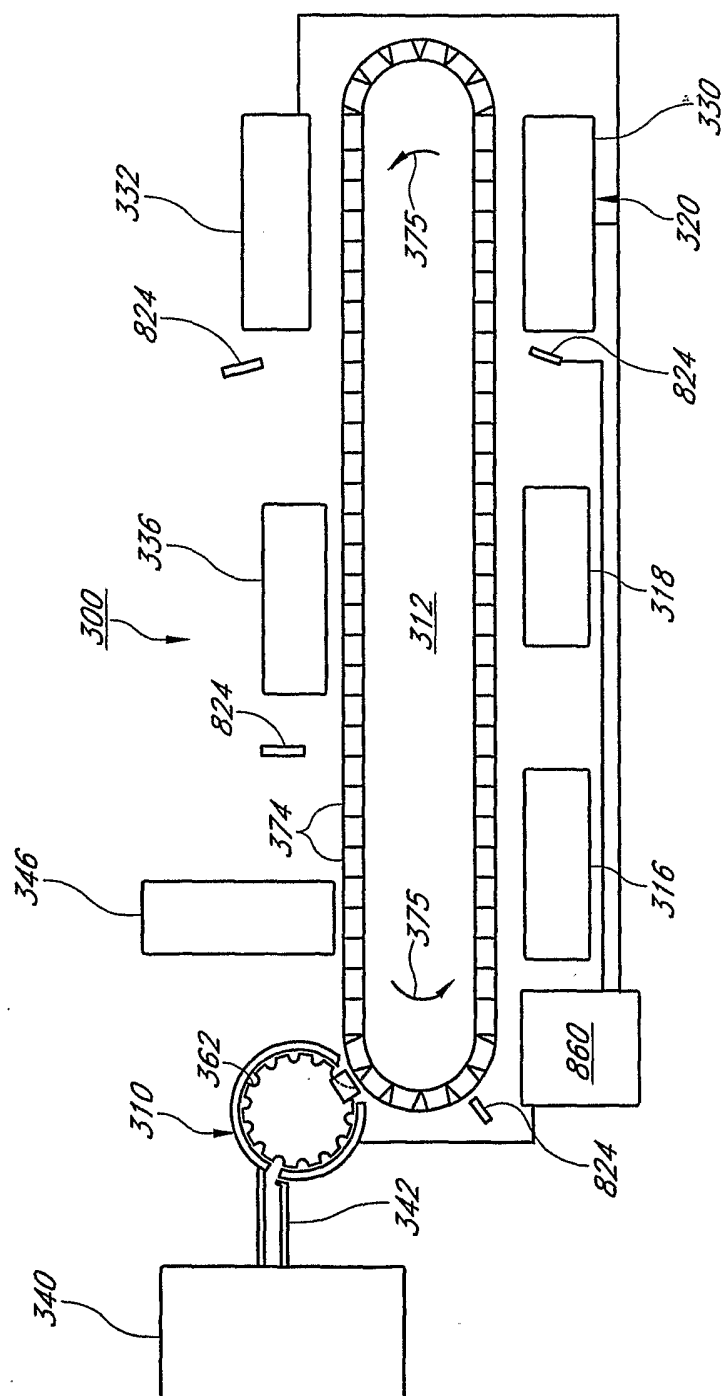


FIG. 18

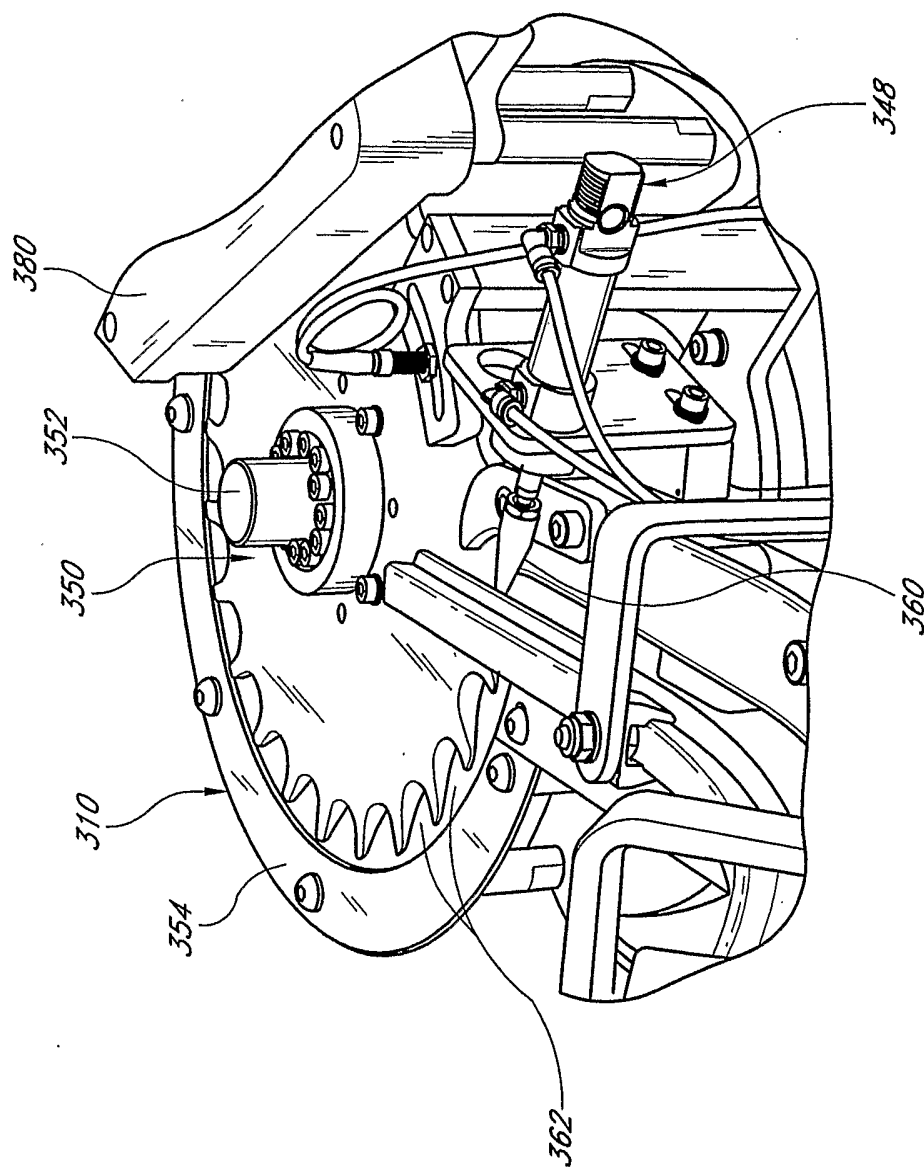


FIG. 19

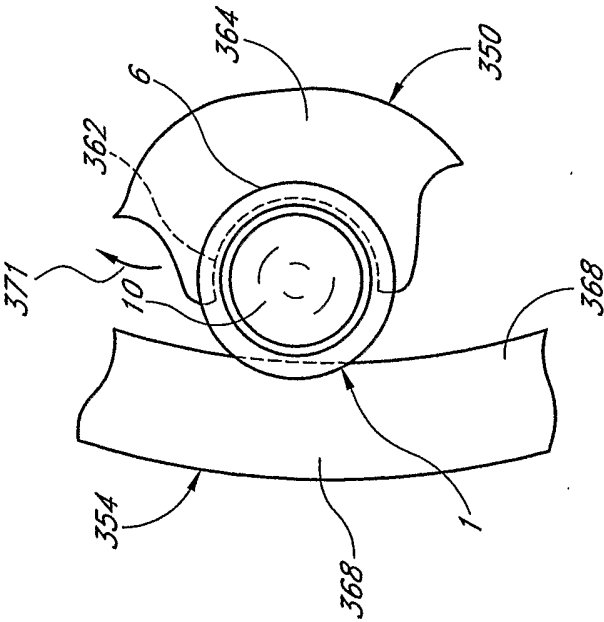


FIG. 20

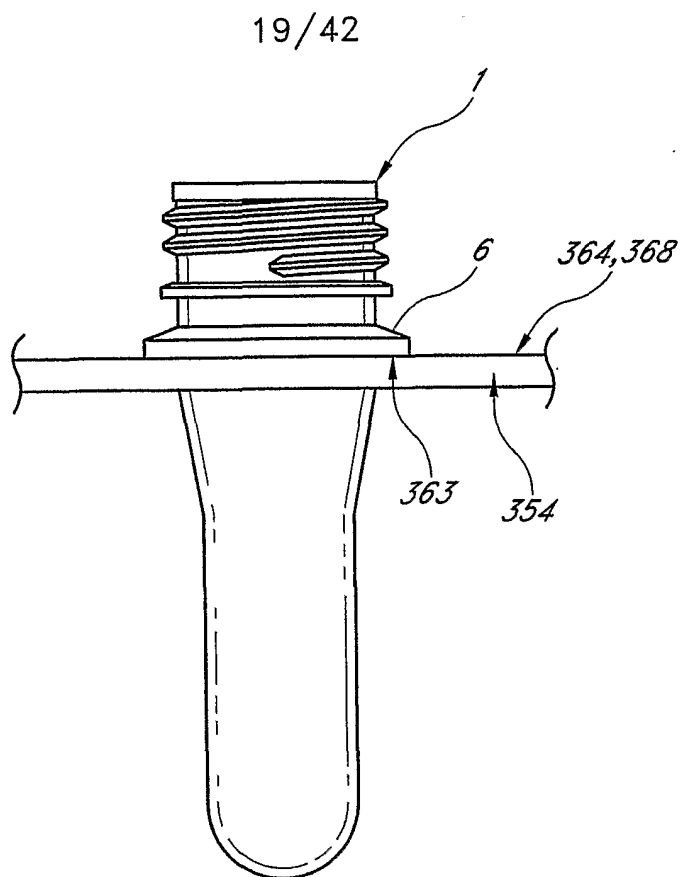


FIG. 21

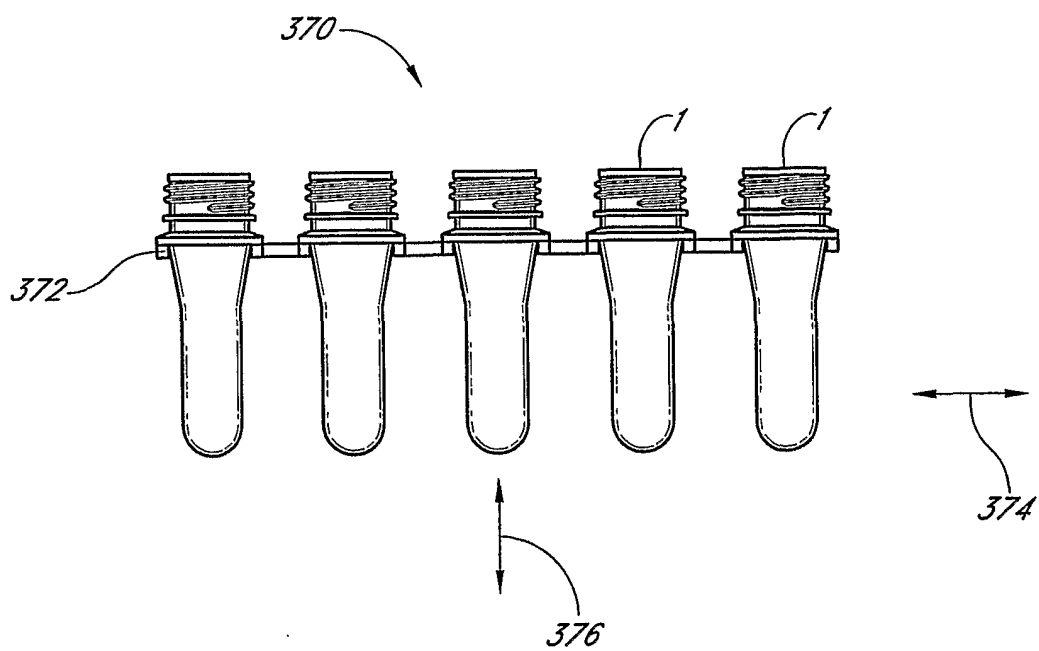


FIG. 22

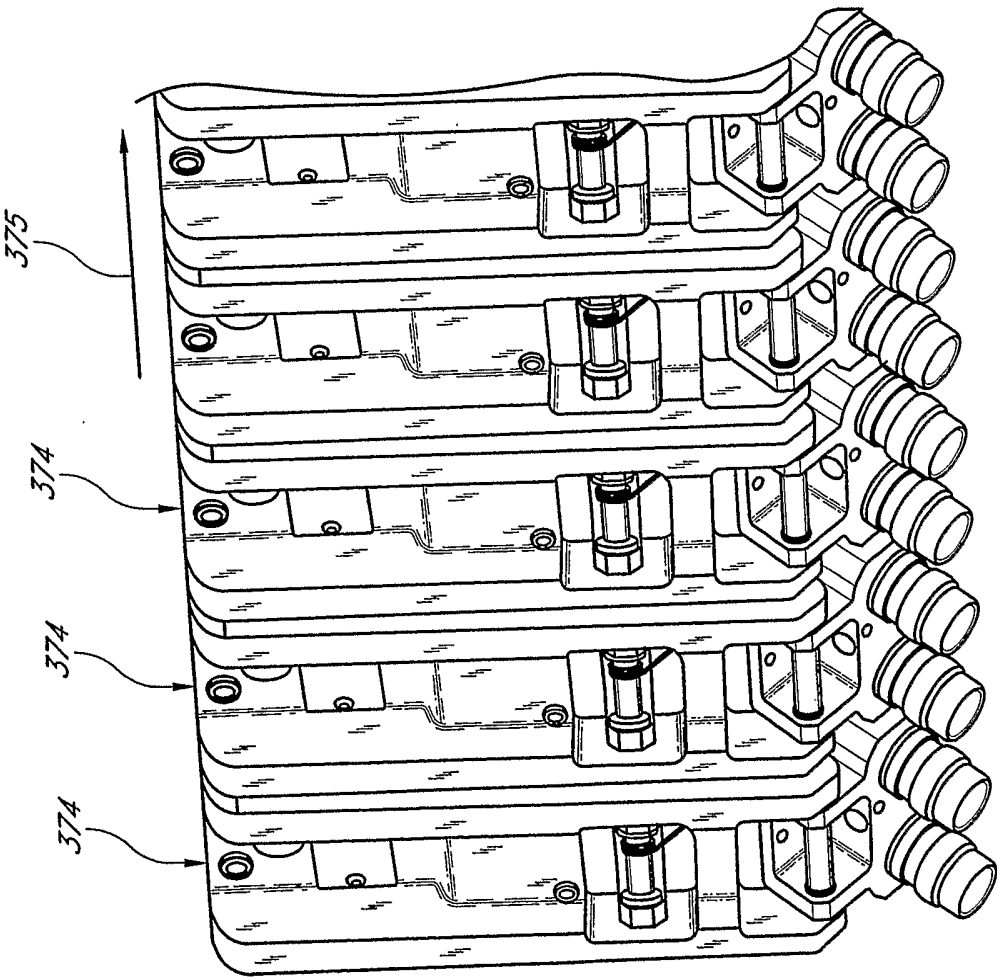


FIG. 23

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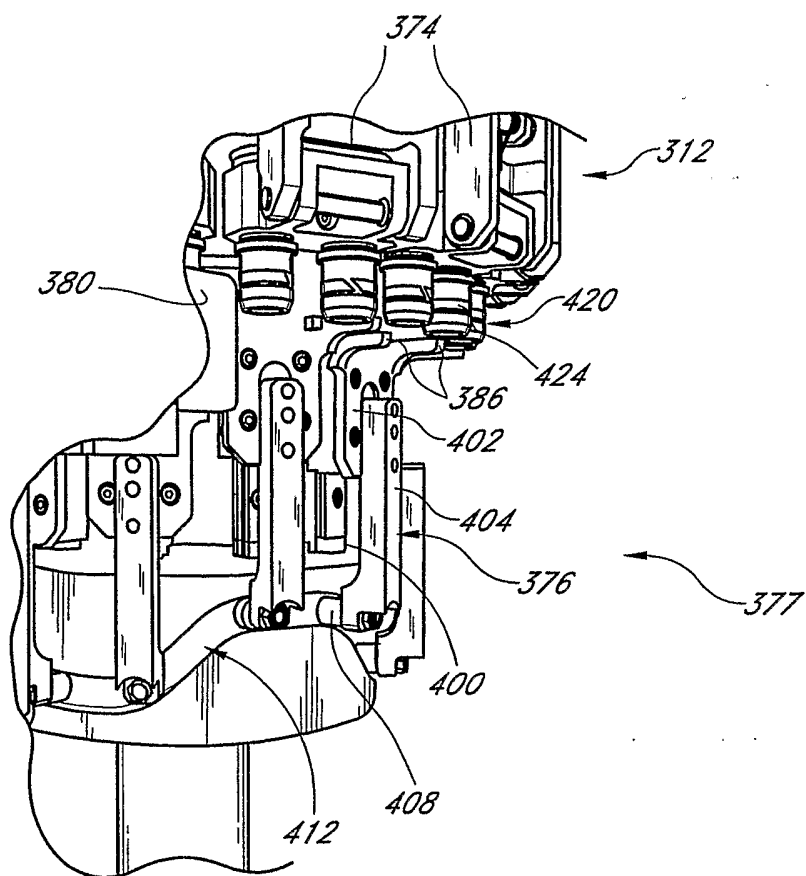


FIG. 24A

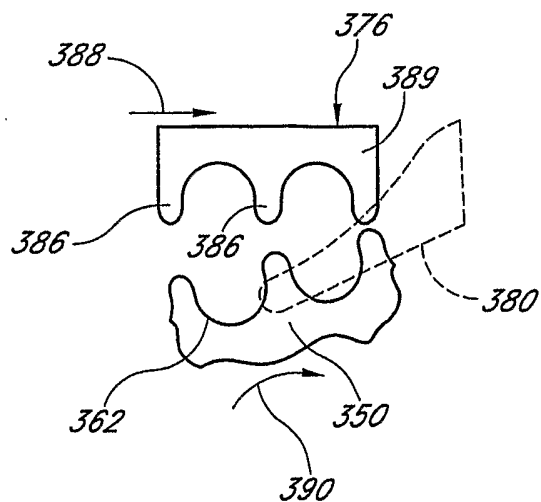


FIG. 24B

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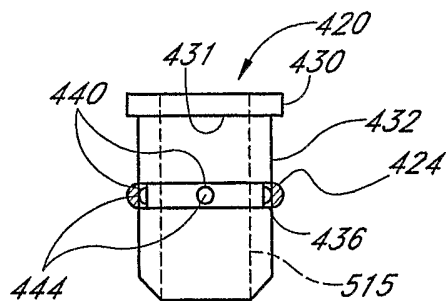


FIG. 25

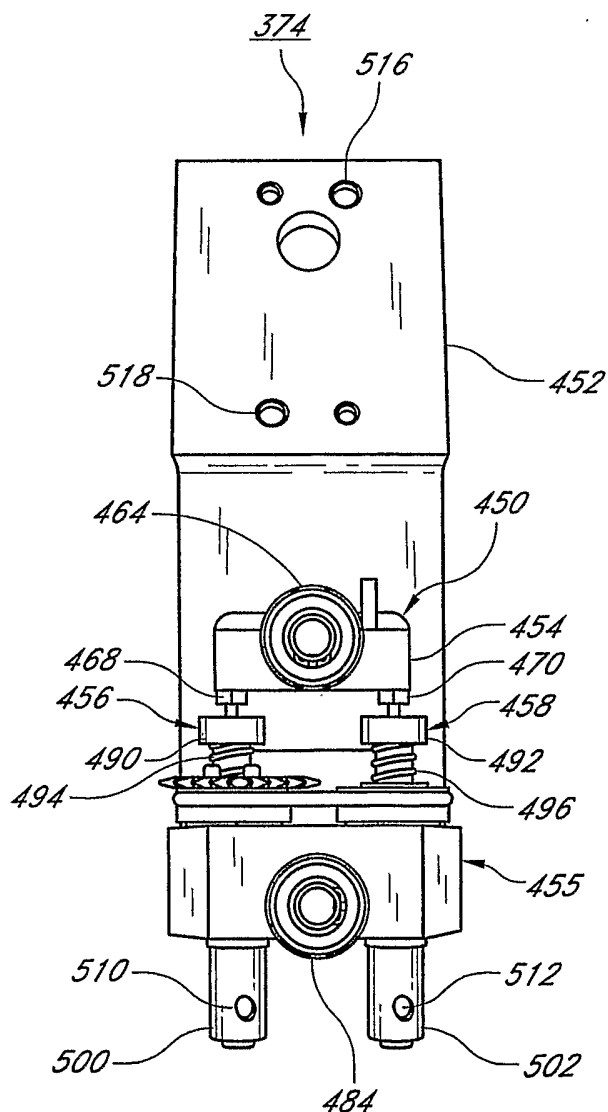


FIG. 26A

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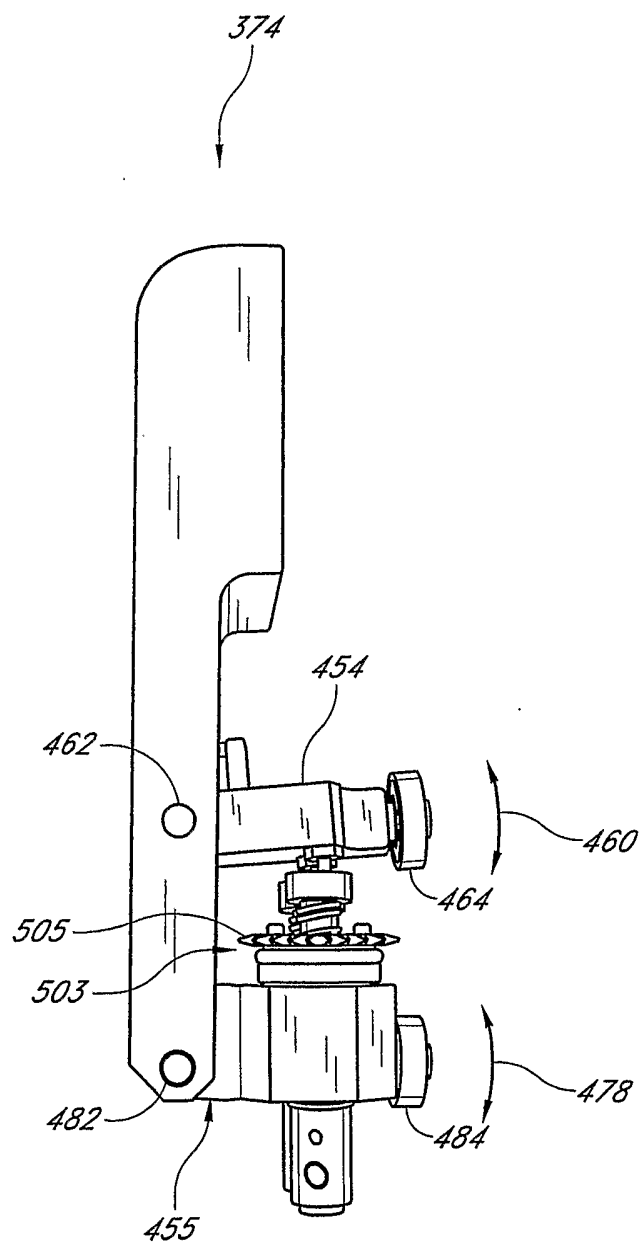
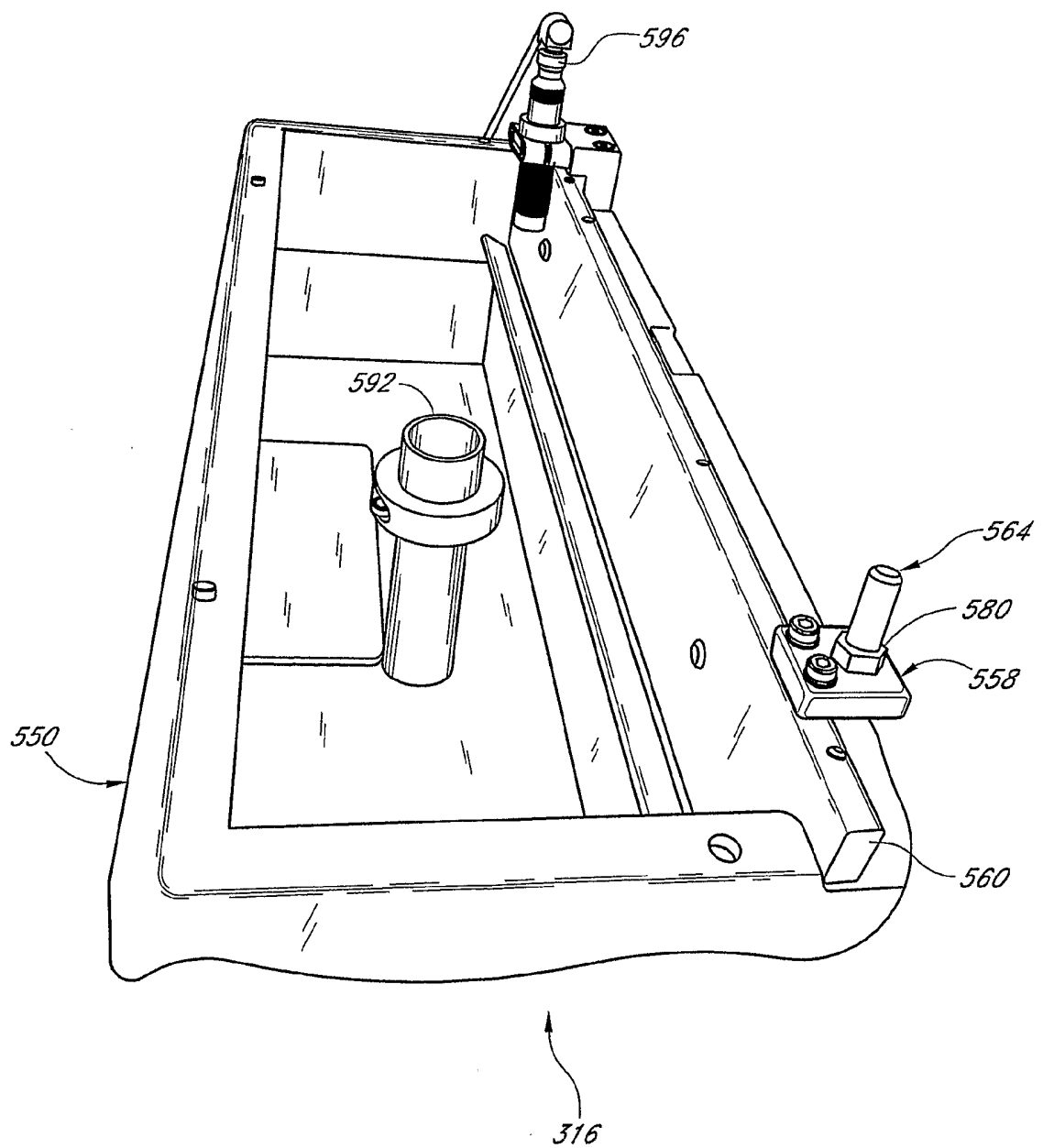
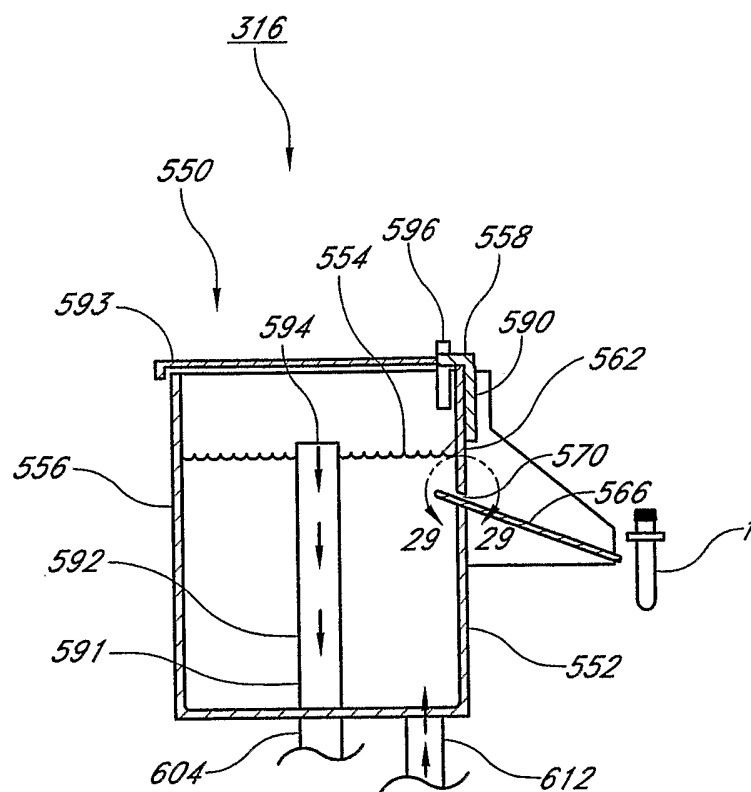
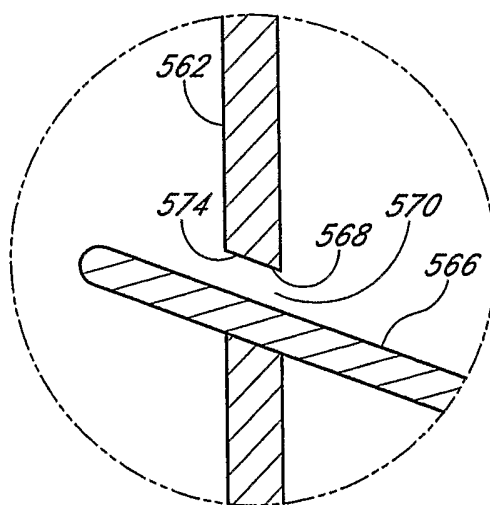


FIG. 26B

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**FIG. 27**

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**FIG. 28****FIG. 29**

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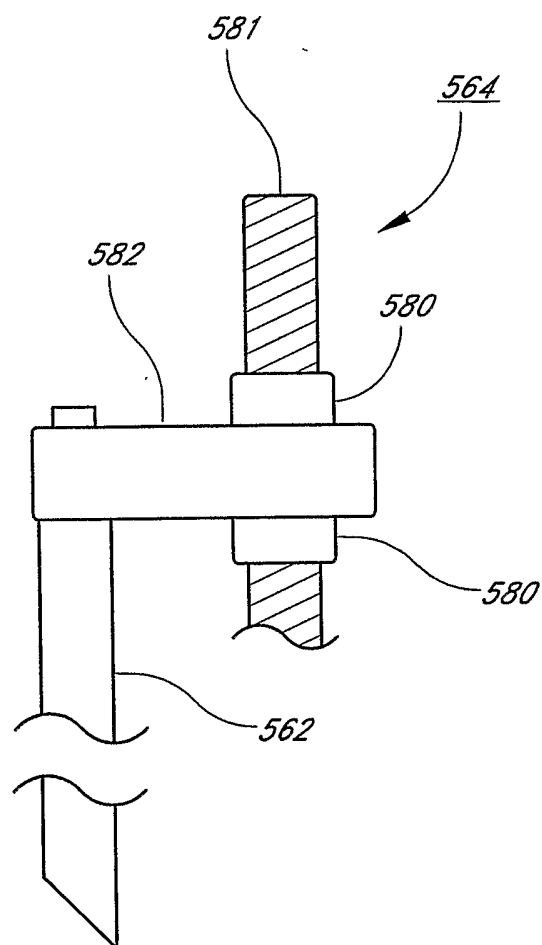
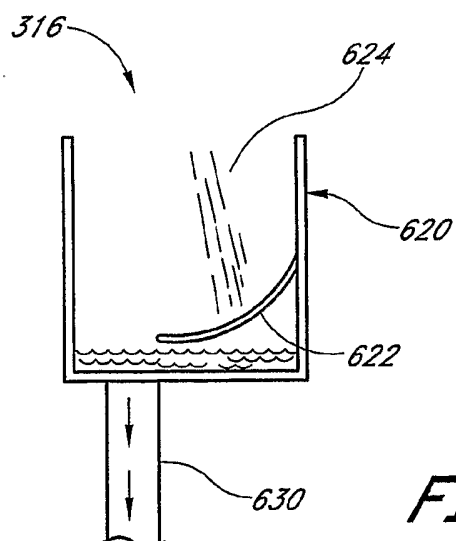
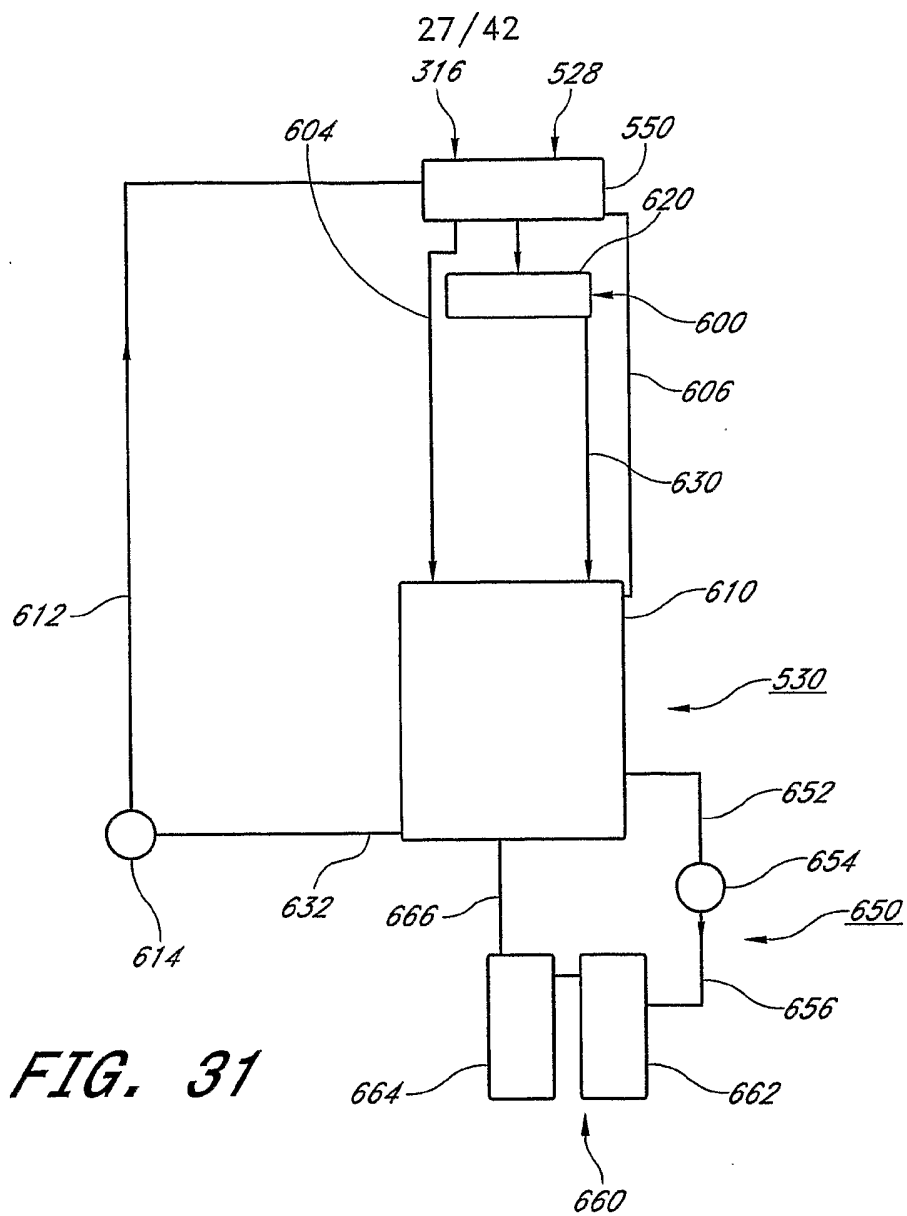
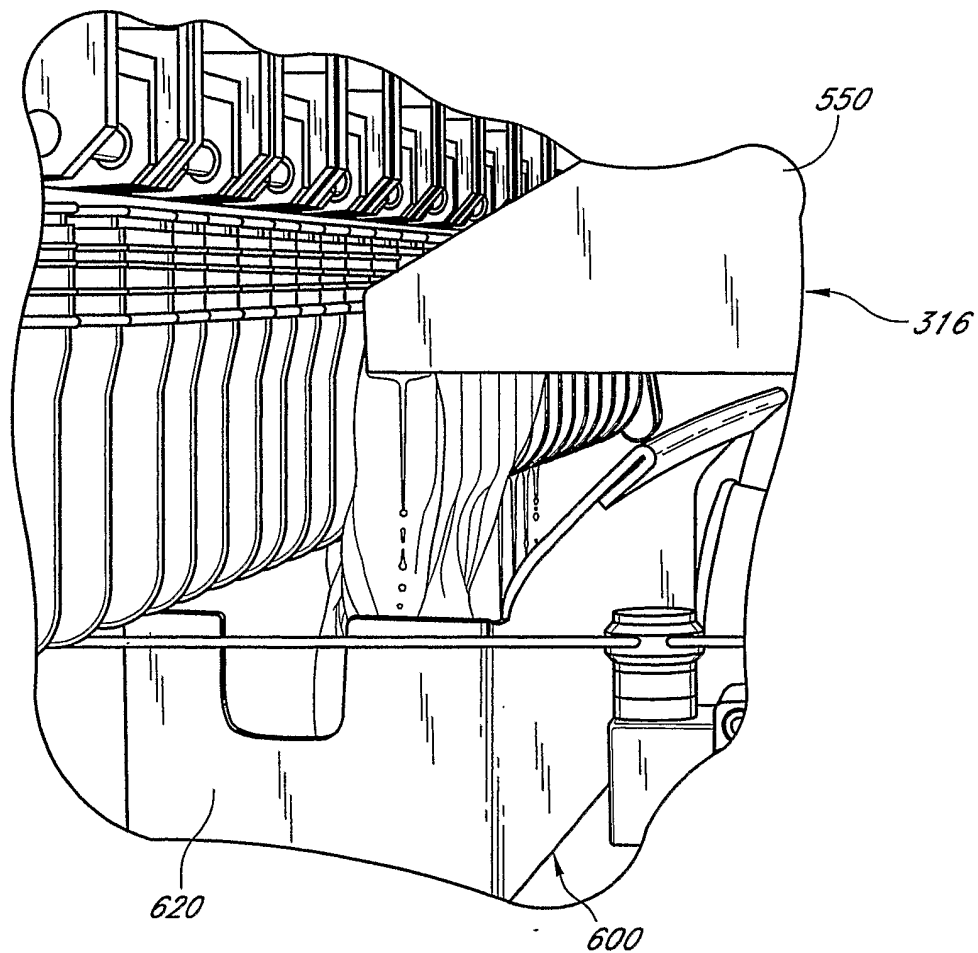
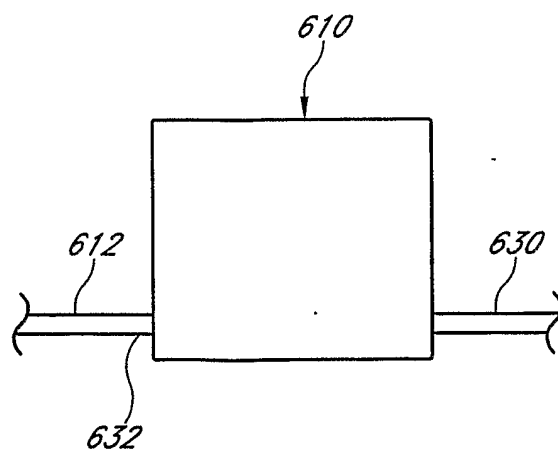


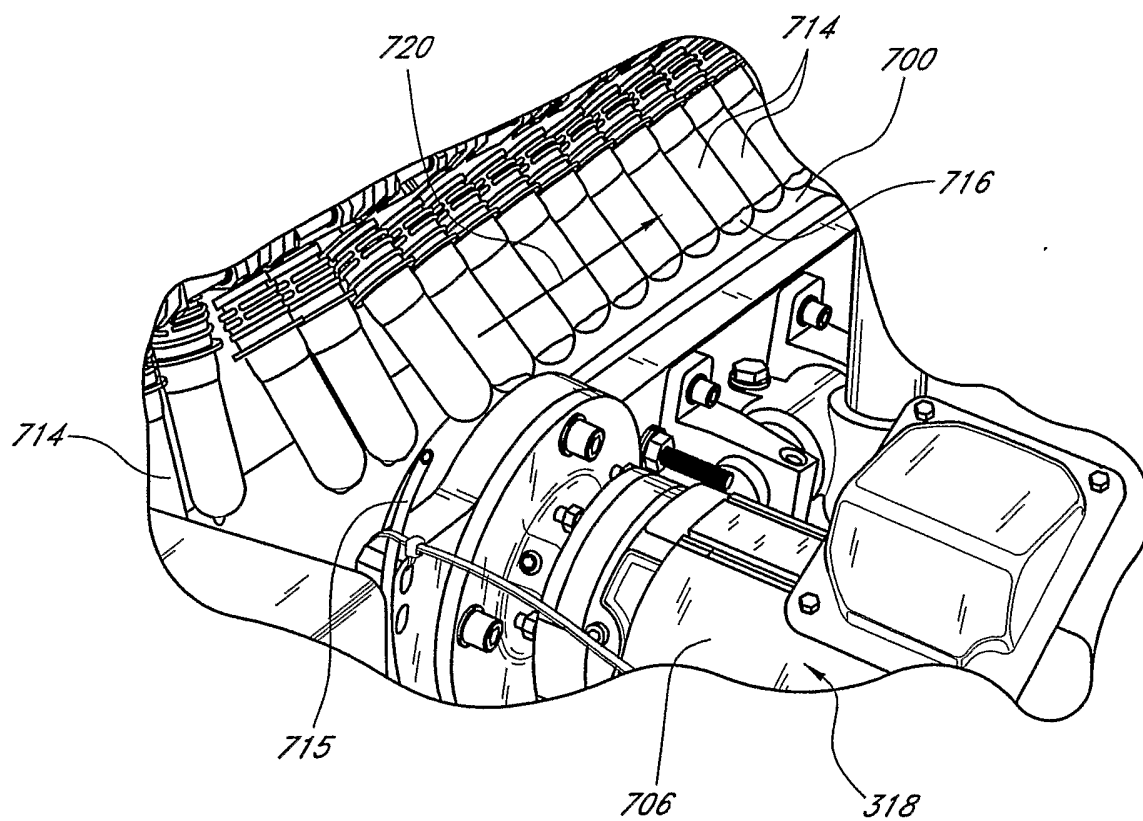
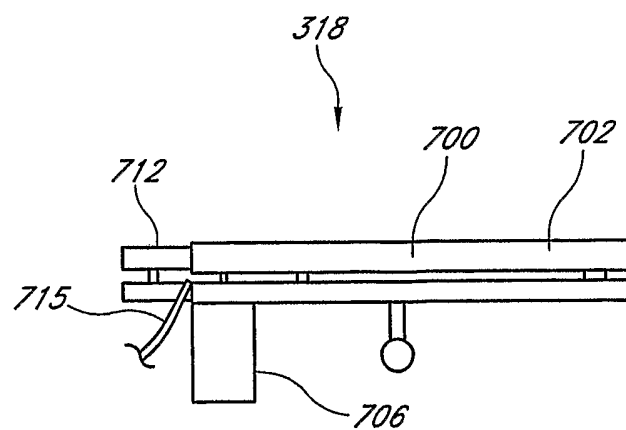
FIG. 30



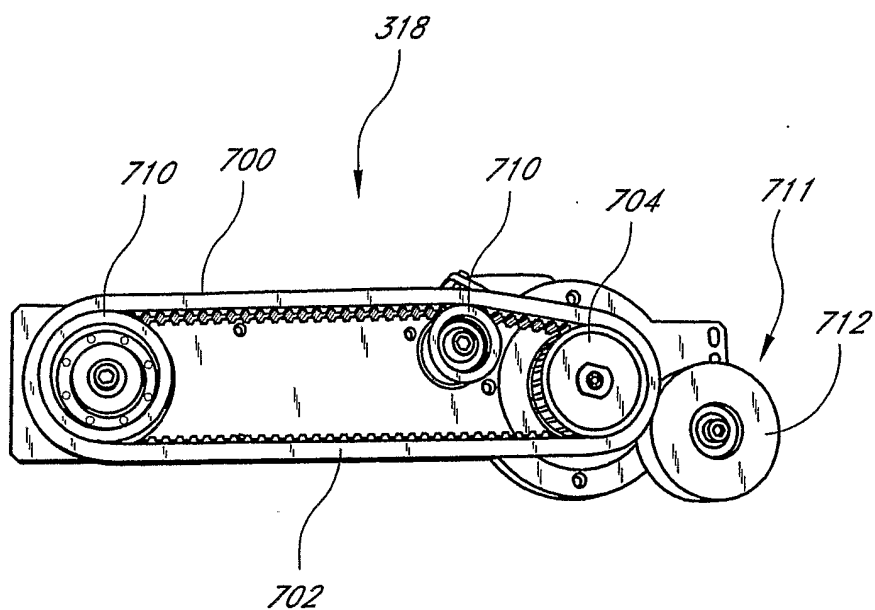
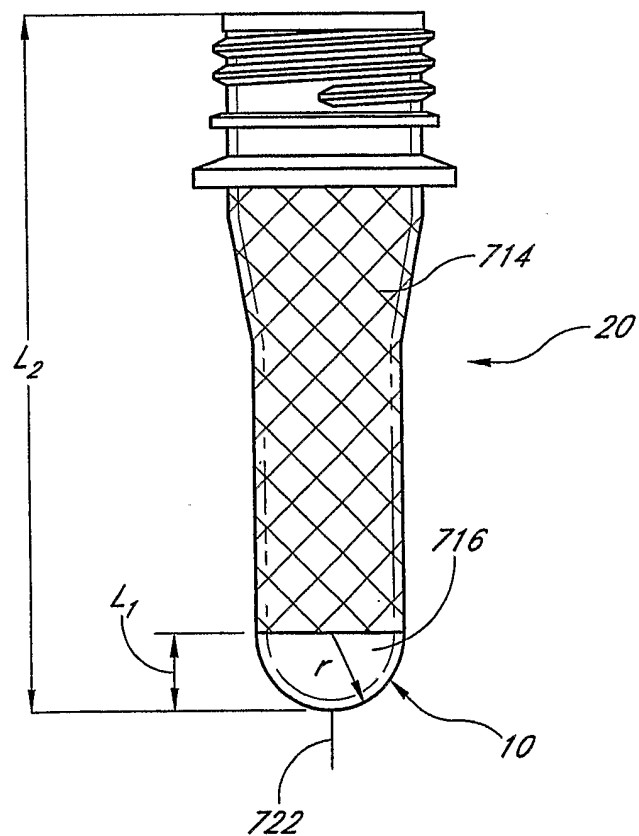
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**FIG. 33****FIG. 34**

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**FIG. 35****FIG. 36**

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**FIG. 37****FIG. 38**

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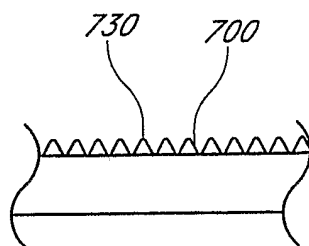


FIG. 39A

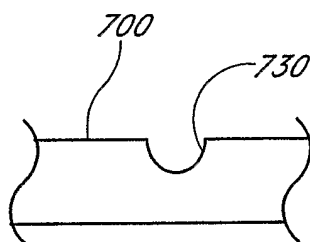


FIG. 39B

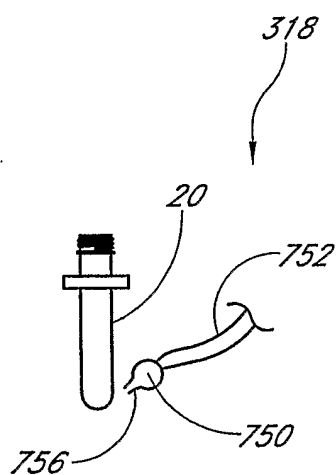


FIG. 39C

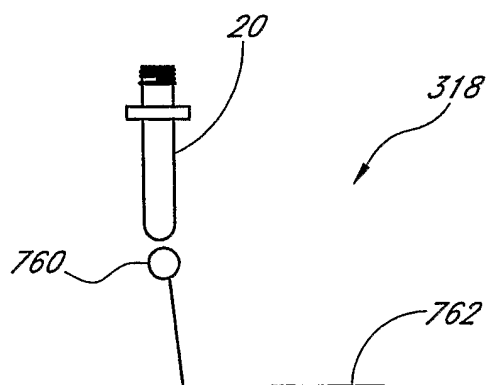


FIG. 39D

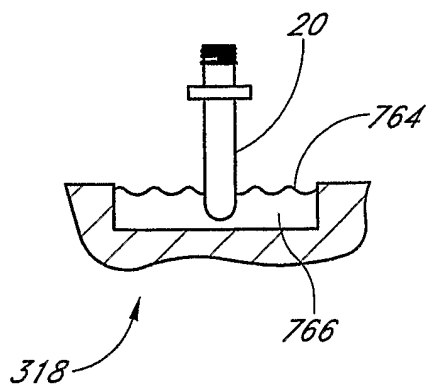
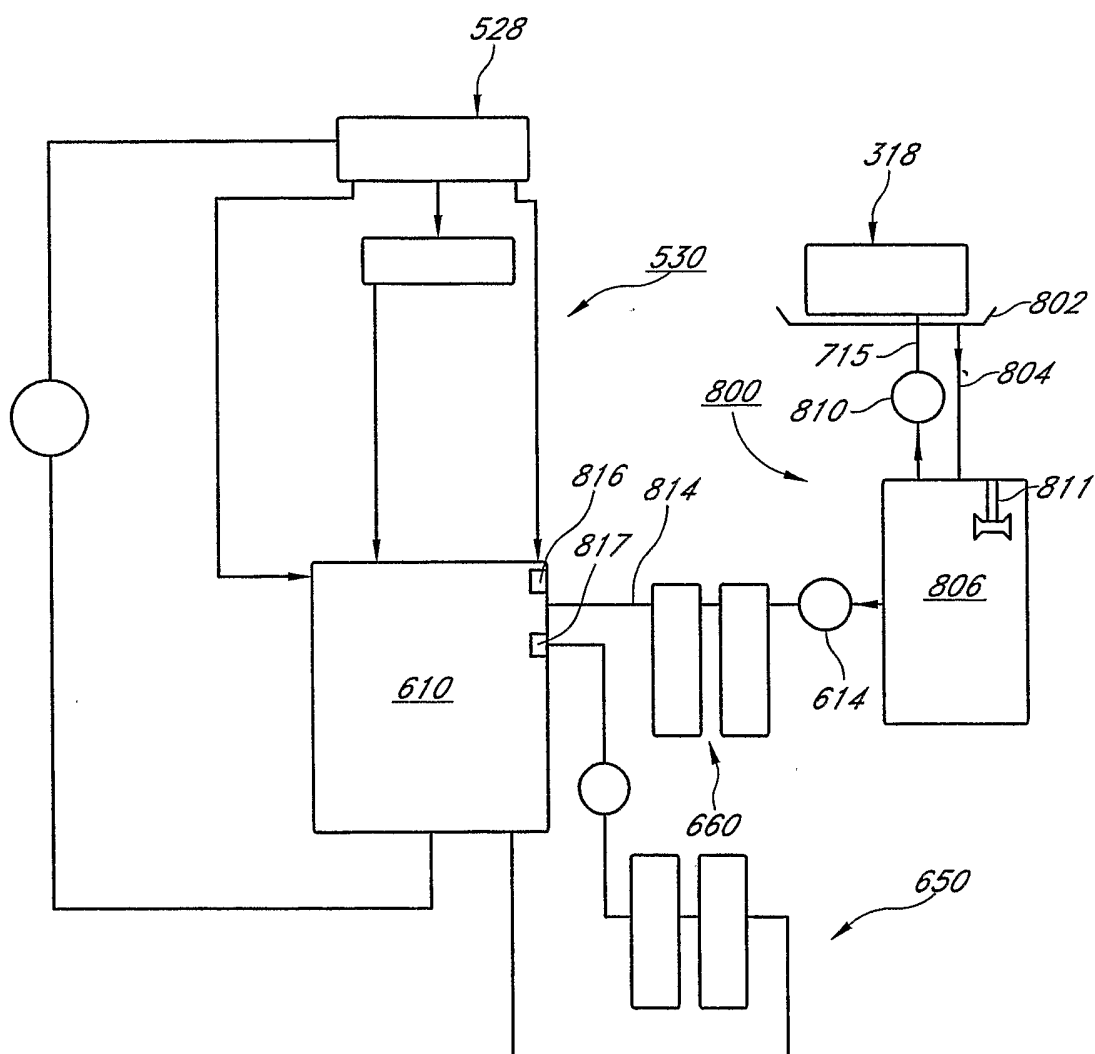
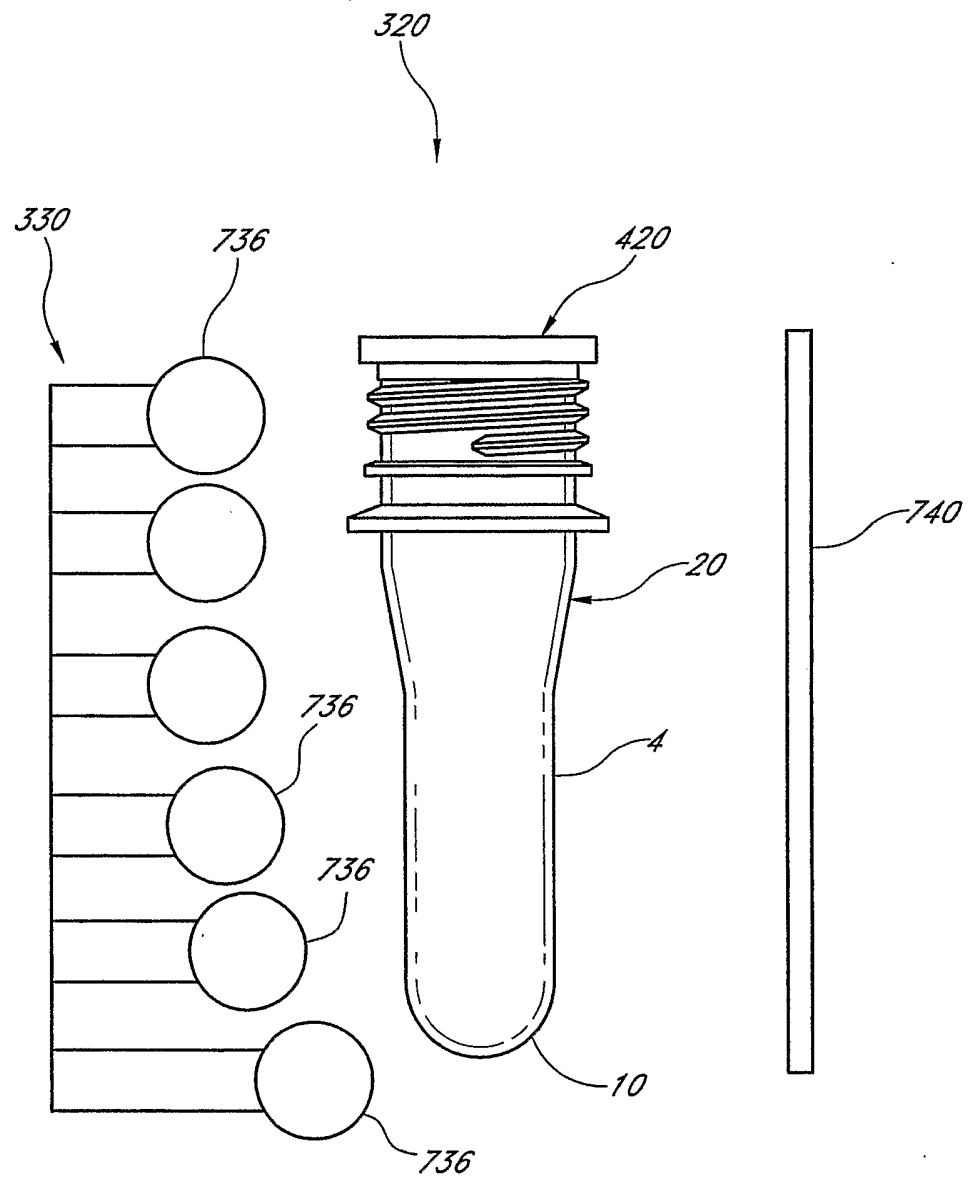


FIG. 39E

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*FIG. 40*

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**FIG. 41**

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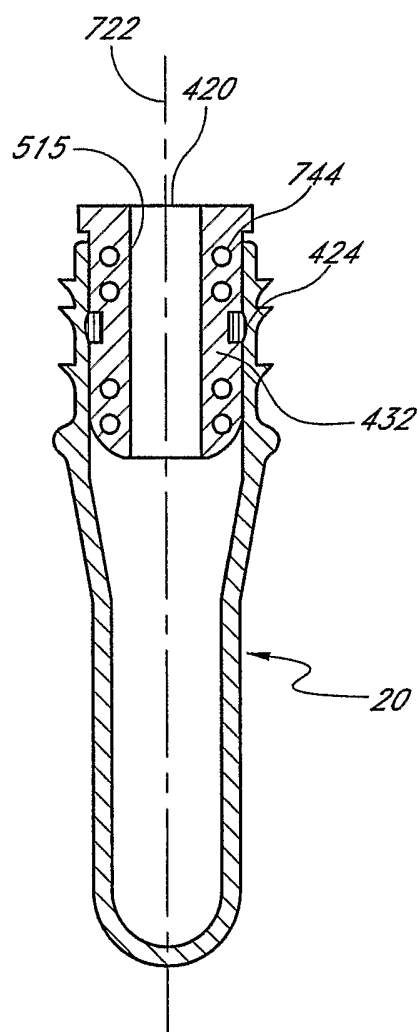
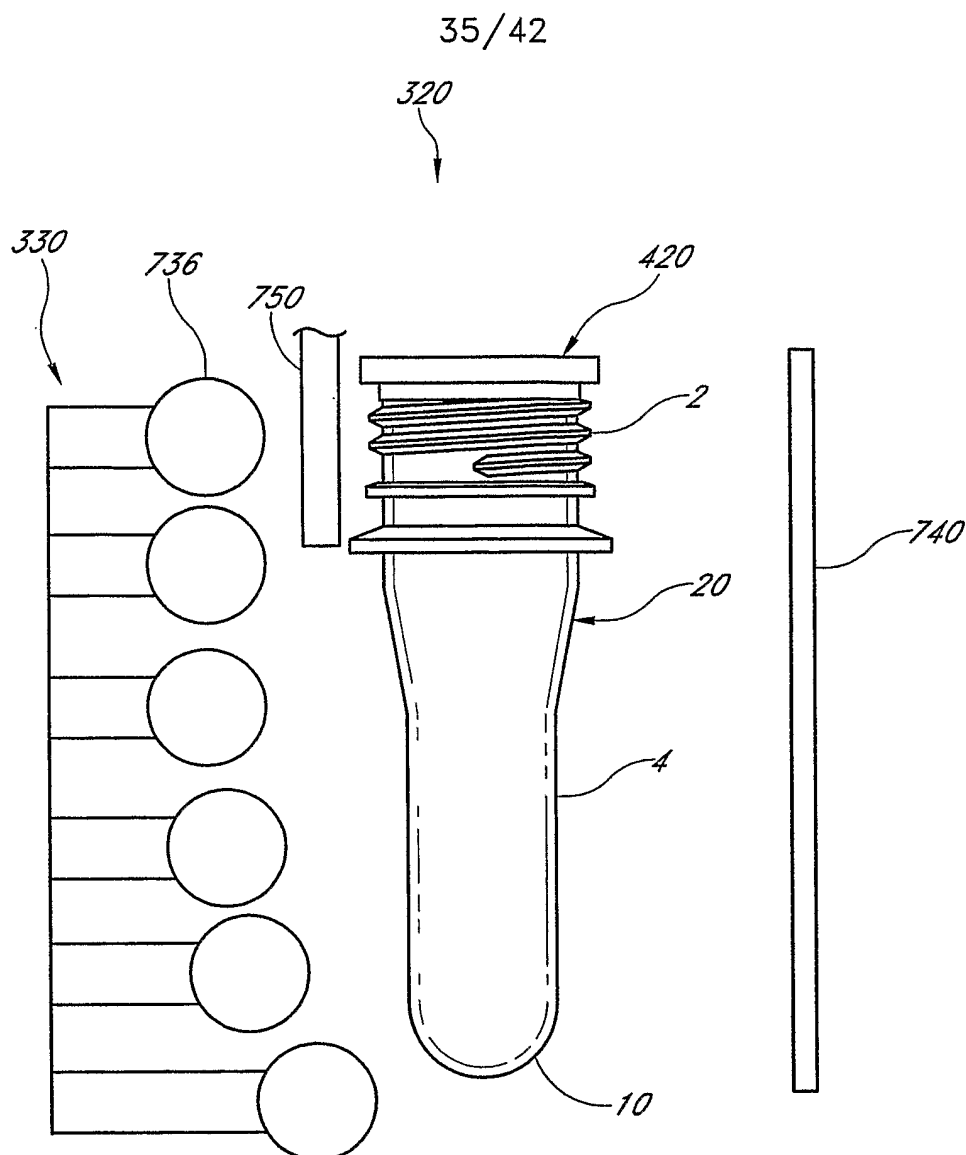
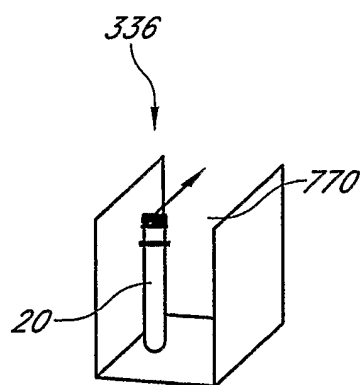


FIG. 42

**FIG. 43****FIG. 44**

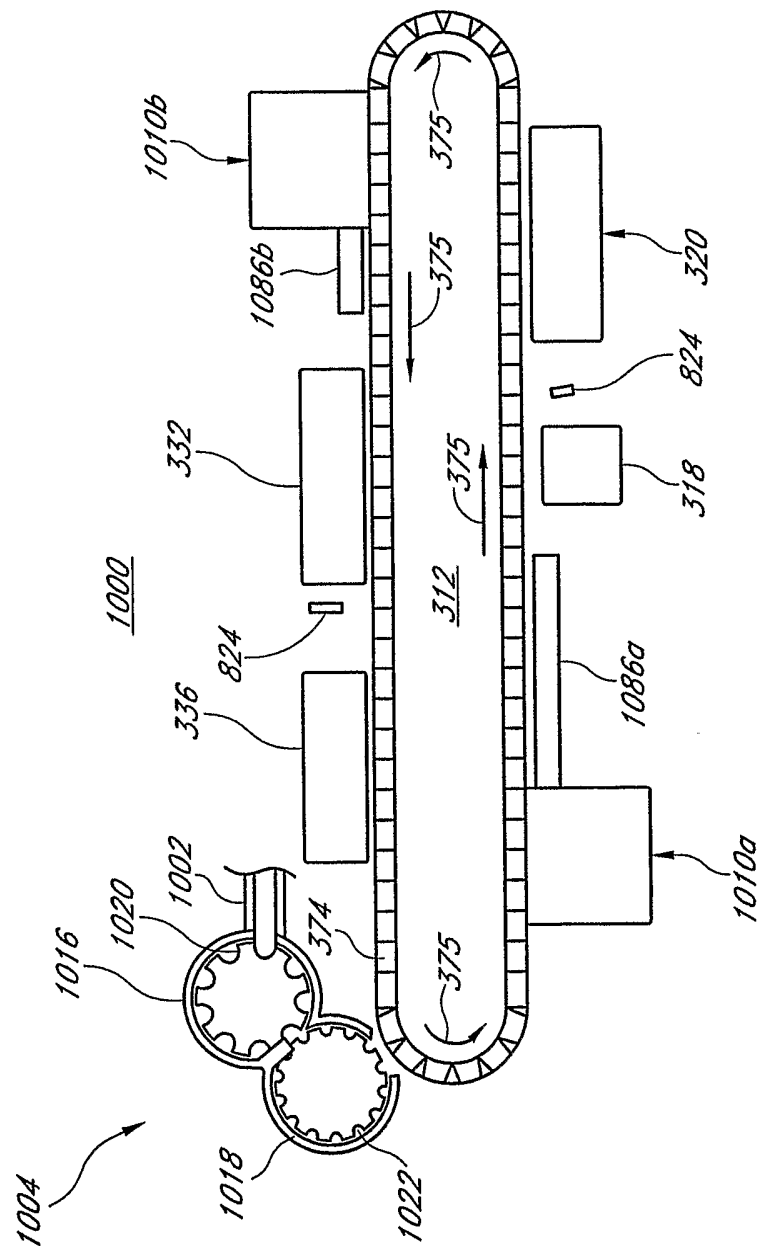


FIG. 45

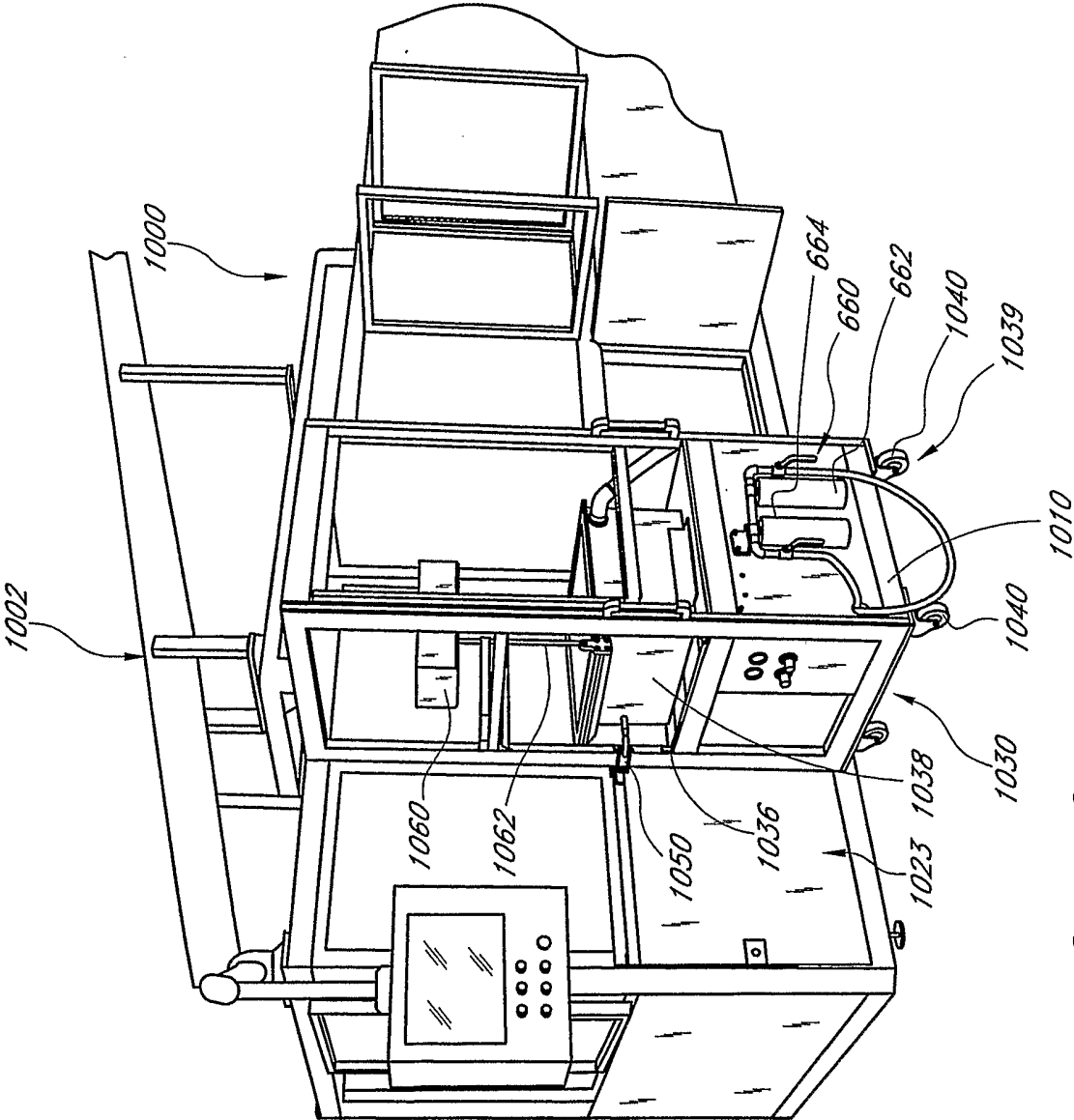


FIG. 46

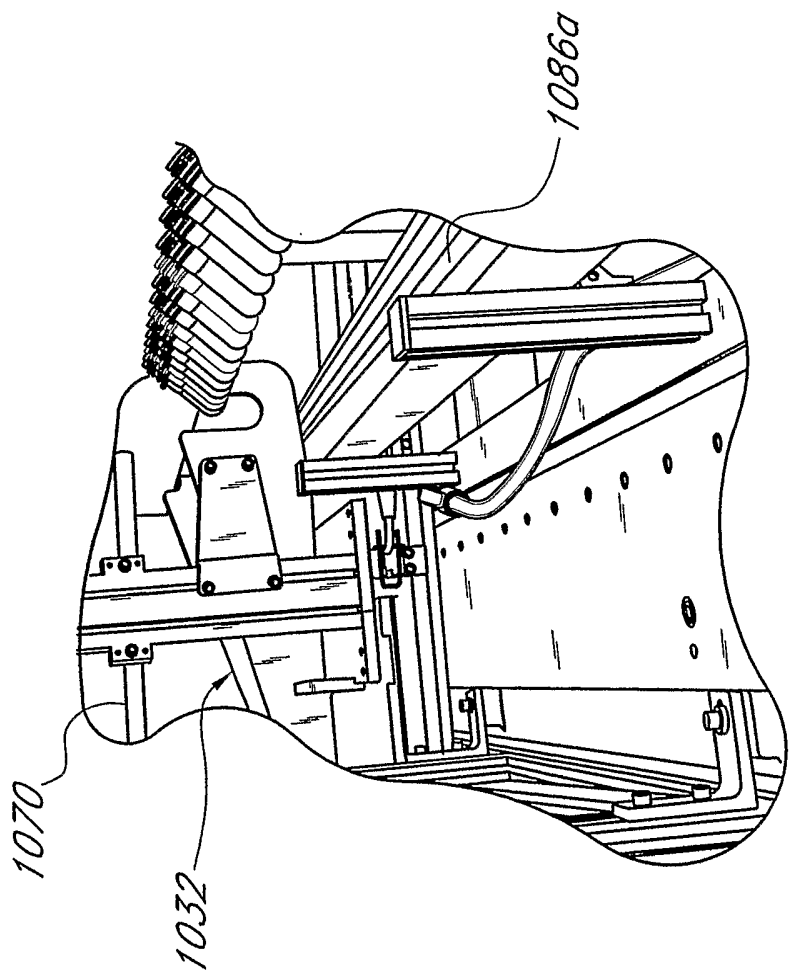


FIG. 47

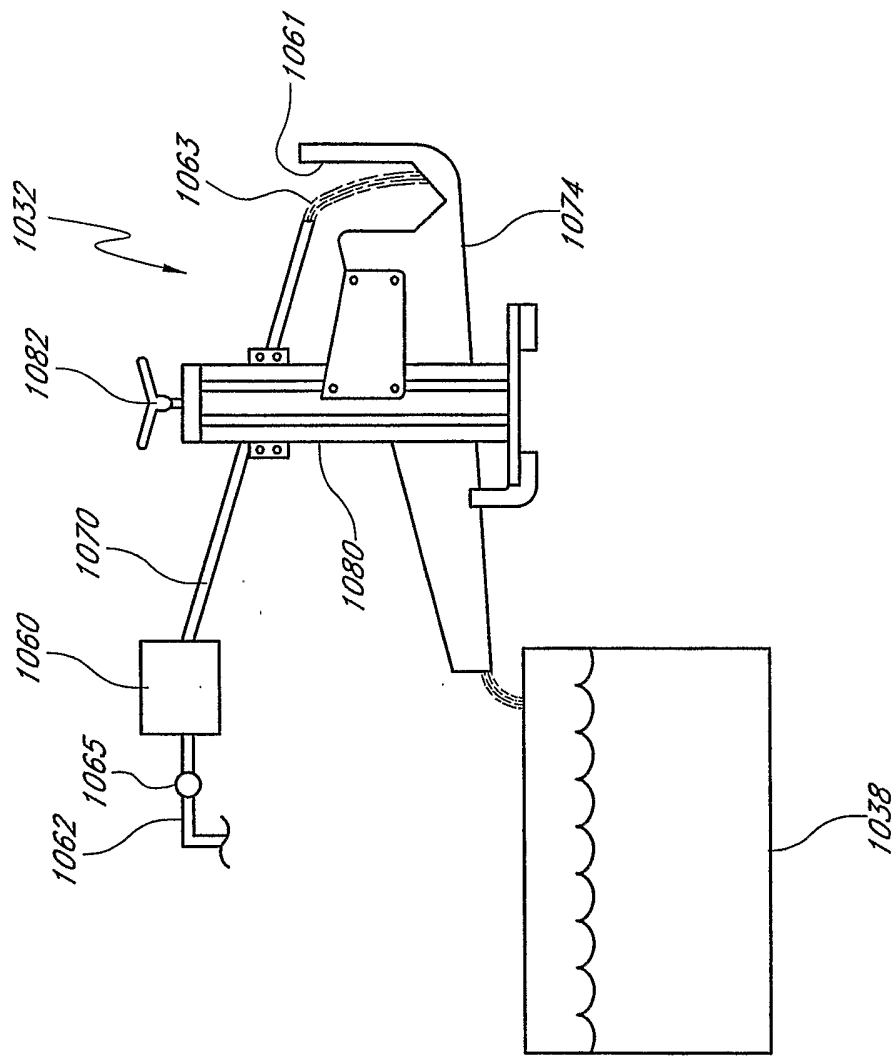
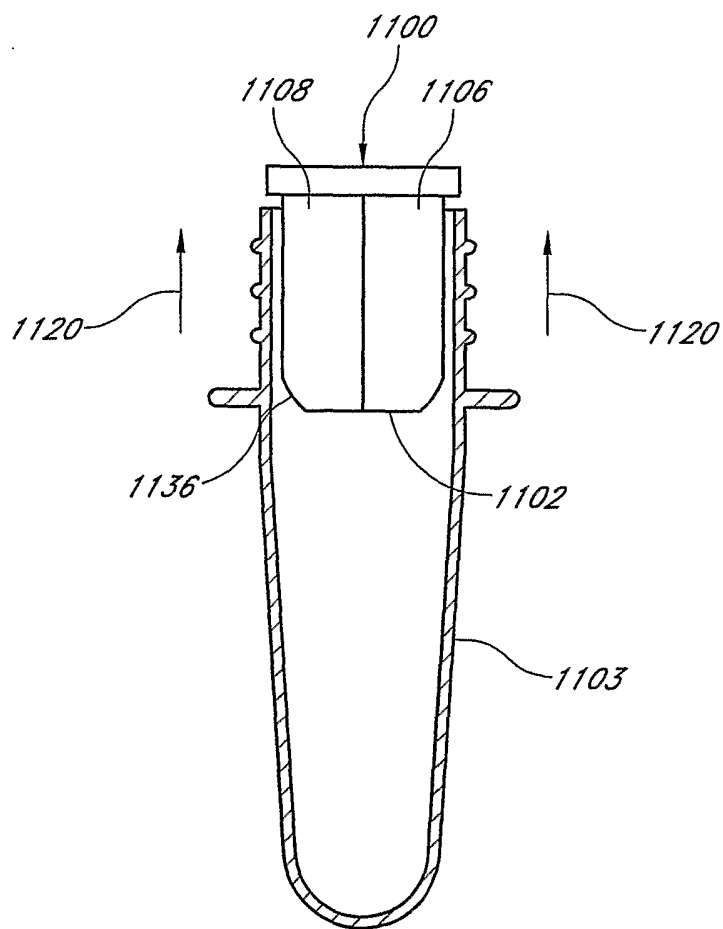
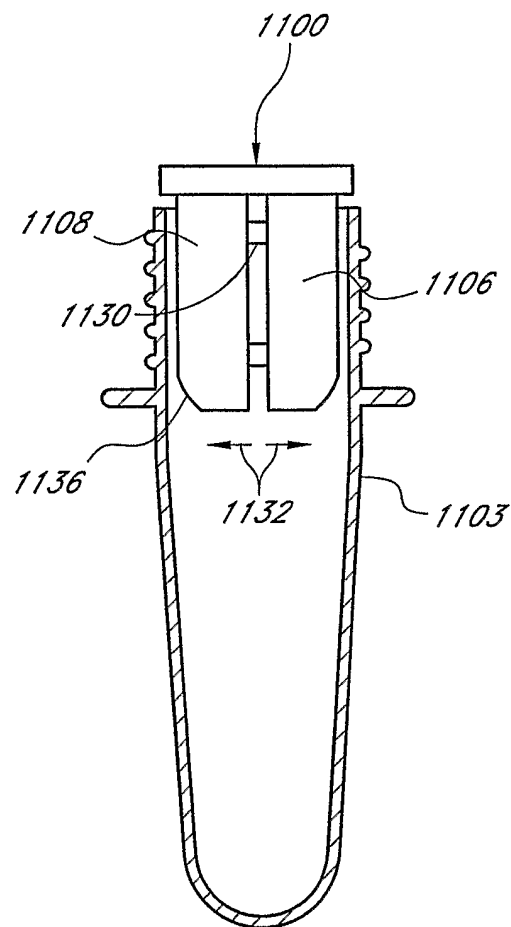


FIG. 48

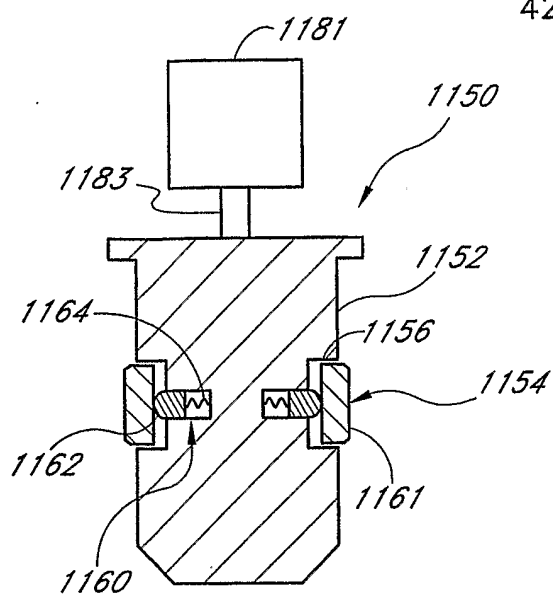
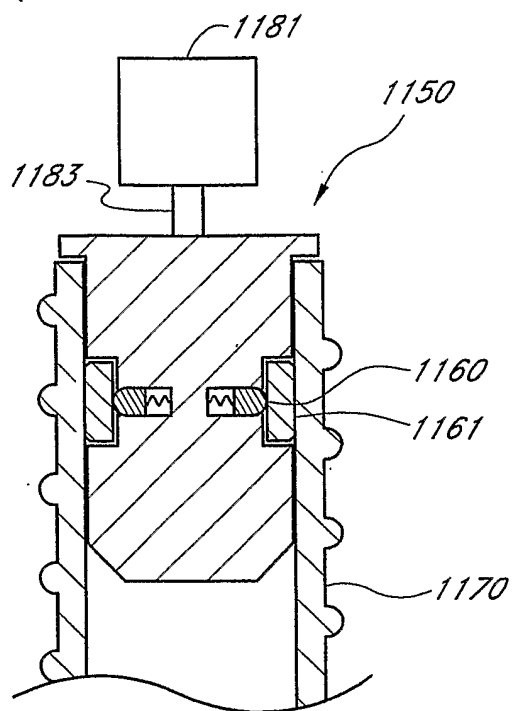
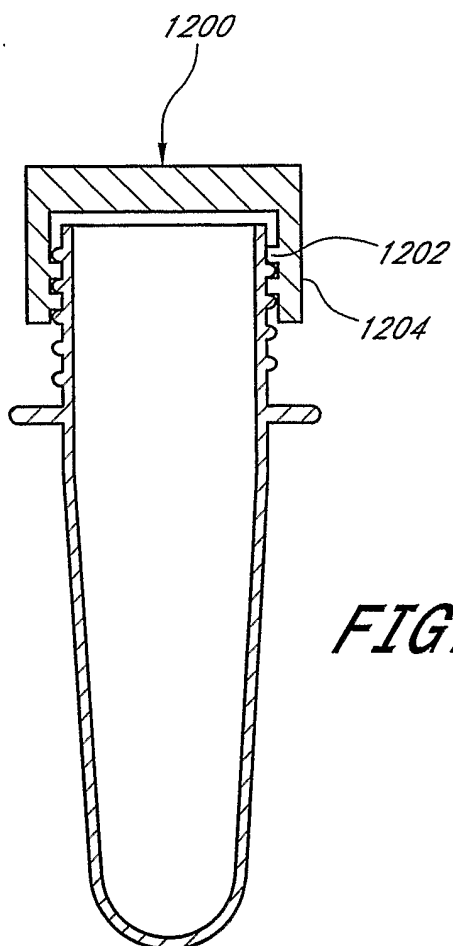
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**FIG. 49**

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*FIG. 50*

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**FIG. 51****FIG. 52****FIG. 53**