

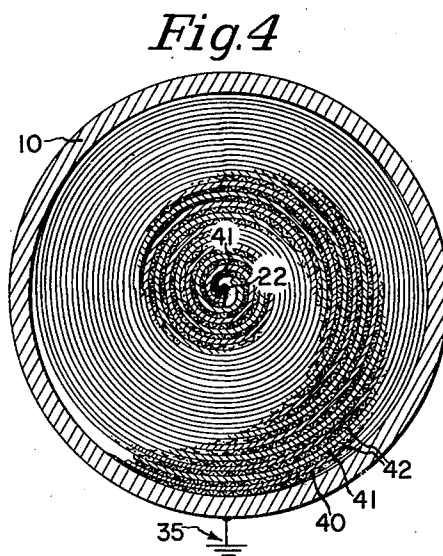
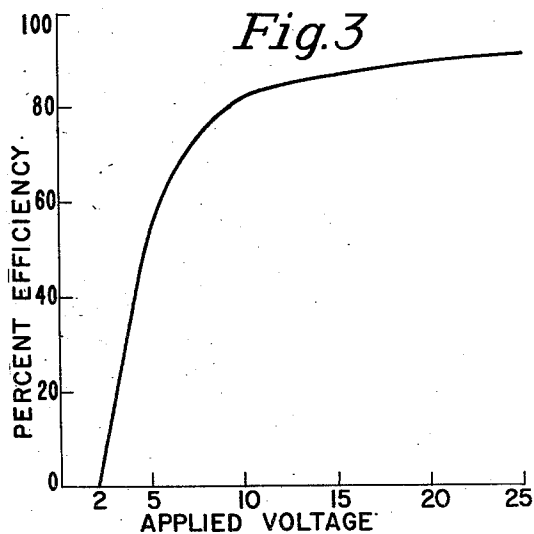
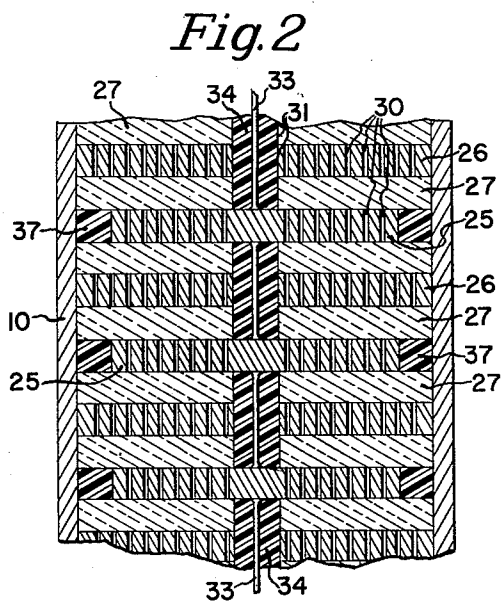
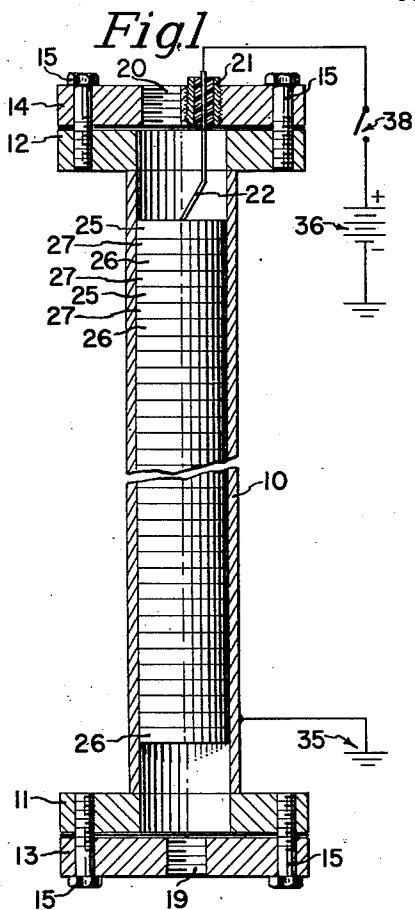
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ELECTROLYTIC DRYING METHOD

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ELECTROLYTIC DRYING METHOD

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3 Claims. (Cl. 204—130)

This invention relates to a method and apparatus for the drying of fluids, and particularly to an electrolytic method and apparatus for the drying of fluids which is coulometric in principle and which is adapted to regeneration of the water absorbing medium over an indefinite period.

Numerous processes have been devised for the removal of water from fluids by absorptive and adsorptive processes; however, there are disadvantages as regards changes in water-removal propensities in the course of use, difficulties in regeneration and relatively low efficiencies, particularly where the amount of water present in the fluid is small and measured in parts/million. A primary object of this invention is to provide an electrolytic process and apparatus for the drying of fluids which is coulometric in principle and, therefore, consumes electrical energy in direct proportion to the amount of water which is removed. Another object of this invention is to provide a method and apparatus for the drying of fluids wherein the water-removing characteristics of the absorbent are maintained at a high and substantially constant level. Another object of this invention is to provide a method and apparatus for the drying of fluids which can be utilized for the drying of fluids in continuous flow. The manner in which these and other objects of this invention are obtained will become apparent from the following detailed description and the illustrative drawings in which:

Fig. 1 is a partially schematic view of a preferred embodiment of the apparatus of this invention shown in longitudinal section,

Fig. 2 is a partially schematic sectional view of several electrode elements and their relationship with respect to one another for the apparatus of Fig. 1,

Fig. 3 is a plot of percent efficiency versus applied voltage for the drying method of this invention, and

Fig. 4 is a cross sectional view taken transverse the direction of fluid flow of a second embodiment of the apparatus of this invention.

Generally, this invention comprises a method of drying a fluid, and the provision of means for carrying out the method, wherein the water in the fluid is absorbed in a hygroscopic substance which is electrically conductive only when wet and then subjecting the absorbed water to complete quantitative electrolysis to thereby remove it in the form of the elemental gases hydrogen and oxygen. The invention is particularly described as applied to the situation where the presence of hydrogen and oxygen intermixed with the fluid to be dried is not objectionable; however, it is possible to effect drying according to this invention with removal of the gaseous products of electrolysis from the fluid stream by a modification which is hereinafter fully described.

Referring to Figs. 1 and 2, the method of this invention can be conveniently carried out by apparatus comprising a metal conduit section 10 which is provided with flange ends 11 and 12 to which are secured companion flanges 13 and 14, respectively, by bolts 15. Flanges 13 and 14 are tapped for connection with the process fluid supply and delivery lines, the inlet connection for the apparatus depicted being shown at 19 in flange 13 and the outlet

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connection being indicated at 20 in flange 14. Flange 14 is further provided with an integral electrical conduit 21 for the reception of insulated electrical lead 22 which supplies current to the anode elements as hereinafter described.

The electrode elements of the apparatus are indicated schematically in Fig. 1, the anodes being represented at 25 and the cathodes at 26, these being arranged in alternation as indicated and separated from one another by insulating discs 27. As shown more clearly in Fig. 2, the anodes 25 and cathodes 26 are both provided with a multiplicity of through going passages 30 which serve as passages for the flow of fluid axially of the conduit while opposing little resistance to such flow. If desired, the anodes and cathodes may, in fact, be made from screen material, platinum screen being suitable for the anodes and stainless steel screen for the cathodes. The insulating disc 27 may be fluid-pervious glass cloth or the like which is also sufficiently open to oppose a minimum of resistance to fluid flow therethrough. Cathodes 26 and discs 27 are provided with central openings 31 for reception of the electrical conductors 33 which serve as the continuation of lead 22 between successive anode elements 25, and the cathodes and discs may be provided with radial slits, not shown, for convenience of assembly of the multiplicity of electrodes into the arrangement shown in Figs. 1 and 2. Conductors 33 are provided with annular insulators 34 barring short circuiting contact with adjacent cathode elements.

As indicated in Fig. 2, successive anodes may be joined in electrical circuit by conductors 33 which are soldered or otherwise joined to opposite faces of anodes 25, the topmost anode of the assembly being in electrical connection with lead 22 running to the electrical power source 36. Cathode elements 26 fit tightly in abutting relationship with the inside of conduit 10 and are in electrically conductive relationship with the conduit, which is grounded at 35 to establish return connection with the grounded negative of the power source 36. Switch 38 is interposed in the power circuit for control purposes. The power source should, of course, be of direct current type delivering a voltage sufficient to effect electrolysis of any water absorbed in the hygroscopic substance coating the electrodes, a 45 volt radio "B" battery being a suitable source for very small drying installations. It will be noted that anodes 25 are of somewhat smaller diameter than cathodes 26 and are insulated from contact with the inside of conduit 10 by the annular insulators 37.

From the foregoing, it will be understood that the anodes 25 are electrically insulated from the cathodes 26 by discs 27. In the course of assembly, adjacent faces of electrodes, passages 30 and discs 27 are well coated with a hygroscopic substance which is electrically conductive only when wet and which is capable of absorbing water from the fluid to be dried. This hygroscopic substance bridges the space between adjacent electrodes through the pores of discs 27 and affords a low resistance path for electrical flow when the hygroscopic substance contains absorbed water.

Numerous hygroscopic electrically conductive materials are available for use in conjunction with this invention, depending upon the nature of the fluid which it is desired to dry, it being understood that the electrolytic properties of the hygroscopic material should be unaffected by the presence of all substances in the process stream, and, of course, that the material should be capable of removing water quantitatively from the fluid. Phosphoric acid has proved to be completely satisfactory for the drying of fluid streams comprising one or more of the ingredients air, ethylene and halogen-substituted hydrocarbons such as the "Freons" and ethyl chloride, and is applied by merely

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brushing it on over the paired electrodes and also over discs 27 therebetween. Since the more concentrated solutions of phosphoric acid are relatively viscous, and are thus somewhat more difficult to apply than dilute solutions of the order of 10% acid content, it is preferred to apply the acid in dilute mixture and then operate the apparatus without putting a fluid stream through it for a sufficient time to dry the acid thoroughly and thus bring it up to a hygroscopic level capable of absorption of water from a fluid stream to be dried, this condition being signalled by failure of the acid to further conduct the electric current. When the acid is thus dehydrated by electrolysis prior to use in the drier, it displays strongly hygroscopic properties and, since during operation water absorbed in it is completely removed by electrolysis without any vitiation of the acid, it remains hygroscopic indefinitely.

Other examples of suitable hygroscopic substances which can be utilized according to this invention are potassium hydroxide or sodium hydroxide, the use of either of which, either singly or in mixture, is convenient where acidic properties are objectionable but where basic characteristics can be tolerated.

In operation, it will be understood that the apparatus is first placed in readiness for absorption removal of water from the fluid stream by drying through electrolysis of any water in the hygroscopic substance by connection with the power source 36 for a suitable period which may require 30 hours or more, the achievement of drying being indicated by a rapid increase in electrical resistance, accompanied by a drop in current flow. At this time wet fluid may be introduced through inlet connection 19 and removed from the apparatus after transit through the passages of the electrode assembly through outlet 20. As the fluid traverses the electrode assembly, it is brought into intimate contact with the hygroscopic substance spanning the electrodes and any water therein is removed by absorption and electrolyzed very quickly to hydrogen and oxygen which bubbles from the electrodes into the fluid stream and is carried from the apparatus by the stream.

Tests on an experimental unit made up of an assembly of 19 electrode discs 2" in diameter separated one from another by 18 glass fiber discs showed a removal efficiency in excess of 90% in the separation of water from air where the air flow rate was $\frac{1}{3}$ C. F. M. and the input water concentration was 100 p. p. m. The anodes of the experimental unit were fabricated from 40 mesh platinum wire screen while the cathodes were 100 mesh stainless steel screen. The voltage of the power source was 25 v. and operation was conducted at atmosphere pressure and a temperature of about 30° C., the pressure drop in transit through the unit being about 2 lbs./sq. in. per cu. ft./minute. The efficiency in terms of applied voltage was determined for the apparatus and the relationship obtained is depicted in Fig. 3. In general, it can be said that the removal of each part/million of water from one million cu. ft. of an air stream by the process of this invention requires 0.2 kw. hr. based on a supply voltage of 4 v. In the example hereinabove described the fluid dwell time was only of the order of about 0.2 second. If this dwell time is doubled, as by doubling the length of the drying unit, the drying efficiency is increased to about 99%, and further lengthening of the drying path is accompanied by a corresponding increase in the drying efficiency.

It will be understood that the drying method of this invention is coulometric in principle and that water removed in the course of operation can be calculated in accordance with Faraday's law. A determination of water removed from the fluid dried can be obtained by determining the current drawn from the power source over a finite period of operation; however, in the interests of simplicity and economy it is preferred to determine water by electrolysis in accordance with the teachings of my copending application S. N. 505,599, filed of even date.

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A second embodiment of the apparatus of this invention is shown in Fig. 4, wherein the electrodes comprise lengths of screen disposed axially within the conduit 10, the cathode in this case being screen 40 in electrically conductive contact with the inside periphery of conduit 10, while the anode is screen 41. The screens are separated throughout their widths and lengths by porous insulator 42, which may conveniently be a glass fabric. The anode-insulator-cathode assembly is soaked thoroughly with the hygroscopic electrolyte substance and wound spirally in tight, compact convolutions to present a maximum surface area to contact with the fluid stream to be dried. Any clearance between the outside of the electrode assembly and the inside of conduit 10 is preferably packed with an impervious material, not shown, to prevent bypass channeling of the process stream. The electrical circuit for the embodiment of Fig. 4 is the same as that for the apparatus of Figs. 1 and 2, connection to the anode being made by an insulated lead 22, while conduit 10 is grounded as indicated at 35.

The embodiments hereinabove described in detail discharge the products of electrolysis into the fluid stream which is dried and, in many cases, this is unobjectionable and outweighed by the simplicity of construction of the drying apparatus. However, it is obvious that this invention can be adapted to water removal as an absorption step carried out in contact with the fluid to be dried, followed by electrolysis in a separate chamber out of communication with the fluid stream, thus enabling the separate discharge of the hydrogen and oxygen electrolysis products from the system.

Numerous systems for carrying out separate water absorption-electrolysis can be devised, one of which utilizes a power driven, endless belt type electrode assembly which is incrementally interposed in the fluid path and then withdrawn to a separate enclosure where the electrolysis is conducted with simultaneous evacuation of the hydrogen and oxygen formed. Another design might utilize an electrode construction simulating the periphery of a wheel, sections of which rotate in sequence from a region in contact with the fluid to one in which the electrolysis is carried out, the cycle being repeated indefinitely. Yet another system might utilize a conventional chemical packing, such as Raschig rings or the like, coated with the hygroscopic electrolyte, which packing is cyclically processed with the aid of star valves and elevator conveyors or similar devices to sequentially subject the hygroscopic substance to exposure to the fluid to be dried and then to electrolysis for removal of absorbed water. Yet another system might utilize liquid impervious particulate solids coated with the hygroscopic electrolyte substance, employing the fluidized solids technique for contact with the fluid to be dried, followed by electrolytic removal of absorbed water in an unfluidized bed as a separate step after the solids are removed from the process stream, then recycling.

From the foregoing it will be understood that this invention comprises a drying process and apparatus which is adapted to the drying of both liquids and gases and which possess very great advantages over methods of drying now known to the art, in that the efficiency of the drying agent per se is maintained substantially constant and at a high level, the operating cost is very low, especially when low concentrations of water are to be removed, the process is readily controllable and the drying action is selective to water in all systems wherein there are no other materials present having an overvoltage lower than water. It will be understood that this invention can be modified in numerous respects without departure from the essential spirit, wherefor it is intended to be limited only within the scope of the following claims.

What is claimed is:

1. A method of drying a fluid comprising contacting the wet fluid with a hygroscopic substance electrically conductive only when wet and absorbing substantially all of

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the water from said fluid, subjecting the water absorbed in said hygroscopic substance to complete quantitative electrolysis and collecting said fluid from which said water has been removed as dry product.

2. A method of drying a fluid according to claim 1 wherein said hygroscopic substance comprises one of the group consisting of dried H_3PO_4 , dried KOH and dried NaOH.

3. A method of drying a fluid comprising contacting the wet fluid with a hygroscopic substance electrically 10 conductive only when wet and absorbing substantially all of the water from said fluid, withdrawing hygroscopic substance together with water absorbed in said hygroscopic substance from contact with said fluid to be dried, elec-

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trolyzing water absorbed in said hygroscopic substance removed from said fluid to be dried to elemental oxygen and hydrogen, separating said hygroscopic substance from said oxygen and hydrogen and recycling hygroscopic substance from which said absorbed water has been electrolyzed to contact with additional wet fluid to be dried.

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