Aug. 17, 1971 R. DAVIS 3,600,135

APPARATUS FOR REAGENT FORMATION

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FIG. 1

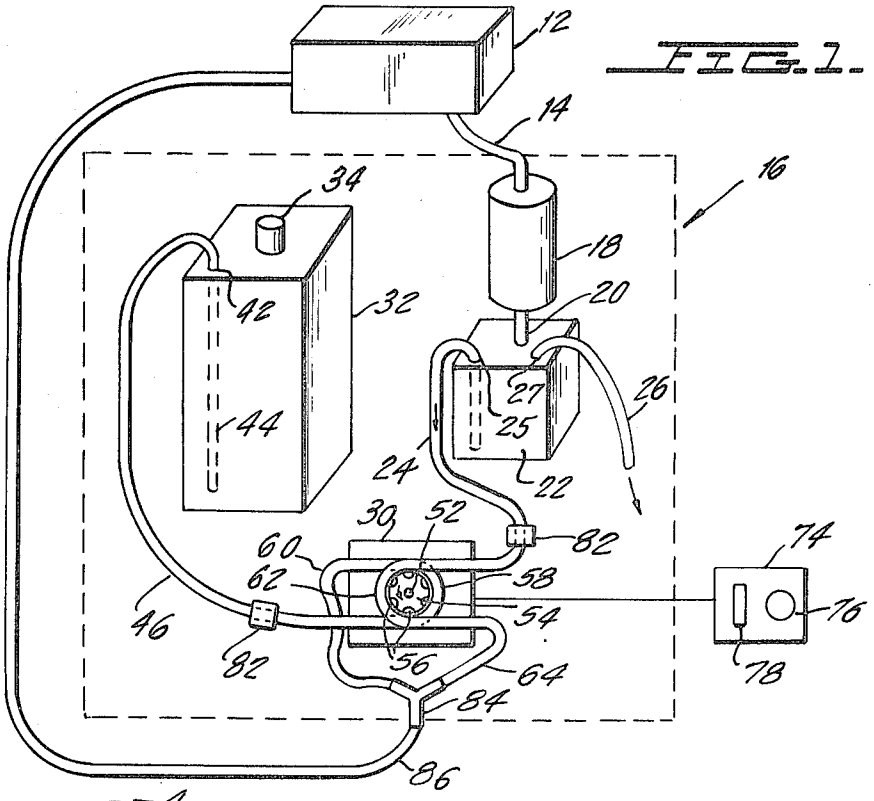
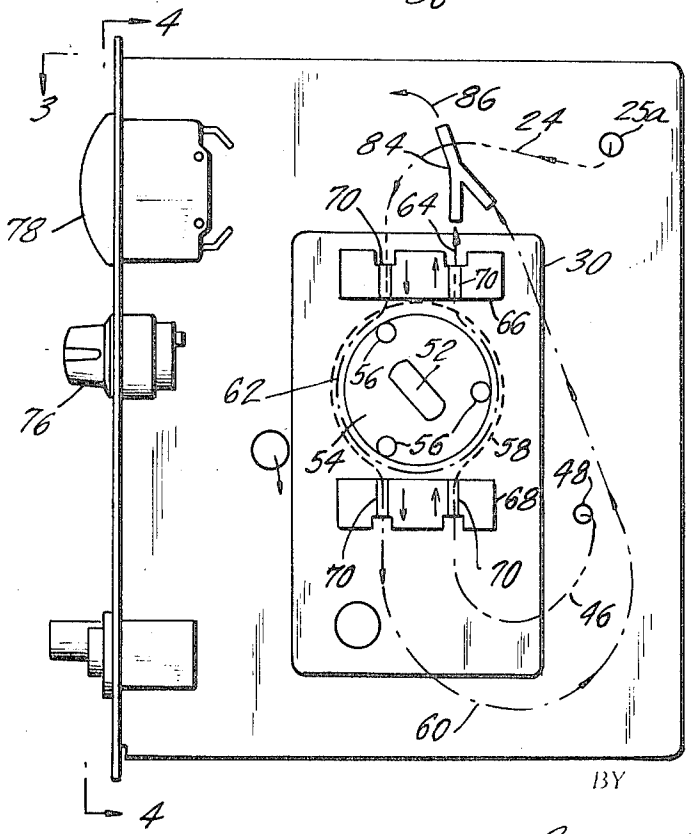


FIG. 2



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FIG. 3.

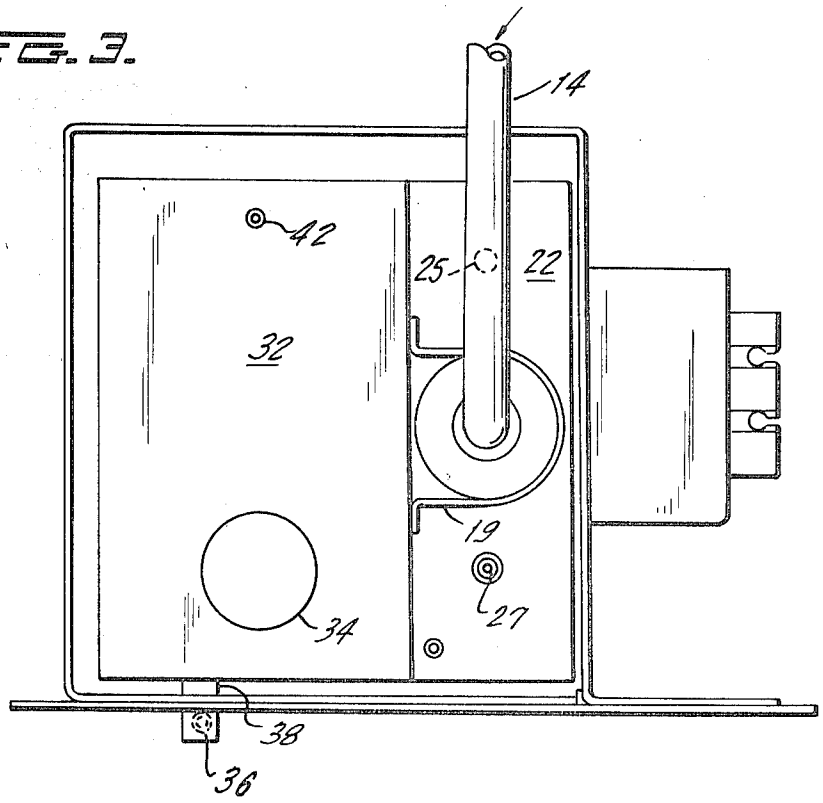
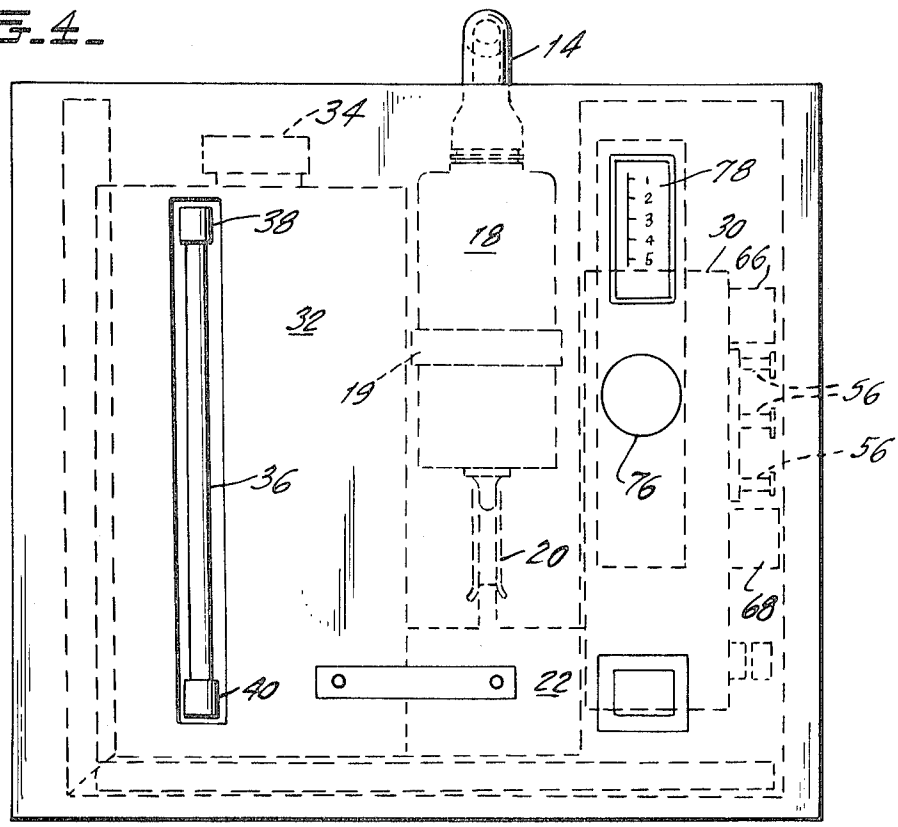


FIG. 4.



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APPARATUS FOR REAGENT FORMATION

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U.S. Cl. 23—253 3 Claims

ABSTRACT OF THE DISCLOSURE

Reagent for use in an apparatus is formed from concentrated reagent mixed with an additional reagent component, e.g. a diluting medium, such as deionized and demineralized water; the newly formed reagent passes through an apparatus that uses and alters the reagent; the liquid from the apparatus passes through a treatment cartridge where certain components are removed and/or others are added, e.g. a deionizing and demineralizing cartridge where the ions and minerals are removed from the spent and altered reagent creating deionized and demineralized water; this treated liquid is newly reformed additional reagent component which is again mixed with concentrated reagent to form new reagent.

The present invention relates to a device for forming reagent. The reagent formed may be used in a sample analyzing apparatus or in any other type of apparatus where reagent is required. The invention is most useful when used in conjunction with an analyzing apparatus requiring a continuously replenished supply of fresh reagent over an extended period of time.

Presently, reagent is formed at the needed dilute concentration at a location remote from where it is to be used. Then a supply of the completed reagent is transported to an apparatus requiring it.

Alternatively, concentrated reagent is provided in a reservoir located where the completed reagent is to be used, and an outside source of either diluting medium, such as water, or of another component of the reagent, for being mixed with the concentrated reagent, is provided. The diluting medium or the reagent component from the outside source flows together with the concentrated reagent, and together they form new reagent.

Consider the first of the above-described prior art apparatus. Dilute preformed reagent is used up at a faster rate than concentrated reagent which is mixed with a diluting medium or an additional reagent component. Hence, the frequency with which the reservoirs of dilute reagent must be replaced increases with the extent of dilution of the reagent. Greater frequency of changing reagent reservoirs shortens the period of time for which equipment may be left unattended. This increases the number of man-hours that must be expended in servicing the equipment. To reduce the frequency with which reagent reservoirs must be replaced, larger reservoirs are used. Equipment using large reservoirs has to be larger and heavier than equipment which can use smaller reservoirs. Heavier equipment is less portable. More storage space for reagent reservoirs is required if the reagent is diluted since the reagent is used up at a faster rate and a greater volume of reagent must be kept on hand.

There are other reasons why it is undesirable to use dilute reagent. Dilute reagent is normally a mixture of concentrated reagent and a diluting medium, like water. When the dilute reagent is originally formed, the water is purified and fresh. But, as the water sits in the container, it becomes stale and absorbs ions from its container or from its surroundings, including the outside air and the air in the container. Hence, the entire batch of reagent in the container deteriorates. The reagent concentrate, on the other hand is more stable. Where reagent is stored at greater concentration, therefore, since the reagent container holds less water by volume, there is less material to deteriorate and the deterioration in the reagent quality is reduced.

When reagent is stored at high concentration and it deteriorates slightly, since the stored reagent is mixed with an additional reagent component, e.g. a diluting medium, such as water, the slight deterioration that occurred in the concentrated reagent will be divided by the same factor by which the concentrated reagent is diluted by the additional component, whereby the effect of the deterioration is reduced.

Furthermore, with presently available equipment, and within the limits of reasonable expense for forming reagent, reagent of desired concentration can be formed with only a certain degree of accuracy. This degree of accuracy is obtainable regardless of whether the reagent is more or less concentrated. After a concentrated reagent solution is formed, it is diluted to a fraction of its previous strength in the apparatus of the invention. Any errors in the formation of the concentrated reagent are divided by the same factor as the concentrated reagent is diluted, whereby the effects of incuracies in the formation of the concentrated reagent are proportionally reduced.

The second form of prior art apparatus makes use of a supply of concentrated reagent. Such apparatus must be connected to a continuous supply of diluting medium, such as water, or to a continuous supply of additional reagent component. Thus, a separate reservoir of diluting medium or reagent component must be provided or the reagent formation apparatus must only be used where there is ready access to a continuous supply of diluting medium or reagent component.

If the supply of diluting medium or extra reagent component is carried about with the reagent forming apparatus, this increases the weight and bulkiness of the apparatus and decreases its portability. In addition, the diluting medium or additional reagent component may deteriorate in its container if stored too long. The newly formed reagent is intended to react with other substances and the reaction must be identical under conditions where an identical volume of reagent and substance being reacted with the reagent are present. Periodic zero checks must be made on the supply of diluting medium or additional reagent component to compensate for changes in its qualities among different containers of this material. If the effect of the changes is not cancelled out by frequent adjustments after frequent zero checks, the reactions with the completed reagent will not be consistent, and measurements of these reactions will be unnecessarily inaccurate.

If, on the other hand, connection to an outside supply of liquid must be made, the apparatus can only be set up near a needed liquid supply source which reduces the choice of places where the apparatus may be used.

Furthermore, where the diluting medium or additional reagent component is water or another material obtained from an outside source of supply, as the liquid supply flows, its qualities and the impurities in it may vary. Here, too, frequent zero checks are required on the liquid from the outside source to compensate for variations in its qualities.

The requirement for frequent zero checks in both versions of the second form of prior art apparatus means that they may not be left unattended for a long period of time, thereby increasing the man hours which must be used servicing the apparatus during operation.

The present invention makes use of containers holding reagent in concentrated form and includes an apparatus

for forming and then mixing either a diluting medium or an additional component with concentrated reagent. A diluting medium is effectively an additional reagent component. For simplicity, the discussion hereafter will mention only an additional reagent component, but all reagent components are included, including diluting mediums.

The present invention is intended for use in conjunction with a reagent using apparatus, e.g., an analyzing apparatus, which requires reagent be delivered substantially continuously, or periodically, to it over a period of time. The reagent using apparatus causes a change in the character of the newly formed reagent passing through it. For example, if the reagent using apparatus contains a substance that reacts with the reagent, the reagent is changed by the reaction and has certain ions and minerals removed and/or added to it. Impurities may have been picked up. The now altered and contaminated reagent moves to the input to the present invention. The apparatus of the present invention includes equipment for treating the spent reagent to form anew the additional reagent component. Hence, no separate connection to an outside source of additional reagent component, e.g. to a water supply if the component is water, is required. It is not necessary to carry around a portable supply of additional reagent component. In the treatment equipment the spent and contaminated reagent is altered to form anew the additional reagent component. Where the treatment equipment is a deionizing and demineralizing means which removes all cations and anions from the liquid passing through it, the liquid is treated to become deionized and demineralized water.

The additional reagent component is not stored, but is used fresh immediately after its formation. Deterioration of the additional reagent component is thereby precluded, which reduces the frequency or eliminates the need for frequent zero checks.

After passing through the treatment equipment, the reformed additional reagent component is drawn through a pump means. A separate container of concentrated reagent which is to be mixed with the newly formed additional reagent component is connected to the pump means. The pump means may be located in the apparatus and may operate on any of the elements of the apparatus to bring about the required pumping operation.

The pump means pumps both concentrated reagent and additional component in correct proportions to a mixing means which may merely by a junction between the conduit from the concentrated reagent container and the conduit carrying reformed additional component.

To provide proper proportioning of the volume of concentrated reagent to the volume of reformed additional component, appropriate flow restriction devices are placed in the flow paths of the concentrated reagent and the additional component.

The mixing means for mixing the flow of concentrated reagent and the flow of newly formed additional component is downstream of the flow restriction means that apportions the rate of flow of concentrated reagent and additional reagent component. The mixing means would normally be downstream of the pump means, although it may be upstream of the pump means within the contemplation of the invention.

A particular type of pump means that may be employed is a peristaltic pump. Peristaltic pumps generally act upon flexible tubing that is filled with liquid which it is desired to move through the tubing. The tubing is occluded at one location. Then the means which occludes the tubing progressively occludes it further downstream of each preceding occlusion, whereby the liquid in the tube in front of each occlusion is moved downstream.

In the illustrated embodiment of the present invention, flexible tubes which conduct both concentrated reagent and reformed additional reagent component pass around rigid studs which press against and occlude the tubes. The studs are moved along the tubes, while continuing to occlude them, thereby pushing liquid downstream of the studs downstream through the tubes.

The newly formed reagent then passes to the reagent using apparatus where it again is acted upon and altered. The spent and altered reagent again passes into the treatment means of the invention where, again, additional reagent component is reformed to be later mixed with concentrated reagent to form more reagent.

It is apparent, therefore, from the foregoing that it is not necessary to connect an apparatus in accordance with the present invention to an outside source of additional reagent component or with a separate reservoir of the component, whereby a user of the apparatus of the invention is not limited as to the location where he may use the apparatus and the apparatus need not be unnecessarily heavy. Because the present invention makes use of concentrated reagent, it also has all of the benefits described above of a concentrated reagent using prior art apparatus. Additionally, frequent zero checks are not needed.

Accordingly, it is a primary object of the present invention to provide an apparatus for forming reagent.

It is another object of the present invention to provide such an apparatus which forms reagent by mixing concentrated reagent with an additional reagent component that is formed by the apparatus from previously used and altered reagent.

It is another object of the present invention to provide such an apparatus where supplies of materials for forming reagent are not used up unnecessarily rapidly.

It is another object of the present invention to provide such an apparatus which can be operated without frequently replacing the reagent reservoir.

It is another object of the present invention to provide such an apparatus where reservoirs of materials for forming reagent need not be unduly large and heavy.

It is another object of the present invention to provide such an apparatus which will minimize the effects of deterioration in one of the materials for forming the reagent.

It is another object of the present invention to provide such an apparatus which reduces the requirement for access to an outside source of diluting medium or reagent component.

It is another object of the present invention to provide such an apparatus which maximizes the number of different locations where the apparatus may be employed.

It is another object of the present invention to provide such an apparatus which does not require frequent checks on the operation of the apparatus once it has commenced.

It is another object of the presention to provide such an apparatus which is readily portable.

These and other objects of the present invention will become apparent when the following description is read in conjunction with the following drawings in which:

FIG. 1 schematically illustrates an apparatus designed in accordance with the present invention;

FIG. 2 is a side elevation of an apparatus designed in accordance with the invention;

FIG. 3 is a top plan view in the direction of arrows **3** of FIG. 2 of the apparatus of FIG. 2;

FIG. 4 is a front elevation in the direction of arrows **4** of FIG. 2 of the apparatus of FIG. 2.

Since all of the figures show the invention, all corresponding elements are identically numbered.

Reagent using apparatus **12** is not part of the invention. But, it is the function of the invention to provide reagent to apparatus **12**. For illustrative purposes only, apparatus **12** might comprise a bed of material including a component which is intended to be reacted with reagent. The reagent flows over the bed, reacts with the material in the bed, is altered, and forms a solution containing various cations and anions. It also may pick up impurities and minerals from the bed. Alternatively, apparatus **12** may

be used to determine the quantity of a component present in a gaseous sample. The reagent reacts with the component and is altered and forms a solution of various ions and minerals; and the reaction is measured.

The now changed and contaminated liquid material in apparatus **12** moves through conduit **14** under the force of gravity into the apparatus **16** of the present invention. The first stage in the apparatus is the treatment cartridge **18** which contains a material that operates upon the liquid flowing through it to form anew an additional reagent component which is to be later mixe with concentrated reagent to form a new supply of reagent for apparatus **12**, as described below. Throughout the rest of this description, the material formed by the treatment cartridge **18** will be generically referred to as a reagent component. The active materials in treatment cartridge **18** may be adapted to remove certain components, e.g. ions or minerals, from the liquid flowing through the cartridge and/or may be adapted to add certain components to the liquid.

As shown in FIG. 3, the cartridge **18** is held by a bracket **19** to the side wall of the to be described reagent reservoir **32**.

In a preferred embodiment of the present invention, the reagent component desired to be formed is deionized and demineralized water, which is later to be mixed with concentrated reagent to dilute same. Any conventional deionizer for removing both cations and anions would be acceptable. One ion remover which might be employed in cartridge **18** is a resin containing a styrene divinyl benzene copolymer carrier with a cation remover comprising a strongly acidic sulfonic acid and ananion remover comprising strongly basic quaternary ammonium moieties. The deionizer will also remove minerals in ion form. Other impurities may be removed by adsorption on a typical adsorption medium, such as carbon.

The now treated liquid from cartridge **18**, which as been formed by the catridge into additional reagent component, passes under the force of gravity through conduit **20** into a temporary storage reservoir **22**.

Conduit **26**, which is not shown in FIG. 3, exists from reservoir **22** through fitting **27**. Conduit **26** carries away floating wastes on the surface of the liquid in reservoir **22** and also carries away excess or overflow reagent component in the reservoir.

Conduit **24** from reservoir **22** leads from fitting **25**. Conduit **24** is not shown in FIG. 3. The conduit passes through fitting **25***a* shown in FIG. 2. The reagent component in temporary reservoir **22** is drawn by pump **30** toward the pump through conduit **24**.

A separate reservoir **32** of concentrated reagent is provided. The reservoir may be a replaceable container which is replaced when the liquid in it is used up. Alternatively, reservoir **32** may be permanent fixture in the apparatus, which is filled with concentrated reagent through filler cap **34**. The material of which reservoir **32** is comprised may be any material which adequately protects the concentrated reagent and which will not react with the reagent.

In FIG. 4, a reagent volume gauge **36** is provided for reservoir **32**, which comprises an elongated transparent tube comprised of a material which will not react with or cause deterioration of the concentrated reagent, and which tube communicates at its top through a conduit **38** and at its bottom through a conduit **40** with the interior of the reservoir **32**. The liquid concentrated reagent within reservoir **32** will seek its own level within gauge **36** and thereby the level of the concentrated reagent within reservoir **32** can be observed.

Reservoir **32** includes an outlet fitting **42** having an outlet conduit **44** passing therethrough and extending into reservoir **32**, thereby to draw concentrated reagent out of the reservoir. Conduit **46** leads from fitting **42** toward the pump **30**. Conduit **46** is not shown in FIG. 2 through 4. However, conduit **46** passes through outlet fitting **48** in FIG. 2.

Returning to FIG. 1, pump **30** is a peristaltic pump. As was discussed above, a peristaltic pump pumps fluid through a flexible tube by occluding the tube and then moving the location of the occlusion progressively downstream, whereby fluid in front of the occlusion moves downstream. As shown in FIGS. 1 and 2, pump **30** comprises a pump housing containing a pump motor which is a conventional electric motor for rotating the pump shaft **52**. Secured on pump shaft **52** is a disc **54** which is rotated by the shaft. Extending outward from the disc is at least one and preferably a plurality of rigid studs **56**.

As shown in FIG. 1, tube **46** passes at **58** around studs **56**. After passing around the studs, the conduit at **60** leads away from pump **30**. Similarly, conduit **24** passes around studs **56** at **62**, and after passing around the studs, the conduit leads away from the pump at **64**.

FIG. 2 schematically shows the same liquid pathways through pump **30** as FIG. 1 through the use of directional broken lines.

Pump **30** causes the liquid within conduit **46**, **58**, **60** and the liquid within conduit **24**, **62**, **64** to move past the pump by having the disc **54** rotate counterclockwise, as viewed in FIGS. 1 and 2, and by having the liquid conducting tubes drawn sufficiently tight against studs **56** that the studs occlude the tubes. When the studs move, each stud moves downstream along a tube, thereby forcing the liquid in the tube progressively downstream of the occlusion caused by the stud.

Turning to FIG. 2, to retain the liquid conducting tubes tightly against the studs **56**, tube gripping blocks **66** and **68** are provided which have receiving slots **70** therein for receiving and gripping securely the liquid conducting tubes. The tubes are drawn tightly around studs **56** and then are secured in position in slots **70**.

Pump **30** also has a speed control means **74** connected with it, including a speed control knob **76** and a gauge **78** which indicates the speed of pump rotation and hence the rate of reagent production. The pump is an electrical pump and the speed of rotation may be varied by varying the power supplied to the pump through any conventional electric power varying means, such as a variable resistor.

The concentrated reagent in reservoir **32** must be diluted with the reagent component in reservoir **22**. The amounts of reagent component and concentrated reagent flowing together must be accurately apportioned in order that the concentration and other qualities of the resulting reagent can be predictable. Means must, therefore, be provided for apportioning the rate of flow of the concentrated reagent with respect to the rate of flow of the additional reagent component. For example, if the reagent component being mixed with the concentrated reagent is a diluting medium, such as water, for diluting the concentrated reagent, and if, for example, reagent in reservoir **32** is at ten times the desired concentration, then the flow rates through conduits **46** and **24** must be chosen so that ten times the amount of diluting medium is pumped through conduit **24** and out conduit **64** than the amount of concentrated reagent that is pumped through conduit **46** and out conduit **60**.

One way of accomplishing relative flow rate adjustment would be to adjust the diameter of the opening through conduit **46** with respect to the diameter of the opening through conduit **24**.

Another way of adjusting the relative flow rates is by providing flow restriction means **82** in the path of flow through each of conduits **24** and **46**. These flow restriction means might merely be narrowed bore fittings where the diameter of the bore is chosen to provide a desired flow rate.

The concentrated reagent now in conduit **60** and the additional reagent component in conduit **64** must be mixed to complete the formation of reagent. Accordingly, a mixing means **84** is provided, which is shown as comprising a simple Y-fitting which joins the flow through conduits **60**, **64** into flow through a single exit conduit **86**.

While the mixing means **84** is shown as being down-

stream of pump **30**, it may be upstream of the pump. The mixing means must, however, be downstream of the flow rate apportioning means so that the amount of each of the reagent component and the concentrated reagent are fixed before they are mixed.

Exit conduit **86** leads to the apparatus **12** previously described, thereby completing the cycle.

As shown in FIGS. 2–4, the entire apparatus designed in accordance with the invention may be enclosed within a relatively small housing, whereby the apparatus is light in weight and readily portable to remote locations where the apparatus may be needed.

In one use for the invention, the reagent newly formed by the apparatus of the invention is used in apparatus **12** to analyze a gaseous sample for the presence of sulfur dioxide. The concentrated reagent in reservoir **32** is comprised of concentrated hydrogen peroxide and dilute sulfuric acid. The cartridge **18** contains a complete deionizer and demineralizer so that the reagent component formed in cartridge **18** and passing into temporary reservoir **22** comprises deionized and demineralized water. Upon the mixing of the concentrated reagent and the water in correct proportions, diluted reagent is newly formed.

When the diluted reagent passes into apparatus **12**, which is an analyzer, and contacts the sulfur dioxide, a reaction occurs by which the reagent becomes more acidified. The acid level is electrically sensed and measured. The strength of the electric signal may be expressed in terms of the extent of the presence of sulfur dioxide.

Were there unwanted ions, minerals or impurities present in the water which is mixed with concentrated reagent or had the concentrated reagent deteriorated, this would adversely affect the measurements made by the apparatus **12**. However, the inventive apparatus forms water diluting medium which is always identical in quality. The water is used almost immediately, so that there is no time for it to deteriorate. Therefore, with the present invention, no zero checks are required of the water in reservoir **22** to compensate for changes in the quality of the water. Furthermore, the reagent used with the invention is concentrated and it will not deteriorate materially before use. Further still, the reagent which passes to the analyzer will be accurately diluted by the apparatus of the present invention to ensure that accurate measurements will be made by the apparatus **12**.

Although the invention has been described above with respect to its preferred embodiments, it will be understood that many variations and modifications will be obvious to those skilled in the art. It is preferred, therefore, that the scope of the invention be limited not by the specific disclosure herein but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. A reagent formation apparatus comprising,

a treatment cartridge for treating a liquid to form an additional reagent component to be mixed with a concentrated reagent; a conduit connecting said cartridge with a storage container so that the liquid passing through said cartridge will empty into said storage container;

a first conduit for conducting the additional reagent component which is in said storage container toward a pump means; said first conduit including a first flow restriction means;

a reservoir for holding a solution of liquid reagent in concentrated form;

a second conduit connected to said reservoir for conducting the concentrated reagent toward a pump means; said second conduit including a second flow restriction means;

said first and said second flow restriction means being chosen so as to proportion the rate of flow through each of said first and second conduits that the reagent formed from the flow of liquid through these two conduits is at the proper concentration level;

a junction between said first and said second conduits for mixing the separate flows of additional reagent component and concentrated reagent;

a third conduit for conducting the completed reagent formed from the mixture of concentrated reagent and additional reagent component which exits from said junction to an apparatus where the newly formed reagent is operated upon;

a peristaltic pump means which acts directly upon said first and second conduits to pump additional reagent component which exits from said cartridge and to pump concentrated reagent from said reservoir toward the apparatus; said junction being downstream of said pump means; and

a fourth conduit for conducting the liquid to said cartridge, whereby no separate supply of additional reagent component is required because the liquid is treated to supply additional reagent component anew.

2. The reagent formation apparatus of claim **1**, wherein said cartridge contains a material for changing the characteristics of the operated upon additional reagent component passing through said cartridge so as to form it into additional reagent component for diluting the concentrated reagent.

3. The reagent formation apparatus of claim **2**, wherein said cartridge contains a material for both deionizing and demineralizing the operated upon additional reagent component passing through said cartridge, thereby to form deionized and demineralized water as an additional reagent component.

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U.S. Cl. X.R.

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