United States Patent

[11] 3,620,813

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[54] **METHOD OF TREATING WORKPIECES IN A TREATING FLUID**
22 Claims, 19 Drawing Figs.

[52] **U.S. Cl.** ..... **117/94,** 117/95, 117/102 R, 118/7, 118/73, 118/423, 118/429, 118/602, 134/32, 134/34, 148/6.15, 148/6.2

[51] **Int. Cl.** **B05b 3/04,** B05b 3/02

[50] **Field of Search** 21/56, 57, 58, 93; 134/32, 34; 117/94, 95, 101, 102; 34/10, 11, 12, 20, 21, 22, 26, 203; 148/6.15, 6.16, 6.2; 99/214–216; 243/1, 38

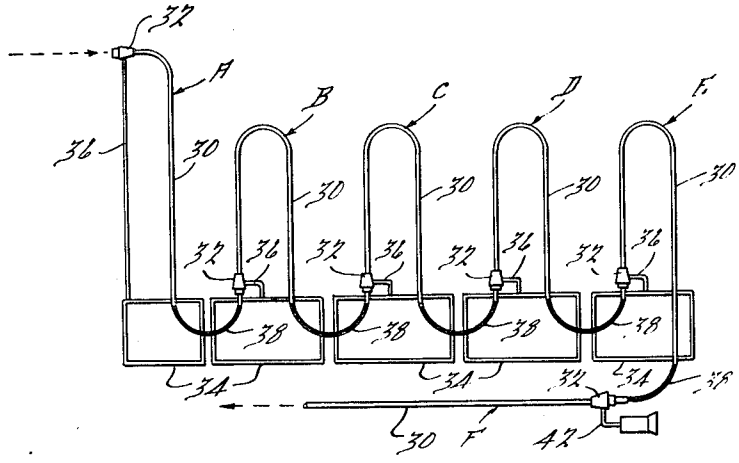
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ABSTRACT: An apparatus and method for simultaneously treating and conveying containerlike workpieces in which the workpieces are introduced and entrained in aligned orientation in a confined stream of a selected treating fluid and are subsequently extracted therefrom and whereafter, if desired, the workpieces are successively introduced into separate succeeding confined streams of alternative selected treating fluids to effect a multiple stage treatment thereof.



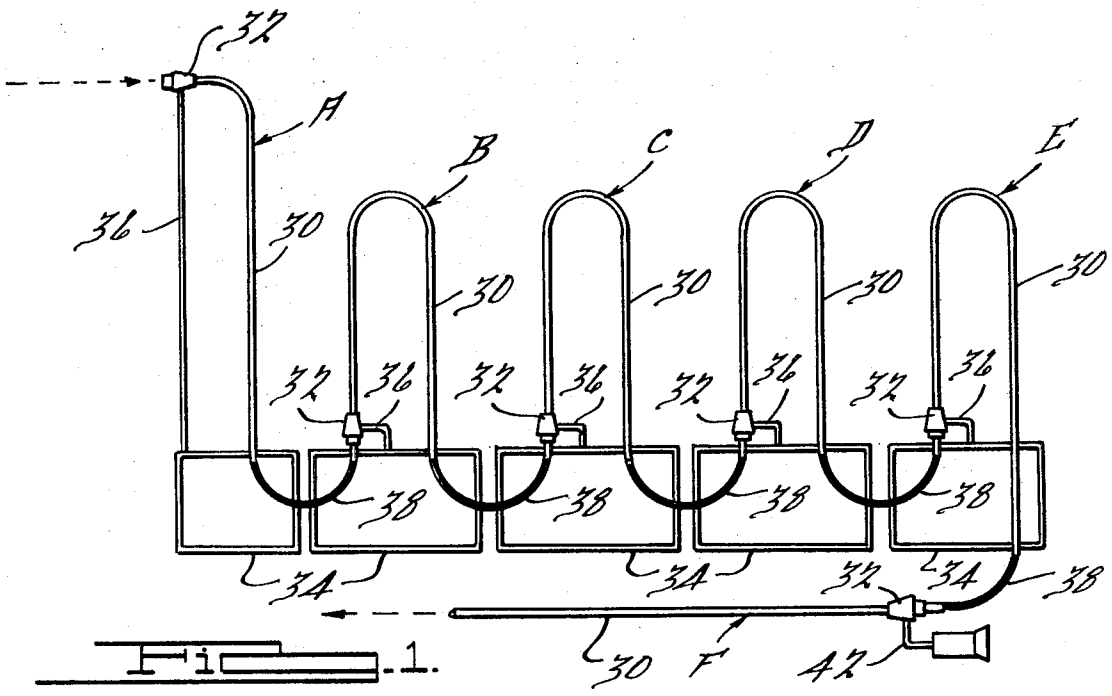
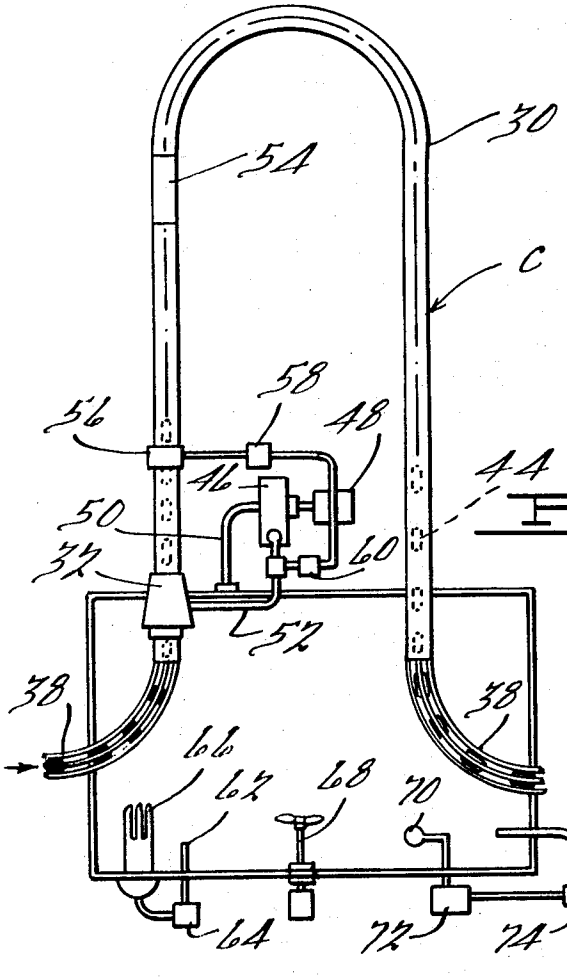


Fig. 1.



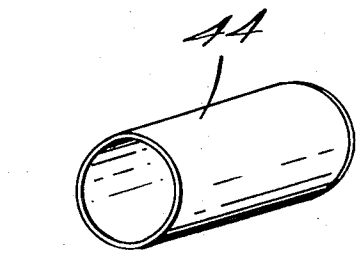


Fig. 2.

Fig. 3.

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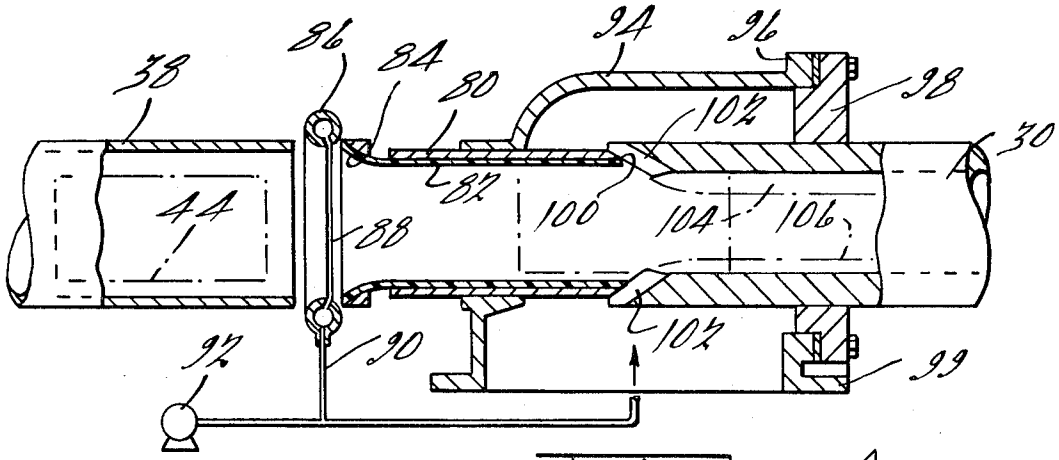


FIG. 4.

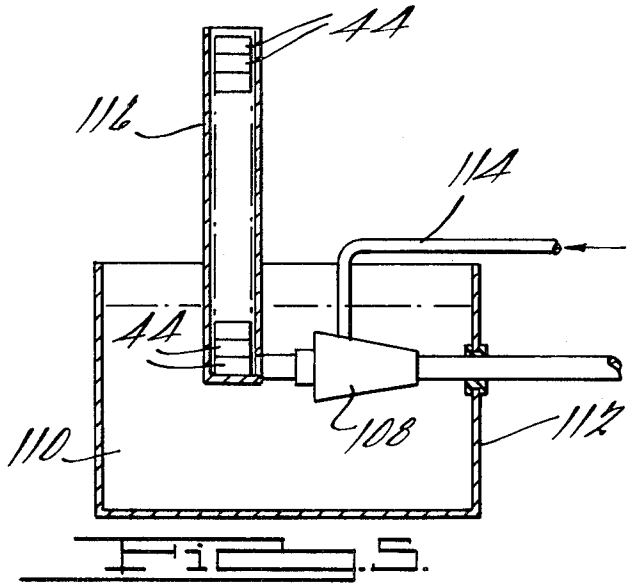


FIG. 5.

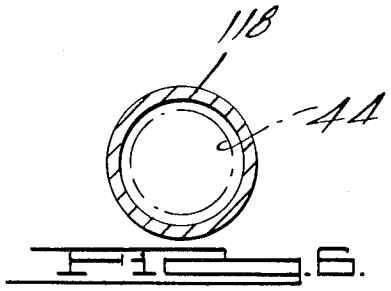


FIG. 6.

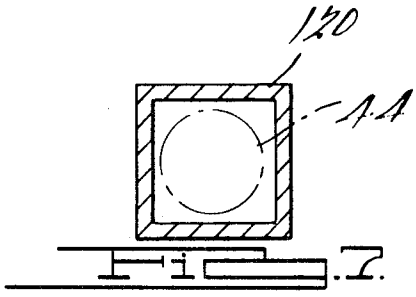


FIG. 7.

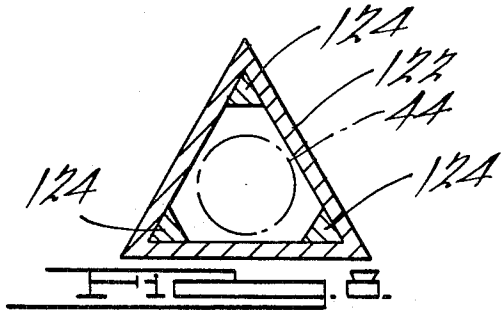


FIG. 8.

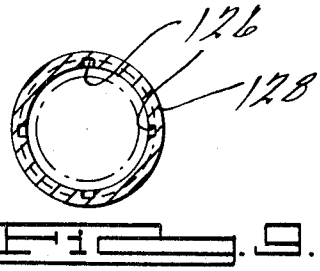


FIG. 9.

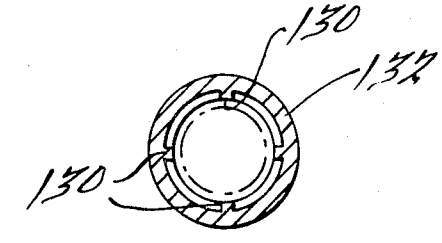


FIG. 10.

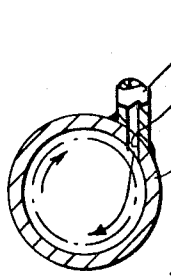


FIG. 11.

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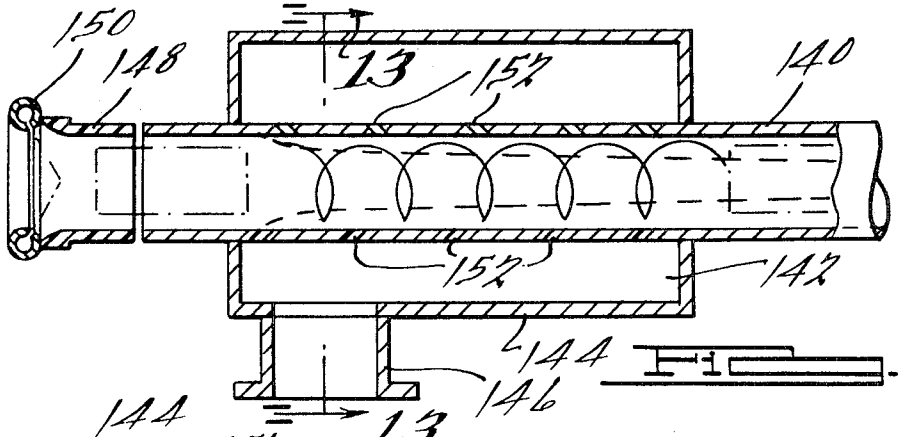


Fig. 12.

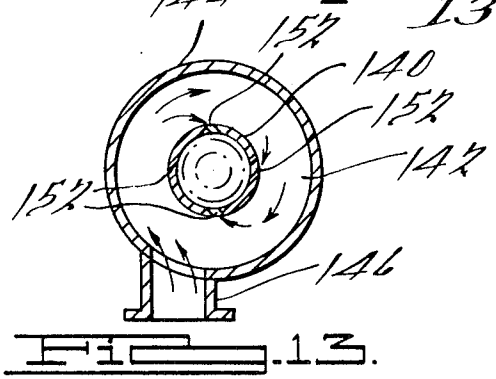


Fig. 13.

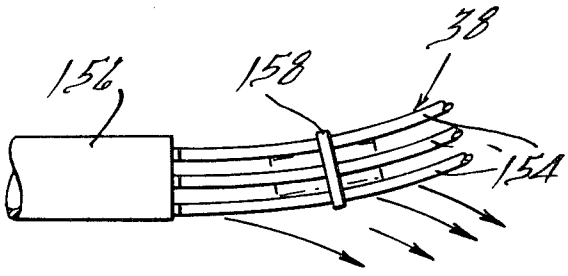


Fig. 14.

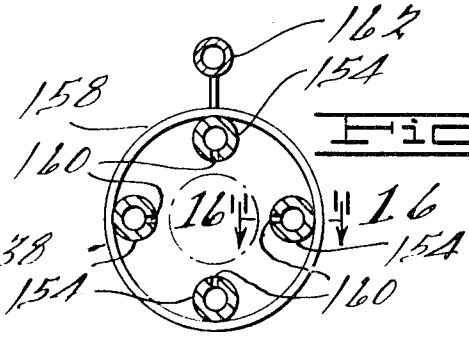


Fig. 15.

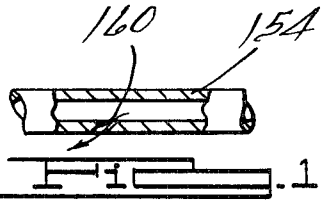
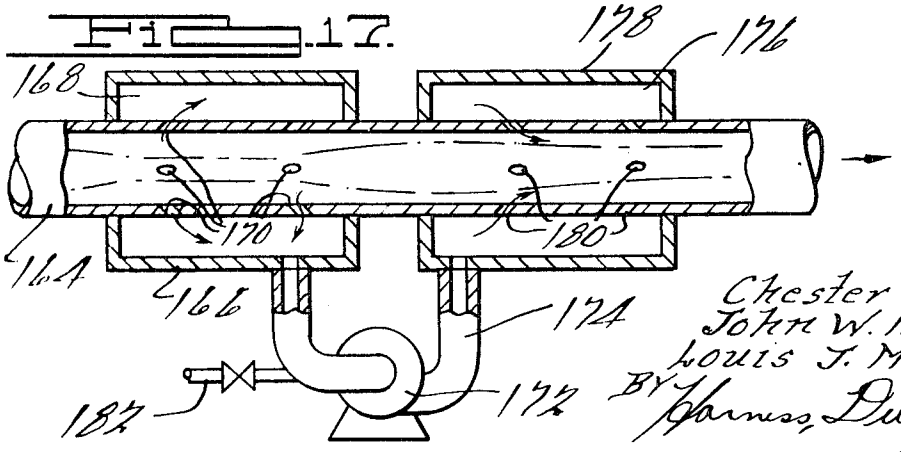


Fig. 16.

Fig. 17.



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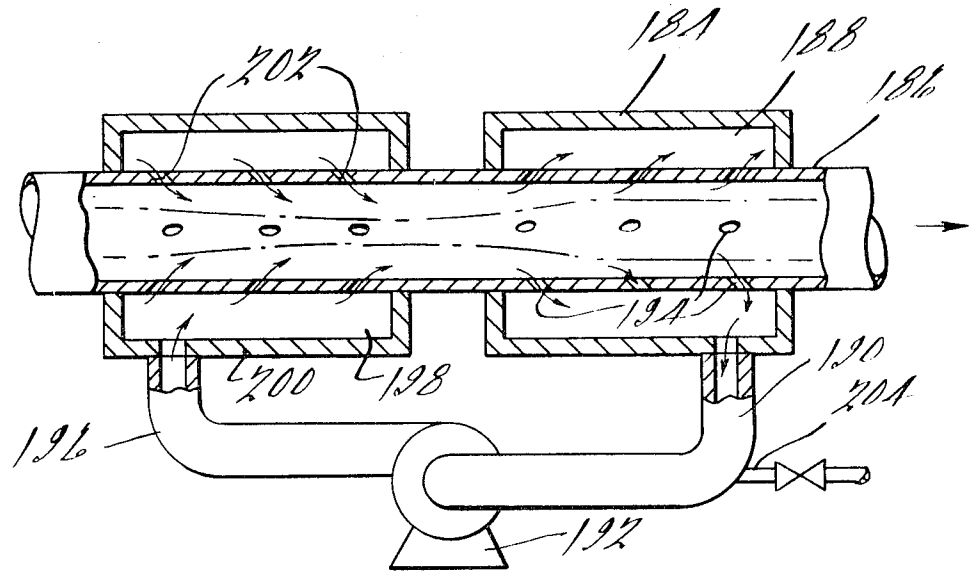


Fig. 18.

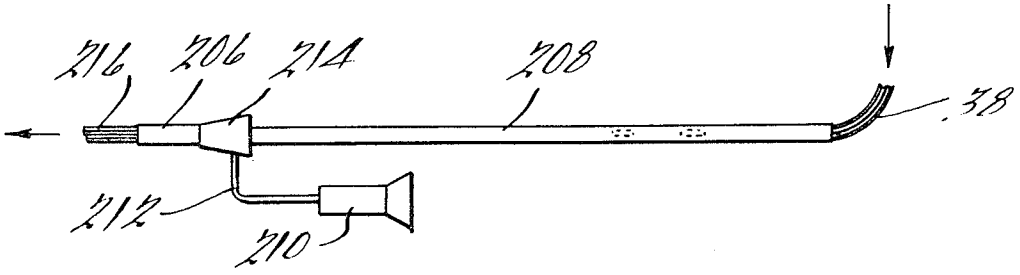


Fig. 19.

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METHOD OF TREATING WORKPIECES IN A TREATING FLUID

CROSS-REFERENCE TO RELATED APPLICATIONS

The subject matter of this application is related to that described in copending United States application Ser. No. 774,923, filed Nov. 12, 1968, for "Method and Apparatus for Processing Workpieces."

BACKGROUND OF THE INVENTION

Improvements in the technology of product packaging and distribution has occasioned an increased demand for new materials and fabricating techniques for manufacturing containers of high quality and in quantities sufficient to provide an economical means for packaging a variety of products. Typical of such products are foodstuffs including various beverages which are packaged in sealed containers whereby the contents are kept in a wholesome, palatable condition over prolonged periods of time. The advent and increasing widespread use of pressurized containers for storing and dispensing various products, such as paints, deodorants, insecticides, etc., has also contributed to the impetus in seeking improvements in the fabrication of containers which are of economical cost and high quality. In addition to various plastic materials employed in fabricating such containers, glass, and more frequently metals and metal alloys, are employed such as, for example, tin-plated steel, plastic-lined steel, aluminum and aluminum alloys, etc., which are formed on high-speed automatic machines capable of forming such containers in any desired preliminary or final form.

Due to the stringent requirements imposed on such containers in connection with their strength, cleanliness, resistance to corrosion, deterioration during storage and the like, it has been and is conventional to subject such containers to various post-treatments after a preliminary or final fabrication thereof. Such treatments conventionally comprise various chemical treatments such as, for example, a cleaning treatment to effect removal of contaminating substances from the interior and exterior surfaces thereof, the application of various protective coatings and/or linings to the container, the alteration of the surface characteristics of the container to provide a required physical alteration thereof or a desired decorative appearance, as well as various intermediate treatments such as rinsing, drying and the like. The large number of such containers and the increasing complexity of the post-treatments to which they are subjected has created a heretofore unfilled need for an improved method and apparatus for processing such containers at high production rates and which avoids the time-consuming and costly individual handling of the containers while concurrently assuring careful control of the post-treatment to which each container is subjected.

In accordance with the method and apparatus comprising the present invention, the disadvantages associated with mechanical apparatuses and processes heretofore known for supporting and conveying such containers through a prescribed post-treatment are overcome by providing an apparatus and method which is adaptable to high-speed processing of such containers while concurrently providing for a substantial simplification in the apparatus and a substantial increase in the flexibility and versatility of operation, which heretofore was unattainable in apparatuses and techniques of the types heretofore known.

SUMMARY OF THE INVENTION

The advantages and benefits of the present invention are achieved by an apparatus comprising an elongated conduit including means for introducing a treating fluid into the conduit for flow therethrough and means for introducing a workpiece container into the treating fluid in a manner so as to effect an entrainment thereof in the stream in a manner to achieve a simultaneous conveyance and treatment of the workpiece during the course of its travel through the conduit. A correlation is provided between the length of the conduit and the velocity of the treating fluid so as to provide the desired duration of treatment of the containers which are thereafter extracted from the conduit at a point downstream from their point of introduction. A multiple-stage treatment of the workpieces can be achieved by successively introducing the containers extracted from one conduit into a next conduit having a separate desired treating fluid therein in a manner so as to provide a multiple-step, sequentially phased treatment of the containers. Each conduit of the apparatus can be formed in any one of a desired variety of shapes so as to provide optimum utilization of plant space, as well as for discharging the containers at the desired location for further processing or handling, as the case may be.

It will be understood that the entire post-treatment of such containers can be achieved by employing one or a plurality of such conduits or, alternatively, a portion of such post-treatment can be achieved by the apparatus and method comprising the present invention and the balance thereof by conventional processing equipment as may be required or desired in any particular instance to achieve optimum processing flexibility and economy.

Still further advantages and benefits of the present invention will become apparent upon a reading of the description of the preferred embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic plan view of an apparatus constructed in accordance with the preferred embodiments of the present invention consisting of a series of interconnected conduit sections for providing a multiple-stage treatment;

FIG. 2 is a perspective view of a typical cylindrical container which is applicable for treatment in accordance with the method and apparatus comprising the present invention;

FIG. 3 is an enlarged plan view of one section of the apparatus shown in FIG. 1;

FIG. 4 is an enlarged longitudinal vertical sectional view of an inductor of a type suitable for introducing a container and the treating fluid into the inlet end of a processing conduit;

FIG. 5 is a fragmentary side elevational view partly in section illustrating an alternative satisfactory arrangement in which the inductor is submerged in a treating liquid contained in a reservoir to which the workpiece containers are successively transferred;

FIG. 6 is a transverse cross sectional view of a processing conduit of a substantially circular cross sectional configuration;

FIG. 7 is a transverse cross sectional view of a processing conduit having a substantially square cross sectional configuration;

FIG. 8 is a transverse cross sectional view of a processing conduit having a substantially triangular cross sectional configuration;

FIG. 9 is a transverse cross sectional view of a processing conduit provided with a plurality of helical grooves in the interior surface thereof for imparting directional guidance to the treating fluid passing therethrough;

FIG. 10 is a transverse cross sectional view of a processing conduit provided with a plurality of helically extending lands along the interior surface thereof for imparting a preselected flow pattern to the treating fluid passing therethrough;

FIG. 11 is a transverse vertical sectional view of a processing conduit provided with a supply tube for injecting supplemental treating fluid to the interior of the conduit in a substantially tangential direction, thereby imparting a prescribed flow pattern thereto;

FIG. 12 is a longitudinal vertical sectional view of an alternative satisfactory inductor for introducing the workpiece containers and treating fluid into the inlet portion of the processing conduit;

FIG. 13 is a vertical transverse sectional view through the inductor shown in FIG. 12 and taken substantially along the line 13–13 thereof;

FIG. 14 is a fragmentary side elevational view of the outlet end of a processing conduit and a transfer chute for effecting an extraction of a workpiece from the treating fluid;

FIG. 15 is a transverse vertical sectional view through the transfer chute shown in FIG. 14 and taken substantially along the line 15—15 thereof;

FIG. 16 is a fragmentary enlarged longitudinal sectional view through one of the tubular rails of the transfer chute shown in FIG. 15 and taken substantially along the line 16—16 thereof;

FIG. 17 is a fragmentary side elevational view partly in section of a portion of the processing conduit provided with a booster arrangement for extracting a portion of the treating fluid from the conduit and thereafter returning the extracted portion to the conduit under increased pressure and velocity;

FIG. 18 is an alternative arrangement of the booster shown in FIG. 17; and

FIG. 19 is an alternative arrangement of section F of the apparatus shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in detail to the drawings, and as may be best seen in FIG. 1, a processing apparatus is schematically illustrated comprised of six individual sections designated as A through F, inclusive. Each section includes a processing conduit 30 and an inductor 32 at the inlet end thereof for introducing a container to be treated and a separate treating fluid into the conduit for simultaneous conveyance and treatment during its travel through the processing conduit. Each of sections A through E, inclusive, is provided with a receptacle or tank 34, which serves as a reservoir for each individual treating fluid which is recirculated from the outlet or discharge end of the processing conduit 30 back to the inductor 32 through a pressurized supply line 36. The outlet end of the processing conduit 30 of one section is connected to the inlet end of the processing conduit of the next adjacent section by means of an arcuate transfer chute 38 providing a continuous uninterrupted transfer of the workpiece containers through the processing apparatus.

The arrangement as schematically illustrated in FIG. 1 is typical of one in which a liquid treating fluid is employed in sections A through E, inclusive, and a gaseous treating fluid, such as air, is employed in section F. The air is introduced into the inductor 32 of section F by means of an axial compressor 40 connected to a supply duct 42 and the air is subsequently discharged from the outlet end of the processing conduit and may be discharged to the atmosphere or a portion of all thereof may be recirculated as may be desired.

The apparatus shown in FIG. 1 is typical of a variety of multiple treatments that can be achieved in a continuous in-line operation employing one or a plurality of interconnected individual processing sections through which the workpieces are sequentially conveyed. The multiple-stage treatment provided by the arrangement of FIG. 1 may consist, for example, of a multiple-stage chemical conversion coating treatment of aluminum containers, such as the cylindrical container 44 shown in FIG. 2, which is integrally formed with a continuous circular cylindrical sidewall and bottom typical of containers used for packaging for beverages of various types. The provision of a conversion-type coating on the internal and external surfaces of the container enhances the resistance of the aluminum container to chemical attack, as well as providing for an improved base for the application of supplemental decorative and/or protective coatings thereto. The versatility of the apparatus and method comprising the present invention enables the apparatus as shown in FIG. 1 to be connected directly to the output end of one or a plurality of fabricating machines for making the containers 44 which are suitably transferred in end-to-end relationship in the direction of the arrow into the inductor 32 of section A, which in turn effects a concurrent cleaning and conveyance of the containers from the fabricating plant area to the treating area disposed remotely therefrom. For this purpose, the treating fluid employed in the processing conduit of section A may comprise any suitable aqueous or organic cleaning solution such as, for example, an acid cleaner having a phosphoric acid or sulfuric acid base incorporating a suitable surface active agent or preferably an alkaline cleaner usually comprising a mixture of alkali metal salts such as sodium salts of carbonates, phosphates, polyphosphates and hydroxides, which are employed in amounts of 0.5 to 4 ounces per gallon and usually range in pH from 9 to 11. The cleaning solution effects a removal of contaminating substances and oxides from the surfaces of the containers, as well as performing a mild surface etching thereof.

The length of the processing conduit 30 of section A and the velocity of the cleaning liquid are correlated so as to provide a contact or residence time of the containers with the cleaning liquid for a period of time sufficient to effect a substantially complete removal of the contaminating substances. Conventionally, such cleaning cycles may range from about 10 seconds up to about one minute. The cleaning fluid upon discharge from the outlet end of the processing conduit of section A is returned to the reservoir 34 from which it is again recirculated to the inductor through the supply line 36.

Section B of the apparatus shown in FIG. 1 may conveniently comprise a water rinse treatment in which the treating fluid comprises water or deionized water to effect removal of any residual cleaning liquid from the container surfaces, as well as any remaining contaminating substances. The rinsing cycle may consist of one or a plurality of sections rather than the single section B illustrated in FIG. 1 to provide the appropriate rinsing of the containers. The rinse liquid similarly is returned to the reservoir 34 of section B for recycling through supply line 36 to the inlet end of the processing conduit.

The containers, after the rinsing cycle in section B, are transferred to section C in which a suitable chemical conversion coating treating liquid is employed such as a chromate coating of any of the types well known in the art typically including hexavalent chromium ions in concentrations usually ranging from about 0.2 to about 10 grams per liter and wherein the treating liquid is maintained within a controlled temperature range such as, for example, from about 60° to about 130° F. and at a pH usually ranging from about 1 to about 3. The aluminum container is retained in the chromate conversion coating treating liquid for a period of time sufficient to form an amorphous corrosion protective film of a desired thickness so as to provide the requisite corrosion protection and/or base for subsequent paints or other organic finishes, as well as a final decorative finish. The length of the process conduit and the velocity of the treating liquid are correlated so as to provide a treating duration conventionally of at least about one second up to about 12 seconds or greater as may be desired. The treating fluid discharged from the outlet end of the processing conduit of section C, as in the preceding sections, is returned to the receptacle or reservoir 34 for recirculation to the inductor 32 by means of the supply line 36.

After treatment in section C, the containers are transferred to section D which, in this particular instance, provides a water rinse treatment in which the containers are rinsed in tap water and thereafter are transferred to section E in which they are subjected to a final deionized water rinse. Rinsing times of a length usually ranging from 1 to 3 seconds are generally acceptable for most purposes. After emergence from section E, the treated and rinsed containers are transferred to section F at which a drying operation is performed during the concurrent advance of the containers to a desired remote plant location at which further fabrication and/or container filling operations are performed as desired. The air introduced into section F is preferably heated to accelerate a removal and evaporation of any residuary rinse water from the container surfaces and render them in a sufficiently dry state for further processing.

It will be apparent from the foregoing description in connection with the multiple-section apparatus illustrated in FIG. 1, a continuous in-line high-speed processing of the workpiece containers is achieved without any intervening handling or

manual manipulation of the workpiece containers. In such multiple-section apparatus, it is conventional to control the longitudinal flow velocity of the treating fluid in each section so that the velocity of the workpieces transferred therethrough is at least equal to and preferably slightly greater than the velocity of the workpieces in the preceding section to assure unobstructed continuity of workpiece flow. By correlating the several factors to provide the requisite minimum treatment time, production rates of from 100 to over 1,000 containers per minute can be satisfactorily achieved in accordance with the apparatus and method comprising the present invention.

It will also be apparent in the arrangement shown in FIG. 1 that the processing conduits may be arranged in any one of a variety of configurations in order to achieve optimum utilization of plant space and to effect a discharge of the workpieces from each section at a desired location either remote or adjacent to their point of entry in that processing conduit. In this regard, it will be noted that the processing conduits of sections B through E, inclusive, are of a generally U-shaped configuration corresponding to a so-called return-type arrangement wherein the point of introduction of the workpieces at the inlet end of the processing conduit is disposed proximate or adjacent to the point of discharge of the workpieces. On the other hand, the arrangement of the processing conduits of sections A and F are such to provide a desired transfer of the workpieces from their point of introduction to a point disposed remotely therefrom coinciding with a desired location at which further processing or handling thereof is to be performed, thereby minimizing material handling problems and enhancing the efficiency of the operation. It will also be understood that the individual processing conduits of each section can extend to different vertically spaced levels to provide an optimum material flow pattern and may additionally extend underground, providing unobstructed plant working areas adjacent to the treating fluid reservoirs for accommodating additional equipment as may be desired.

It will be appreciated that alternative suitable treatments in addition to the specific multiple-stage chemical conversion treatment of aluminum containers can be provided in accordance with the apparatus of the present invention. For example, other chemical treatments typical of those feasible include the application of phosphate coatings, acid pickling, acid etching, electroless coatings, the application of coatings or dyes, such as anodized aluminum surfaces, chemical drying employing solvents such as trichloroethylene and the like. The treating fluids correspondingly may consist of homogenous gases or liquids or may comprise liquid emulsions, fluid suspensions containing solid particles entrained within a liquid or gaseous carrier, as well as two-phase mixtures consisting of gas and/or liquid and/or air.

The variations provided in the nature of the treating fluids and in the number and configuration of the individual treating section provides for almost limitless flexibility and versatility in the apparatus and method comprising the present invention for effecting any one of a variety of treatments of workpiece containers consistent with their intended end use. It will also be understood that in addition to the circular cylindrical container having one end closed as shown in FIG. 2, workpiece containers of alternative configurations and lengths including ones having both ends opened or partially opened such as by protruding flanges can be satisfactorily processed in the practice of the present invention. The term "containers" as herein employed, is intended to broadly encompass generally cup-shaped articles having open or closed ends and is intended to encompass such other articles within this general category including, for example, ammunition shell cases, beverage and food containers, pressurized aerosol containers and the like, wherein the longitudinal length to the diameter of the workpiece is such as to facilitate its longitudinal directionally oriented guidance within a conduit for travel therethrough including the arcuate convolutions provided therein. The workpieces, moreover, may be of any one of a variety of cross sectional configurations other than a circular configuration as typified by the container **44** shown in FIG. 2 and may include containers of an elliptical, rectangular, square, triangular or other polygonal or irregular configuration wherein the maximum diameter thereof approaches but is disposed in clearance relationship with respect to the inner surfaces of the processing conduit and wherein the length thereof enables unobstructed directionally oriented travel of such containers through the conduit and the arcuate convolutions formed therein.

A more detailed description of a processing section, such as the processing section C, is shown in FIG. 3. This section, which contains the conversion coating treating solution as previously described, includes a centrifugal pump **46** driven by a motor **48** and having an inlet line **50** connecting its suction end to the tank **34** containing the treating fluid. The pressurized treating fluid is transferred through a supply line **52** connected to the discharge side of the pump to the inductor **32** disposed at the inlet side of the processing conduit **30**. In accordance with a preferred embodiment, a section **54** of the processing conduit **30** is of a transparent material such as glass or polymethylmethacrylate, for example, in order to permit a visual inspection of the workpieces and treating fluid passing therethrough.

The control of the velocity of treating fluid introduced into the processing conduit and the correlation of the speed of travel of the workpieces in section C with the preceding and succeeding sections can conveniently be achieved within preselected limits by means of a suitable flow measuring device **56** schematically shown in FIG. 3. The flow measuring device may be of any one of the various types well known in the art which are operable for alternatively counting or indicating the rate of workpieces passing through the conduit and/or the longitudinal velocity of the treating fluid passing therethrough to assure the maintenance of an appropriate spacing between successive workpiece containers and a desired net flow rate thereof. The flow measuring device **56** is suitably connected to a control box **58** which incorporates appropriate circuitry including presettable limits of the type well known in the art which are operative to effect a periodic energization of a motorized control valve **60** in the supply line **52** for increasing or decreasing the supply of treating fluid to the inductor **32** to maintain the velocity within the preset limits. Alternatively, the control box **56** can regulate the speed of rotation of the motor **48** to effect appropriate correction of the treating fluid output from the pump **46**.

In addition to the flow control device, the arrangement illustrated in FIG. 3 also illustrates ancillary control devices which can be conveniently incorporated in one or more sections of the apparatus to maintain coordination therebetween, as well as to control each particular treating fluid within a preselected temperature and composition range, thereby assuring uniformity in treatment of the workpiece containers. As an example, the temperature of the treating liquid can be maintained in prescribed limits by providing suitable temperature sensing device, such as a thermocouple **62**, which senses the temperature of the treating liquid in the reservoir **34** and communicates this information to a control box **64** which in turn regulates the heat or coolant input into a heat exchanger **66** immersed in the treating liquid.

The treating fluid can also be maintained in a substantially homogenous condition, as well as assuring uniformity in temperatures, by means of providing a propeller-type agitator **68** extending inwardly of one of the walls of the reservoir **34**.

The composition of the treating liquid can also be automatically maintained within prescribed concentration limits by the provision of an electrode **70** which is immersed in the treating liquid and is operable to continuously or intermittently sense the electrical conductivity of the treating liquid which in turn is a function of the concentration of dissolved constituents therein. Conductivity electrodes of this type are well known in the art and can be conveniently connected to a suitable control box **72** containing circuitry and presettable means for

monitoring the electrical conductivity as sensed by the electrode. When the solution conductivity falls below a preset limit, indicating that the concentration of the constituents therein is a preselected minimum level, the control box **72** is operative to energize a suitable metering pump **74**, effecting the addition of a makeup solution concentrate from a container **76** through a supply line **78** to the treating receptacle **34**. Still further control devices can be incorporated in the apparatus to provide constant or intermittent sensing of the several physical and chemical variables and a corresponding correction or control thereof as may be desired to assure consistent uniformity of treatment of successive workpieces transferred through the apparatus section.

A typical inductor constructed in accordance with one embodiment of the present invention for introducing fluid and workpiece containers into the processing conduit is illustrated in detail in FIG. **4**. As shown, the inductor comprises a tubular sleeve **80** provided with a lining **82** of a low fiction material, such as a polytetrafluoroethylene plastic, disposed along the interior surface thereof and which is formed with an outwardly tapered or bellmouth configuration **84** at the inlet end thereof to facilitate entry and alignment of workpiece containers such as the container **44** illustrated in phantom. As previously described in connection with FIG. **1**, the workpiece containers are adapted to be guidably transported to the inlet portion of the inductor by a suitable transfer chute, such as the transfer chutes **38** shown in FIG. **1** and fragmentarily indicated in FIG. **4**. A tubular manifold ring **86** is disposed in concentric relationship adjacent to the tapered inlet portion **84** and is formed with an annular nozzle **88** for directing a curtainous conical stream of the pressurized treating fluid inwardly of the tubular sleeve forming a low friction fluid film upon which the workpiece containers **44** are slidably supported during their inward travel into the inductor. The interior of the manifold ring **86** is connected, as schematically shown in FIG. **4**, to a supply line **90**, which in turn is connected to a suitable pressurized source of the treating fluid such as the pump **92**.

The tubular sleeve **80** is rigidly supported by a housing **94** which is formed with an annular flange **96** at its outlet end to which a flange **98** is connected which in turn is affixed to a processing conduit **30** or a suitable extension thereof through which the workpiece containers and treating fluid are conveyed. The lower portion of the housing **94** is formed with a suitable flange **99** to which the supply line **90** is connected for supplying the pressurized treating fluid to the interior of the housing. In accordance with a preferred construction, the tubular sleeve **80** and the inner end of the conduit **30** are formed with conforming tapered edges at their adjacent ends, defining therebetween an annular tapered nozzle **100**, through which the pressurized treating fluid is discharged from the housing into the interior of the processing conduit. The nozzle **100** is formed with a series of angularly disposed vanes **102** which are offset with respect to the longitudinal axis of the conduit **30** such that the treating fluid discharged is in the form of a helix forming a rapidly rotating wall of liquid, indicated in phantom as **104** in FIG. **4**, extending around the inner surface of the pipe and including a central vortex indicated at **106**.

In accordance with this arrangement, the treating fluid has a combined rotary and longitudinal component whereby the workpiece containers entrained therein are caused to rapidly rotate and travel longitudinally along the processing conduit, effecting a concurrent conveyance and treatment of the surfaces thereof. The turbulence of the vortex of treating fluid formed assures intimate contact with the surfaces of the workpiece container, as well as assuring the maintenance of a substantially homogenous treating fluid.

The inductors as previously described in connection with the apparatus as illustrated in FIGS. **1** and **3** are shown in their conventional position in which they are disposed above the level of the treating solutions contained in receptacles **34**. It is also contemplated in accordance with the practice of the present invention that similar type inductors, such as the inductor **108** shown in FIG. **5**, can be immersed in and submerged below the level of a treating liquid **110** in a tank **112** to which pressurized treating liquid is supplied through a supply line **114**. The workpieces, such as the workpiece containers **44**, are suitably supplied to the inlet portion of the inductor **108** by means of transfer chutes, as previously described, or alternatively, by a vertical magazine **116** terminating at a point adjacent to the inlet of the inductor. The inductor **108** may also be of the type as shown in FIG. **4**, wherein the high pressure discharge of the treating fluid from the nozzle **100** imposes a suction at the inlet end of the tubular sleeve, which in turn draws a workpiece container inwardly of the inductor, effecting an entrainment and conveyance thereof in the treating liquid.

The process conduits may be composed of any one of a variety of suitable materials and may be of any one of a desired cross sectional configuration which may remain constant along the length thereof or may vary as desired in order to obtain the desired fluid flow velocity or flow pattern. Typical variations of cross sectional configuration of processing conduits are those illustrated in FIGS. **6** through **8**. A processing conduit **118** is shown in FIG. **6** which is of a substantially circular tubular cross section in which a workpiece container **44**, indicated in phantom, is adapted to be concurrently conveyed and treated. A conduit **120** is shown in FIG. **7** which is of a substantially square or rectangular configuration, while a processing conduit **122** is shown in FIG. **8** having a substantially triangular cross sectional shape. The processing conduit **122** may also be provided with corner fillers **124** for effecting a strengthening of the conduit, as well as providing selected variations in the cross-sectional area and fluid flow pattern.

The processing conduits or select portions thereof may be made of any one of a variety of suitable materials which are of adequate strength and which are resistant to and compatible with the treating fluids circulated therethrough. In addition, all or portions of the processing conduits can include transparent or translucent sections to enable visual inspection of the treating fluid flow pattern and workpiece travel through the processing conduit. In addition to various metals and metal alloys, such as steel and aluminum, for example, which may further be provided with suitable protective linings or coatings, various synthetic plastic materials either of a rigid or flexible structure can be satisfactorily employed including, for example, vinyl polymers and copolymers, acrylics, elastomeric polymers, such as rubber and the like. Processing conduits made of transparent acrylic resin, such as polymethylmethacrylate, have been found particularly suitable due to their transparency, enabling a visual inspection of the workpieces during their entire course of travel through their processing conduit.

It is also contemplated in accordance with the methods of the present invention that the processing conduits can be provided with suitable means along the inner surfaces thereof for providing guidance and variations in the fluid flow patterns during the course of the travel of the treating fluid and workpieces through the conduits. In accordance with the preferred practice of the present invention in which the treating fluid is initially introduced in the form of a vortex, a supplement to the initial helical flow pattern can be provided such as by means of a series of helical grooves **126** formed along and extending in a spiral pattern along the inner surface of a processing conduit **128** as shown in FIG. **9**. Similarly, a series of lands or vanes **130** projecting substantially radially inwardly of the interior surface of a processing conduit **132**, as shown in FIG. **10**, can be provided which extend in a spiral or helical pattern to provide directional guidance and selected variations in the flow pattern of treating fluid.

Selected variations in the flow pattern of a treating fluid passing through a processing conduit can also be achieved in accordance with the construction illustrated in FIG. **11**. In the arrangement illustrated, a conduit **134** is provided at a point intermediate its length with a supply pipe **136** terminating in a

nozzle 138 for injecting a supplemental quantity of the same treating fluid or different treating fluid into the interior of the conduit in a substantially tangential forwardly inclined direction. This arrangement can serve to effect a pressure or velocity boost of the treating fluid at one or more points disposed downstream from the inlet end portion of the conduit and can further supplement the helical flow pattern of the treating fluid. Conventionally, the axis of the nozzle 138 is oriented so as to impart an appropriate pitch to the helical flow pattern of the fluid passing thereby.

An alternative satisfactory construction of an inductor is illustrated in FIG. 12 and 13. As shown, the inductor comprises a conduit 140 which may be integrally formed with or removably coupled to the processing conduit disposed downstream therefrom. An annular chamber 142, as defined by an exterior hollow housing 144, surrounds a section of a conduit 140 to which pressurized treating fluid is supplied through a flanged connector 146. The left-hand or inlet end of the inductor, as viewed in FIG. 12, is provided with a tapered tubular sleeve 148 having a manifold ring 150 disposed adjacent to the inlet opening of the same type and for the same purposes as the manifold ring 86 previously described in connection with FIG. 4.

The conduit 140 enclosed within the housing 144 is formed with a plurality of angularly oriented nozzles 152, the axes of discharge of which are preferably forwardly and tangentially oriented with respect to the longitudinal axis of the conduit so as to impart a helical flow pattern as defined by a rapidly rotating wall of water indicated in phantom having a centrally extending vortex. The discharge of the treating fluid through the plurality of nozzles 152 similarly effects the imposition of a suction at the inlet end portion of the inductor serving to draw workpiece containers inwardly for entrainment in the helically moving treating liquid.

It will be appreciated that the inductor shown in FIG. 4 and inductor shown in FIGS. 12 and 13 can also be employed at one or more points along the length of the processing conduit to effect a boost in the pressure of the treating fluid, as well as to impart or reestablish the desired flow pattern or turbulence of the treating fluid so as to maintain the desired correlation between fluid flow and treatment time. When the treating fluid is injected in accordance with the preferred embodiments in the form of a helical vortex, the combined effects of internal fluid friction and friction with the surfaces of the conduit and workpieces effects a progressive reduction in the velocity which is generally manifested in an increase in the pitch of the helical flow pattern, as well as a reduction in the diameter of the centrally extending vortex. When processing conduits of substantial length are required in order to achieve the requisite treatment time, it is generally desirable to employ boosters, such as the inductors illustrated in FIG. 4 and 12, at one or a plurality of locations therealong to reestablish the desired treating fluid flow pattern and velocity-pressure relationship.

Referring now to FIGS. 14–16, a satisfactory construction is illustrated of the transfer chutes 38, as previously discussed in connection with FIG. 1, for transferring the workpiece containers from the outlet end to the inlet end of adjacent process sections. As shown, the transfer chute 38 is composed of a plurality of tubular rails 154, which are disposed at circumferentially spaced intervals, forming an open enclosure for guidably receiving the workpiece containers discharged from the outlet end of a processing conduit 156. The open construction of the transfer chute enables the separation and discharge of the treating liquid to pass downwardly in the direction of the arrows into a suitable catch basin or receptacle from which it can be recovered and recirculated to the inlet end of the processing conduit. The open construction also enables a disengagement of the treating fluid from the workpiece containers at the completion of one treatment and preparatory to the next successive treatment or processing step. The tubular rails 154 are retained in appropriate circumferentially spaced position by means of a series of straps 158 which are securely fastened to the rails at longitudinally spaced intervals therealong. The specific number and spacing of the tubular rails can be varied consistent with the particular configuration and size of the workpieces being processed in order to assure appropriate guidance and conveyance of the containers along the transfer chutes.

In order to facilitate disengagement of the treating fluid with the workpiece containers and to further overcome any tendency of the containers to slow down during the course of their travel along the transfer chute, it is conventionally preferred to provide one or more of the tubular rails with a plurality of angularly oriented jets 160 disposed at spaced intervals therealong through which a pressurized gas, such as air, is ejected, effecting a propelling of the workpiece containers along the transfer chute. The formation of a plurality of jets is also effective to maintain the workpiece containers in at least partially spaced relationship with respect to the surfaces of the rails, counteracting any centrifugal forces and thereby minimizing friction therebetween. The supply of the pressurized gas to one or more of the tubular rails can be conveniently achieved by a supply header 162, such as shown in FIG. 15, which is disposed in communication with a source, such as a compressor of the pressurized gas.

It is also contemplated in accordance with the present invention that the treating fluid passing through a processing conduit can be completely or partially removed to enable a replacement or replenishment thereof with the same or a different treating fluid as may be desired in certain treating processes. An arrangement for achieving the foregoing is illustrated in FIG. 17 which is processing conduit 164 is illustrated, through which the treating fluid, as shown in phantom, is traveling in a helical pattern including a centrally disposed vortex. A manifold 166, defining an annular chamber 168, is disposed in encircling relationship around an upstream section of the process conduit which is formed with a plurality of angularly oriented nozzles 170, through which a portion of the treating fluid is withdrawn into the annular chamber 168. The interior of the manifold 166 is disposed in communication with the suction side of a booster pump 172 to effect a constant withdrawal of the treating fluid from the annular chamber.

The pressurized discharge side of the booster pump is connected to a supply line 174 through which the pressurized treating fluid is conveyed to an annular chamber 176 defined by a manifold 178 encircling the processing conduit at a point spaced downstream from the withdrawal manifold 166. The process conduit is formed with a series of angularly oriented nozzles 180, through which the treating fluid is discharged in the desired helical flow pattern into the interior of the conduit, effecting a reestablishment of the desired vortex and an appropriate boost in the pressure and velocity of the fluid passing therealong. It will also be appreciated that the arrangement as illustrated in FIG. 17 can be employed for adding supplemental treating fluid at a point intermediate the inlet and outlet ends of a processing conduit such as by providing a secondary supply line 182 connected to the suction side of the booster pump 172.

An alternative satisfactory arrangement of the device shown in FIG. 17 is illustrated in FIG. 18 which similarly enables a partial replenishment or replacement of the treating fluid, effecting a boost in its pressure and/or velocity, as well as a reestablishment of the helical flow pattern at a point intermediate the length of a processing conduit. As shown in FIG. 18, a manifold 184 encircles a processing conduit 186 defining an annular chamber 188 which is disposed in communication with a suction line 190 connected to the suction side of a centrifugal pump 192. The processing conduit 186 disposed within the manifold 184 is formed with a series of angularly oriented nozzles 194, through which the treating fluid is withdrawn from the interior of the processing conduit through the chamber 188 and into the suction line 190.

All or a portion of the treating fluid withdrawn is replaced in the processing conduit by means of a pressure line 196 con-

nected to the output side of the pump **192**, which is disposed in communication with a chamber **198** defined by a manifold **200** encircling the process conduit **186** at a point upstream from the withdrawal manifold **184**. The process conduit **186** disposed within the encircling manifold **200** is provided with a series of angularly oriented discharge nozzles **202**, through which the pressurized treating fluid is discharged from the chamber **198** into the interior of the processing conduit, effecting a boost in the pressure and/or velocity thereof, as well as effecting a reestablishment of the helical or other desired flow pattern.

In normal operation in accordance with the arrangement shown in FIG. **18**, all of the treating fluid withdrawn through the withdrawal manifold **184** is immediately returned at a point immediately upstream through the input manifold **200**, providing the desired velocity and pressure boost, thereby assuring continuity of flow of the treating fluid and workpieces entrained therein. It is also contemplated, as in the arrangement illustrated in FIG. **17**, that a partial replenishment or addition of the same or an alternative treating fluid can be accomplished through a supply line **204** connected to the suction line **190**.

An alternative satisfactory arrangement of processing section F, as illustrated in FIG. **1**, is shown in FIG. **19** in which the inductor is located adjacent to the output end **206** of a processing conduit **208** rather than at the inlet end as shown in FIG. **1**. In the embodiment illustrated in FIG. **19**, an axial compressor **210** is connected by means of a pressure line **212** to an inductor **214** disposed adjacent to the output end **206** of the processing conduit, imposing a suction or negative pressure along the upstream portion of the processing conduit **208**, which is operative to draw workpiece containers. as indicated in phantom, into the inlet end of the processing conduit which is disposed in alignment with a transfer chute **38**. The inductor **214** may be of any one of the types previously described which is operative, by an appropriate nozzle arrangement through which the high pressure fluid, such as air, is discharged, to effect an imposition of a reduced pressure in the upstream portion of the processing conduit, causing supplemental air to be drawn inwardly of the inlet end of the conduit, which in turn effects a conveyance or transfer of the workpiece containers therealong. The workpiece containers, upon passage through the inductor **214**, are advanced outwardly of the outlet end **206** of the conduit by the high pressure air discharged through the inductor and are conveyed by a suitable transfer chute **216** to the next succeeding work station.

It will be apparent from the foregoing description that the processing apparatus and the method comprising the present invention is readily adaptable to a variety of different treating fluids and treating processes in order to effect an appropriate treatment of the workpiece containers. In addition to enabling rapid continuous in-line chemical treatments of such workpieces, alternative treatments, such as electrolytic treatments, coating treatments, mechanical treatments, as well as electromechanical treatments, can also be accomplished by appropriate adjustments in the treating fluids to provide the desired treating action. In each instance, the workpiece containers are concurrently transferred and treated in the processing conduit while entrained in a confined stream of the treating fluid. The movement of the workpieces is substantially in response to the travel of the treating fluid therealong, which may, in some instances, be supplemented by gravity when all or sections of the processing conduit are oriented in a downwardly inclined direction. In addition to inducing the workpieces into the processing conduit by employing an inductor of the type illustrated in FIGS. **4** and **12** of the drawings, supplemental mechanical loading and air jets, for example, can be employed to assist in the rapid transfer of the workpieces from one section to the next adjacent process section.

Still further variations in the apparatus and method as hereinbefore described can be made without departing from the spirit of the invention.

What is claimed is:

1. The method of treating elongated containerlike workpieces which comprises the steps of forming a confined stream of a treating fluid having a helical flow pattern and a cross-sectional size greater than the cross-sectional size of the workpiece, introducing a workpiece into said stream in longitudinally oriented relationship with respect to the longitudinal direction of travel of said stream effecting a rotation of the workpiece about its longitudinal axis and a longitudinal conveyance of the workpiece and a simultaneous treatment thereof during its travel while entrained in said stream, maintaining the workpiece in said stream for a period of time sufficient to perform a desired treatment thereof, and thereafter extracting the workpiece from said stream of said treating fluid.

2. The method as defined in claim **1**, including the further step of recirculating of at least a portion of said treating fluid to said stream.

3. The method as defined in claim **1**, including the further steps of forming a plurality of separate confined streams each composed of a separate treating fluid and successively introducing a workpiece into and extracting a workpiece from each of said separate streams in a preselected sequence for performing a plural treatment on the workpiece.

4. The method as defined in claim **1**, including the further step of guiding the path of travel of said stream in order that the point at which a workpiece is introduced into said stream is located remotely from the point at which a workpiece is extracted from said stream.

5. The method as defined in claim **1**, including the further step of guiding the path of travel of said stream in order that the point at which a workpiece is introduced into said stream is located adjacent to the point at which a workpiece is extracted from the stream.

6. The method as defined in claim **1**, including the further step of introducing at least a portion of said treating fluid into said stream at a point downstream from the point at which a workpiece is introduced into said stream.

7. The method as defined in claim **1**, including the further step of replenishing said treating fluid to maintain the composition thereof within a preselected range.

8. The method as defined in claim **1**, including the further step of controlling the temperature of said treating fluid within a preselected range.

9. The method as defined in claim **1**, in which said treating fluid is a liquid.

10. The method as defined in claim **1**, in which said treating fluid is a gas.

11. The method as defined in claim **1**, in which said treating fluid is an aqueous solution.

12. The method as defined in claim **1**, in which said treating fluid is an organic solution.

13. The method as defined in claim **1**, in which said treating fluid is a liquid emulsion.

14. The method as defined in claim **1**, in which said treating fluid is a two-phase mixture of liquid and gas.

15. The method as defined in claim **1**, in which said treating fluid includes solid particles suspended therein.

16. The method as defined in claim **1**, in which said treating fluid comprises a cleaning fluid for performing a cleaning treatment of the surfaces of the workpiece.

17. The method as defined in claim **1**, in which said treating fluid comprises an aqueous rinse solution for performing a rinse treatment of the surfaces of the workpiece.

18. The method as defined in claim **1**, in which said treating fluid comprises a coating composition for depositing a coating on the surfaces of the workpiece.

19. The method as defined in claim **1**, in which said treating fluid comprises a chemical conversion coating solution for forming a conversion coating on the surfaces of the workpiece.

20. The method as defined in claim **1**, in which said treating fluid comprises a liquid for effecting a chemical drying of the workpiece.

21. The method as defined in claim 3, including the further step of controlling the longitudinal velocity of said steam such that the velocity of any one separate stream is equal to or greater than the velocity of a preceding stream.

22. The method as defined in claim 1, in which the step of forming said confined stream having said helical flow pattern is performed in a manner to form a centrally oriented vortex along at least a portion of the length of said stream.

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