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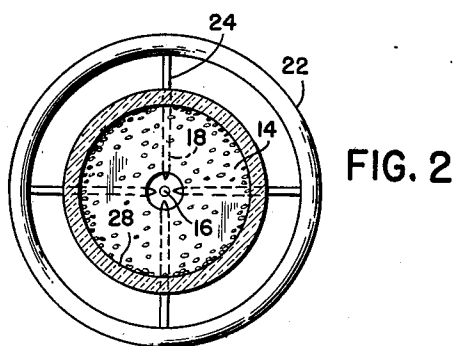
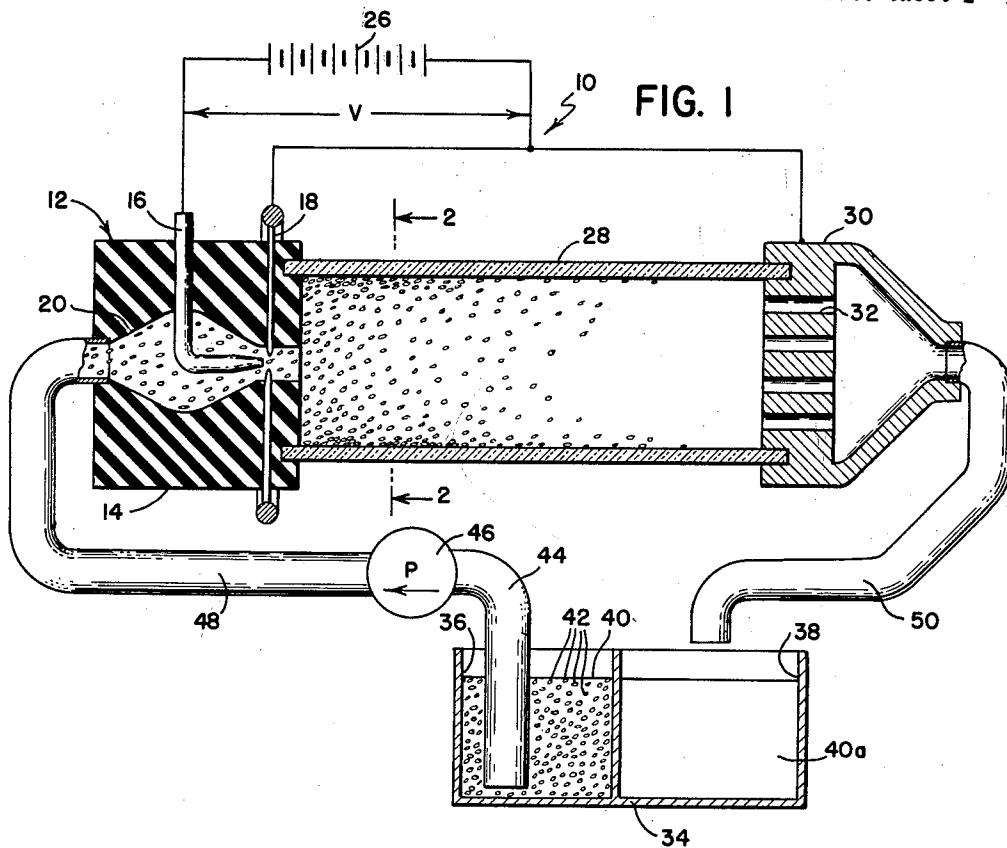
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SPACE-CHARGE FIELD PRECIPITATION METHOD

Filed June 15, 1960

2 Sheets-Sheet 1



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FIG. 4

The diagram shows a curved member 64 on the left, with a horizontal line labeled E_0 above it and a vertical line labeled E_1 to its left. To the right is a multi-layered assembly. The top layer is labeled 54 and has a hatched pattern. Below it is a layer labeled 56. A horizontal dimension V is indicated between two points on the top surface of layer 56. Below layer 56 is a layer labeled 58. Two vertical forces, both labeled F and 66, are applied to the assembly: one acts upwards on the interface between layers 56 and 58, and the other acts downwards on the bottom surface of layer 58. On the right side, two vertical dimensions, both labeled r , are indicated: one from the top surface of layer 56 to the interface between 56 and 58, and another from the bottom surface of layer 58 to the same interface.

FIG. 5

Diagram illustrating a device for measuring the electric field of a laser beam. A laser beam 78 is incident on a surface, creating a reflected beam E_r and a transmitted beam E_i . The transmitted beam E_i passes through a lens 70 and a diaphragm 72, creating a spot 74. The spot 74 is positioned at a distance V from a detector 68. The detector 68 is a rectangular block with a central channel 76. The channel 76 is divided into two regions, each labeled 80. The electric field components E_r and E_2 are indicated in these regions. The detector 68 is also labeled 76.

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The invention relates generally to particle precipitators, and pertains more particularly to a precipitation method employing a space charge field principle.

One object of the invention is to provide a space charge field precipitation method that will effectively hold the precipitate after the separation from the carrier fluid, thereby avoiding undesirable back diffusion. In other words, it is an aim of the instant invention to avoid the loss of precipitation through the loss of charge, or even the reversal of the charge on the precipitator.

Another object of the invention is to provide a precipitation method of the foregoing character which does not require an additional power source other than that for providing initial ionization of the fluid and the particles contained therein. More specifically, the present invention obviates the need for separately energizing plates or electrodes as have been necessary in some prior art devices.

Another object is to provide better hydrodynamic or aerodynamic conditions within the precipitator. In this regard, it is a desideratum of the invention to minimize any turbulence that might occur. In this way, more uniform filtration can be achieved.

A still further object is to provide a precipitation method in which the collector can be of transparent material, thereby facilitating the study of the deposits of precipitators as they are separated from the fluid. It is planned that an invention of this type will possess especial utility in studying bacteria in laboratories and the like.

Other objects will be in part obvious, and in part pointed out more in detail hereinafter.

The invention accordingly consists in the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereafter set forth and the scope of the application which will be indicated in the appended claims.

In the drawings:

FIGURE 1 is a longitudinal sectional view exemplifying one form of precipitator that the invention may assume;

FIGURE 2 is a sectional view taken in the direction of line 2—2 of FIGURE 1;

FIGURE 3 is a schematic view of one prior art device;

FIGURE 4 is a schematic view of a second prior art device, and

FIGURE 5 is a schematic view of a portion of a device constructed in accordance with the teachings of the present invention.

Referring first in detail to FIGURE 1, the embodiment there selected to illustrate the invention has been designated generally by the reference numeral 10. This precipitator comprises a corona point ionizer labelled 12. Included in the depicted ionizer is an electrically insulating support 14 for a pair of electrodes 16 and 18. As can be readily discerned from this view, the support 14 is centrally hollowed at 20 to form a passage through which fluid hereinafter described may flow. The passage 20 also provides a void in which the electrodes 16 and 18 come almost together.

The construction of the electrode 18 can be better understood by reference to FIGURE 2. As illustrated in FIGURE 2, the electrode is shown as having an outer

ring conductor member 22 with inwardly directed electrode portions 24 secured thereto. While any preferred number of electrodes 24 may be employed, four have been pictured. It might be well to point out at this time that the clearance between the internally disposed electrode points is quite small, being of the order of only 1.0 mm. However, the specific electrode spacing is dependent upon the rate of fluid flow and also upon the electrical potential applied across the electrodes 16, 18. An energizing source 26 for the electrodes 16, 18 has been schematically illustrated in the form of a battery 26, the negative side of the battery in this instance being connected directly to the electrode 16 and the positive side of the electrode 18.

Although the ionizer 12 is of conventional construction, it is utilized in a manner believed to be entirely different from that heretofore utilized. In this regard, it is intended that the ionizer 12 be situated at one locus. As a separate and distinct locus is a cylindrical insulating member denoted by the numeral 28. This cylindrical member is in direct communication with the ionizer 12, having its left end embedded or recessed into the support 14 so as to provide a fluid-tight joint. It is of the utmost importance that it be appreciated that the cylindrical member 28 possess a relatively high resistance, the higher the better. Suitable materials for the member 28 would be glass, porcelain, rubber, vinyl or one of the acrylic plastics, etc. These dielectric materials have a fairly high resistance and would be quite suitable. Inasmuch as it is contemplated that this invention will find considerable utility in the filtering out of biological material from a fluid carrier, transparent materials will be desired in conducting such biological examinations because the precipitate may be constantly viewed as it is being collected on the inner wall or surface of the member 28.

The device 10 further includes a metallic ion collector 30 at the right end of the cylindrical member 28, the member 30 having a plurality of passages or apertures 32 extending therethrough. The member 30 is connected to the positive side of the source 26 so as to neutralize any ionic charges that might remain in the fluid prior to its actual discharge. If residual charges are not objectionable, the member 30 may be omitted.

The device or apparatus 10 of FIGURE 1 is shown in association with a suitable receptacle 34 having a compartment 36 and a compartment 38. In the illustrated instance, the compartment 36 contains a liquid 40, such as water, benzene, heptane, or CCl_4 , this liquid containing the biological material or other matter 42 that is to be separated from the liquid.

A tube 44 is shown extending upwardly to the inlet side of a pump 46. The outlet or discharge side of the pump 46 is connected to a tube 48 leading to the passage 20 provided in the insulating support 14 of the ionizer 12. The metallic collector member 30 is suitably reduced at its discharge end so as to form a fluid tight seal with a return tube 50, the return tube leading to the compartment 38 of the reciprocal 34. Inasmuch as the particulate matter 42 will be removed from the liquid 40 during the precipitation process, the liquid that is returned is shown clear and has been distinguished by the suffix "a." While a liquid has been mentioned as the carrier for the matter to be separated, it will be understood that the fluid might be a gas, such as air, in many instances.

Before attempting to explain the operation of the embodiment 10, it will undoubtedly be of help to refer to two prior art devices. The device depicted in FIGURE 3 has been assigned the reference numeral 52, whereas the prior art device depicted in FIGURE 4 has been given the reference numeral 54. The device 52 employs the dielectrophoresis principle which involves separation

through the agency of polarization forces. On the other hand, the device 54 employs corona precipitation and is based on the same principle as used in the conventional Cottrell and Burke type of filter.

Basically, the device 52 of FIGURE 3 utilizes polarization of an uncharged particle in a non-uniform field so as to create a force which will tend to move the particle to locations with higher field strengths, this being what has been herein termed dielectrophoresis. In order to obtain a meaningful comparison between the device 52 (also the device 54) and the apparatus of the present invention, it is highly desirable that an explanation be provided as to just what electrical fields are produced in each of the three situations. In this regard, it will be first pointed out that the device 52 by necessity has a metallic outer tube 56 having concentrically disposed therein a center wire 58. The tube 56 has a radius r_1 and the wire has a radius r_0 .

Impressed between the electrodes 56, 58 is a voltage labelled V. A curve 60 has been presented in FIGURE 3 and shows graphically that the field strength E_0 at the center electrode wire 58 is not high enough to create ionization where the fluid is a liquid. The field strength at the cylindrical electrode 56, however, is greater and has been indicated by the character E_1 . Hence, the curve 60 varies between a relatively small field strength E_0 and much larger field strength E_1 . The field strength, it will be seen, is inversely proportional to the distance r_1 . Also, the force exerted on a particle having a given radius is proportional to the third power of that radius and inversely proportional to the third power of r_1 . Hence, collection takes place at the center electrode 58, the force causing such a collection having been denoted by the letters F and the accompanying arrows 62.

Passing now to a brief discussion of the prior art device 54, it is to be observed that here the center field strength E_0 is in this situation high enough to create ionization. Under the influence of the created space charge, the field is almost constant except in the neighborhood of the center of the electrode 58. This is graphically illustrated by the curve 64. The ions created by the corona discharge, if sufficiently numerous, attach themselves to the particles in suspension and pull them to the outside electrode. Here again, the letters F denote the forces and the arrows 66, the outward movement taken by the particles as a result of these created forces. The charge which the impurities or particles can acquire is proportional to the field strength in this present system. The force labelled F acting on each particle is in turn proportional of the square to the field strength and is independent of the location of the particles in the system except for a small amount of volume or region around the center electrode 58. It is believed that the curve 64 adequately pictures this situation. It should be understood, though, that if the particle or particles should for some reason not acquire a charge, they will not be collected.

As has already been stated, the devices 52 and 54 are schematic representations of what has been done heretofore. At this time, attention is directed to FIGURE 5 where a device 68 is set forth, this device employing the same principles as the previously alluded to embodiment 10. The device 68 comprises a corona point ionizer denoted generally by the reference numeral 70. This ionizer includes a pair of electrodes 72, 74 disposed so that the fluid passing through the ionizer is delivered to an insulating cylindrical or tubular member 76.

Although in the prior art arrangements 52, 54, the ionization process occurs concomitantly with the separation, it is to be observed that in the device 68 now under discussion the ionization occurs in the ionizer 70 and the separation or filtering action takes place within the cylindrical member 76. In other words, a space charge is created in the ionizer 70 which is flushed into the member 76 by movement of the carrier fluid.

The ensuing field which is built up as a result of the

space charge in member 76 above referred to is proportional to the distance r_1 from the axis of the tube or cylinder 76. This proportionality has been presented by the curve 78 which is actually a straight line. Consequently, the field is highest at the inner surface of the member 76, this having been denoted by E_1 . It will also be appreciated that the force on a particle within the confines of the cylinder 76 is proportional to r_1^2 . If a given particle should remain uncharged, the field distribution generated in the present situation still exerts a dielectrophoretic force proportional to r_1 which acts upon the particle. The system automatically creates, furthermore, a longitudinal field E_2 as indicated by the arrows 80. This will oppose the escape of charged particles in the lower part of the system and will aid in their collection there.

Having presented the foregoing information, the manner in which the embodiment 10 operates should be fairly clear. Nonetheless, a brief description of what takes place will undoubtedly be of benefit in providing a full appreciation of the advantages derivable from the precipitator of the instant invention. Accordingly, it will be remembered that the fluid in the illustrated case has been denoted by the reference numeral 40, this fluid containing particulate matter 42 that is to be separated within the cylindrical member 28. The pump 46 withdraws the liquid 40, together with the suspended matter 42, from the compartment 36 and delivers it to the passage 20 formed in the support 14 of the ionizer 12. For purposes of illustration, it will be assumed that the pump delivers the liquid 40 to the ionizer 12 at a rate of 15 m./sec. For such a pumping rate, the spacing of the electrodes 16, 18 with respect to each other can be of the order of 1 mm., as already suggested. The energizing source 26 should provide approximately 15 kv. for this particular flow rate and electrode spacing. It will be understood, of course, that these values are only suggestive and are susceptible to rather wide variations. However, they do provide an indication of what is desirable in the way of operating details.

With the polarity of the source 26 such that the electrode 16 is negative with respect to the electrode 18, negative ions are produced in the ionizer 12 which pass into the cylindrical member 28. Due to the friction of the fluid on the inner surface of the cylindrical member 28, the fluid speed is the lowest in this zone. This in turn makes it easier for small particles to stay in the high field on the cylindrical wall without being exposed by high drag forces by the moving of liquid 40. The field strength within cylindrical member 28 is determined by the charge on its interior. From the equation

$$E = \frac{2\rho r}{\epsilon}$$

where E = the field strength, ρ is the charge at the radius r of the cylindrical member, and ϵ is the dielectric constant for the fluid medium 40.

Up to this point nothing has been said about the radial dimensions for the cylindrical member 28. Here again, dimensions are not crucial, but a radius of approximately one-half inch has been found to be satisfactory for the conditions heretofore assumed. The length of the cylindrical member 28 is also capable of wide modification and should be such as to give the particles 42 a chance to accumulate on the inner surface of the member 28 before passing out through the ion collector member 30.

The ion collecting member 30 will not always be employed, for it is only needed when all charges are to be removed from the liquid 40. If remaining or residual charges are not objectionable, then the member 30 can be dispensed with.

As certain changes could be made in the above construction, it is intended that all matter contained in the above description or shown in the accompanying draw-

ings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the language used in the following claims is intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed:

1. A space-charge precipitation method for particle-laden liquid, which comprises in sequence the steps of passing said liquid through ionizing means to provide ions in said liquid which electrically charge the particles to be precipitated and provide a space charge in said liquid, passing said liquid through a dielectric conduit with a velocity sufficient to move the charged particles away from said ionizing means into said dielectric conduit so that the charged particles are collected on the inner surfaces of the dielectric conduit, and withdrawing the relatively particle-free liquid from said conduit.

2. A space-charge precipitation method for particle-laden liquid, which comprises in sequence the steps of

passing said liquid through ionizing means to provide ions in said liquid which electrically charge the particles to be precipitated and provide a space charge in said liquid, passing said liquid through a dielectric conduit with a velocity sufficient to move the charged particles away from said ionizing means into said dielectric conduit so that the charged particles are collected on the inner surfaces of the dielectric conduit, and withdrawing the relatively particle-free liquid from said conduit while electrically neutralizing any charges that might remain in said liquid.

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