

Nov. 6, 1962

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ELECTROLYTIC DRYING APPARATUS

Original Filed Oct. 3, 1957

2 Sheets-Sheet 1

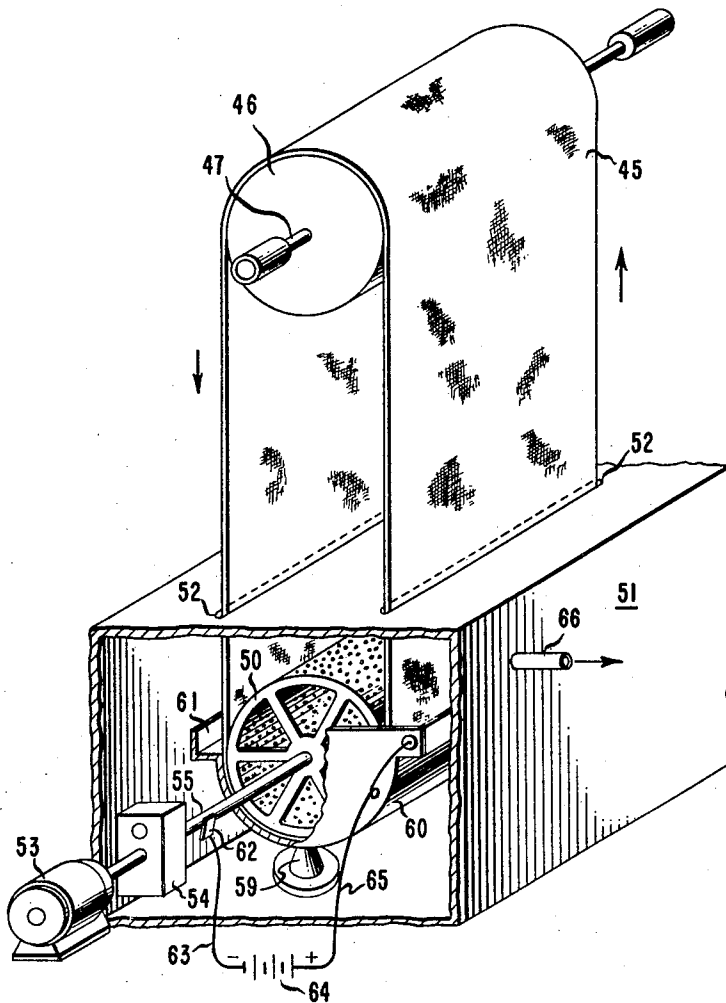


Fig. 1

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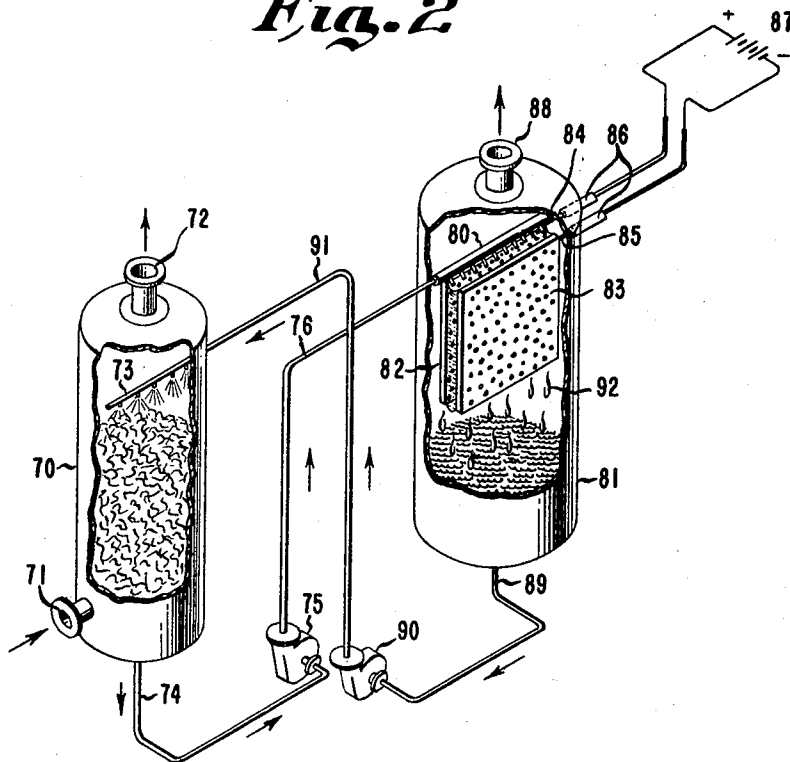
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Fig. 2



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ELECTROLYTIC DRYING APPARATUS

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Original application Oct. 3, 1957, Ser. No. 688,035, now Patent No. 2,944,957, dated July 12, 1960. Divided and this application June 23, 1959, Ser. No. 822,342
2 Claims. (Cl. 204-212)

This invention relates to an electrolytic drying apparatus for the drying of fluids, and particularly to an electrolytic drying 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 of time. This application is a division of application Ser. No. 688,035, now Patent No. 2,944,957, which is, in turn, a continuation-in-part of application Ser. No. 505,598, now issued as Patent 2,816,067 assigned to common assignee.

Numerous processes have been devised for the removal of water from fluids by absorptive and adsorptive processes; however, there are disadvantages arising from variations in the water-removal propensities of the moisture-removing medium 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 per million. A primary object of this invention is to provide an electrolytic 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 an 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 an 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 cut away representation in perspective of a preferred embodiment of this invention wherein the hygroscopic medium is conveyed in sequence through a first compartment wherein water abstraction is conducted and thence to a second compartment, separate from the first compartment, wherein regeneration of the hygroscopic medium is carried out, and

FIG. 2 is a partially schematic cut away view of another embodiment of drying apparatus according to this invention wherein a liquid hygroscopic medium is circulated throughout the system by pumps, and the drying and regeneration operations are conducted in separate vessels.

Generally, this invention comprises electrolytic apparatus having in combination at least one pair of electrically isolated electrodes disposed in close proximity to one another, a deliquescent hygroscopic substance which is electrically conductive only when wet adapted to absorb water by contact with the fluid to be dried and to span the electrodes so as to provide a current-conducting path for electrolysis of water absorbed in the deliquescent hygroscopic substance, and a direct current power source of voltage sufficient to electrolyze absorbed water in the deliquescent hygroscopic substance connected across the electrodes. Various embodiments of this invention are hereinafter described in detail in which the deliquescent hygroscopic medium is cyclically exposed to the fluid to be dried and thereafter moved into and out of contact with electrode structures in order to effect regeneration in a separate

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chamber apart from the chamber in which the drying is effected, apparatus for concurrent drying and regeneration in a single, common compartment being taught in divisional application Ser. No. 688,035 hereinbefore referred to.

As taught in Patent 2,816,067 applicant has provided an electrolytic method for the drying of fluids which employs a suitable deliquescent hygroscopic substance which is electrically conductive only when wet and which is capable of absorbing water from the fluid to be dried. At least one pair of current conducting electrodes is provided and the deliquescent hygroscopic substance, when disposed across the interspace between a pair of such electrodes, affords a low resistance path for electrical flow when the substance contains absorbed water.

Numerous deliquescent 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 material should be unaffected by the presence of all substances in the process stream, and, of course, that it 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 "Freon" compounds and ethyl chloride, and can be applied by merely brushing it over the paired electrodes. 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 deliquescent hygroscopic substances which can be utilized according to this invention are potassium hydroxide, sodium hydroxide and potassium carbonate. The use of either sodium hydroxide or potassium hydroxide, singly or in mixture, is convenient where acidic properties are objectionable but where basic characteristics can be tolerated. Potassium carbonate constitutes a near-neutral deliquescent hygroscopic medium which is particularly suitable where neither a stronger basic or acidic medium can be tolerated.

The apparatus electrodes can be fabricated from a wide variety of materials, depending upon the corrosion resistance propensities which are necessary in the particular environment involved, platinum generally being a very satisfactory material for the anodes while stainless steel has proved useful in the cathodes. Of course, the electrodes may take a wide variety of physical forms; however, screens are particularly preferred because they retain hygroscopic medium to a high degree in the interstices and are, besides, readily available commercially.

It is oftentimes desirable to interpose an electrical insulator between the electrodes of a given pair, and this can be readily accomplished by employing material which has throughgoing passages permitting the deliquescent hygroscopic medium to bridge therethrough between the electrodes and thereby maintain the necessary electrolysis circuit. Open weave glass cloth or the like is eminently suitable as such an insulating medium.

The power source employed with the apparatus of this invention should be of direct current type delivering a voltage sufficient to effect electrolysis of any water absorbed in the deliquescent hygroscopic substance interposed between the electrodes, a 45 volt radio "B" battery being a suitable source for very small drying installations.

Referring to FIG. 1, a preferred embodiment of this invention employs an endless carrier belt 45 of porous, electrically insulating material, such as open weave glass cloth, for example, for the support and conveying of the deliquescent hygroscopic medium employed. Belt 45 is trained over idler pulley 46 journaled on shaft 47 disposed in the chamber (not detailed) wherein drying is to be conducted. The lower end of belt 45 is passed tightly around the circumference of perforated metal cylindrical cathode 50, which is rotated by motor 53 through speed reducer 54 connected in power-transmitting relationship with shaft 55 to which cathode 50 is keyed or otherwise attached.

The anode element 60 conveniently comprises a semi-cylindrical metal tray within which belt 45 is received in snug contact in the course of rotation of cathode 50, so that good electrical contact relationship is preserved at all times in this region. Cathode 50 drives belt 45 by frictional contact therewith. Anode 60 is mounted on pedestal insulators 59 which are, in turn, attached to the floor of regeneration housing 51. The upper edges of anode element 60 are provided with longitudinal trays 61 within which a supply of hygroscopic medium can be maintained to insure that belt 45 is well coated at all times. Contact brush 62 bearing on shaft 55 serves as the negative electrical connection of the apparatus through lead 63 running to the D.-C. power source generally indicated at 64. The positive connection to anode 60 is through lead 65.

The ceiling of the regeneration housing 51 is provided with two slits 52 through which belt 45 passes with only slight clearance, thereby minimizing communication between the drying chamber and the regeneration housing. Housing 51 is provided with a vent 66 for escape of hydrogen and oxygen gases formed in the course of the electrolytic drying operation, and it is preferred to apply a slight vacuum to this vent to guarantee against any leakage of these gases back into the drying space in circumstances where the presence of the products of electrolysis are objectionable.

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 originally in the deliquescent hygroscopic substance by operation of the apparatus with the power source 64 switched on for a suitable period, which may be of the order of 30 hours or more for complete drying, the achievement of this condition being indicated by a rapid increase in electrical resistance accompanied by a drop in current flow. Following this, wet fluid may be passed through the chamber surrounding the upper length of belt 45 at such a rate as to permit take up of water therein by the deliquescent hygroscopic medium with which the belt is coated. Removal of water from the fluid is facilitated by preserving intimate contact between the fluid to be dried and the hygroscopic medium, after which successive increments of belt 45 are carried around by frictional contact of the belt with rotating cathode 50 until they are disposed within regeneration housing 51. Here electrolysis occurs with substantially complete removal of absorbed water from the hygroscopic medium, after which continued travel of belt 45 upwardly into the chamber above regeneration housing 51 returns the medium to contact with more fluid to be dried and the cycle is repeated.

In general, the removal of each part per 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 3 v. A typical dwell time in the drying chamber for air containing an input water concentration of 100 p.p.m.

was 0.2 sec., which gave a removal efficiency in excess of 90%. If this dwell time is doubled, as by doubling the belt surface exposed in the drying unit, the drying efficiency is increased to about 99%, and further increase in the effective drying surface 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 application Ser. No. 505,599, filed May 3, 1955, now issued as Patent 2,830,945.

It will be understood that it is imperative that the speed of travel of belt 45 from the entrance of the region of cathode-anode contact to the exit of this region must be maintained at a rate which will insure, with the electrolysis current and voltage applied, that the hygroscopic medium coating the belt will be thoroughly dried by electrolysis. The time of this contact can, of course, be prolonged by training belt 45 through a multiplicity of anode-cathode assemblies, if desired, or in other ways obvious to persons skilled in the art.

Numerous other systems for carrying out sequential separate water absorption-electrolysis can be devised. In general, each of these systems incorporates a first region reserved to drying by absorption removal of water into the deliquescent hygroscopic substance, a second region reserved to regeneration of the deliquescent hygroscopic substance by electrolysis of moisture therefrom, and conveyor means interconnecting the two regions adapted to sequentially and cyclically expose the deliquescent hygroscopic substance to the fluid to be dried within the first region and thereafter interpose the deliquescent hygroscopic substance between electrodes in the second region effecting the electrolytic regeneration of the deliquescent hygroscopic substance. One such 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 be dried to a separate region in which the electrolysis is carried out, the cycle being repeated indefinitely. Yet another system can utilize a conventional chemical packing, such as Raschig rings or the like, coated with the deliquescent 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 the absorbed water. Yet another system might utilize liquid impervious particulate solids coated with the deliquescent 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.

Where it is desired to obtain somewhat less than complete drying, as where only a reduction in the moisture content of a process gas or liquid may be desired, a somewhat dilute deliquescent hygroscopic medium may be advantageously employed as the drying agent, which then has a viscosity low enough so that it can be readily pumped and sprayed from distributors. In this case, it is practicable to use an arrangement such as that shown in FIG. 2 for conducting the drying, again with separate drying and regeneration facilities.

Referring to FIG. 2, drying is effected in vessel 70 which is provided with a wet fluid inlet 71 and a dry product exit 72. Vessel 70 is preferably filled with a suitable chemical packing to enhance contact between the fluid to be dried and the deliquescent hygroscopic liquid,

which is introduced at the top of the vessel in counter-flow to the fluid to be dried by projection under pressure through multiple spray head distributor 73. Moisture-laden hygroscopic medium is withdrawn from vessel 70 through bottom exit 74 which is connected to the inlet side of pump 75, which discharges the wet medium through line 76 to multiple spray head distributor 80 disposed in the top of the regeneration vessel 81. Vessel 81 is provided with a multiplicity of vertically disposed anode and cathode elements 82 and 83, respectively, which may be metal screens, only one pair of which is shown. The electrodes are disposed in close proximity one to another with anodes alternating with cathodes to make up a multiple electrode regenerating section in which the hygroscopic medium will bridge the electrodes by capillary attraction and thereby furnish a current-conducting path. Electrical connections with electrodes 82 and 83 are made through leads 84 and 85, respectively, insulated from electrical contact with vessel 81 by insulators 86, and connected to a D.-C. power source indicated generally at 87.

Vessel 81 is provided with a vent 88 at the upper end for discharge of the hydrogen and oxygen gases formed in the course of the electrolytic regeneration and with a bottom discharge opening connecting with drawoff line 89 which, in turn is connected to the intake of pump 90. Pump 90 recycles dry hygroscopic medium through line 91 to distributor 73, and thence into vessel 70 for additional drying.

In operation, it will be understood that the liquid deliquescent hygroscopic medium indicated schematically at 92 is continuously circulated in sequence from drying vessel 70 to regeneration vessel 81, drying the fluid in process by water absorption in 70 and being regenerated electrolytically in 81. The relative size of the two vessels and the number of regenerating electrode pairs employed depends on the materials in process, the extent of drying to be effected and other factors peculiar to the system at hand and therefore, these details are not elaborated further herein because they have no relationship to this invention.

From the foregoing it will be understood that this invention comprises drying apparatus which is adapted to the drying of both liquids and gases and which possesses very great advantages over drying apparatus 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 apparatus is readily controllable and the drying action is selective to water in all systems wherein there are no other ma-

terials 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.

I claim:

1. An electrolytic apparatus for drying a flowing fluid comprising in combination a first compartment and a second compartment, an inlet for introducing fluid to be dried into said first compartment and an outlet for withdrawing dried fluid from said first compartment, at least one pair of electrically isolated electrodes disposed in close proximity to one another within said second compartment, a deliquescent hygroscopic substance which is electrically conductive only when wet adapted to absorb water by contact with the fluid to be dried and to span the electrodes so as to provide a current-conducting path for electrolysis of water absorbed in said deliquescent hygroscopic substance, a direct current power source of voltage sufficient to electrolyze absorbed water in said deliquescent hygroscopic substance connected across said electrodes, and conveyor means interconnecting said first compartment and said second compartment for sequentially and cyclically exposing said deliquescent hygroscopic substance to said fluid to be dried in said first compartment and thereafter interposing said deliquescent hygroscopic substance between said electrodes in said second compartment for a sufficient time to decompose electrolytically a substantial portion of said water absorbed in said deliquescent hygroscopic substance.

2. An electrolytic apparatus for drying a flowing fluid according to claim 1 wherein said means for sequentially and cyclically exposing said deliquescent hygroscopic substance to said fluid to be dried in said first compartment and thereafter interposing said deliquescent hygroscopic substance between said electrodes in said second compartment consists of an endless belt of porous insulating material abutting said electrodes snugly provided with means for driving said endless belt through said first compartment and then through said second compartment.

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