

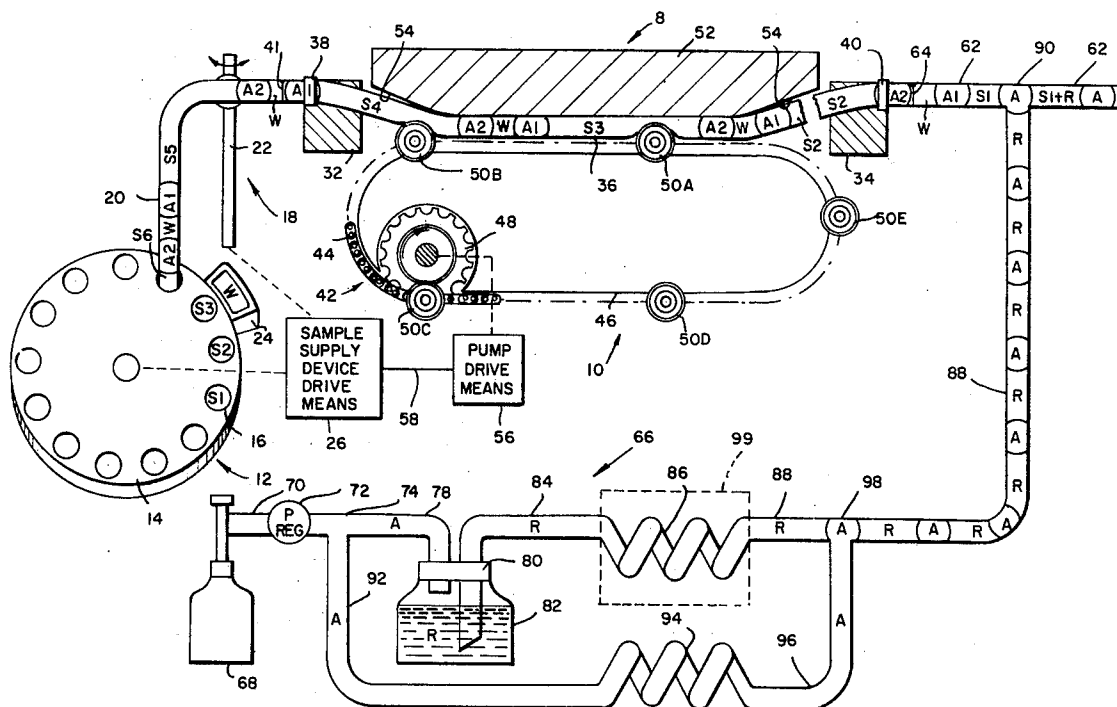
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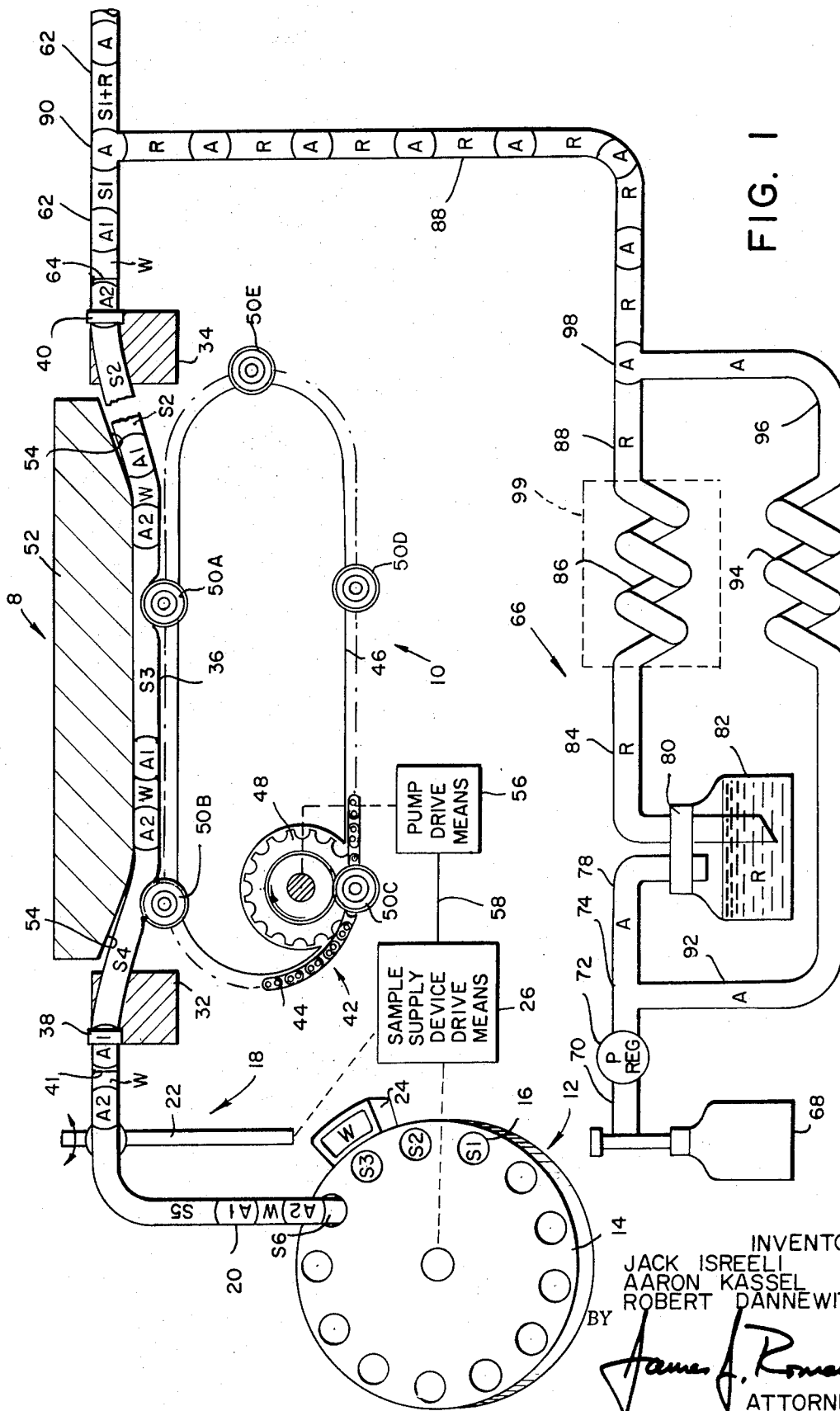
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 3,588,281 6/1971 Isreeli et al. 417/53
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[54] **METHOD FOR THE MINIMIZATION OF THE EFFECTS OF PULSATIONS IN INTERMITTENT PUMPING SYSTEMS**
25 Claims, 5 Drawing Figs.

[52] U.S. Cl..... **417/53,**
417/476
 [51] Int. Cl..... **F04b 43/12,**
F04b 45/08
 [50] Field of Search..... **417/53, 54,**
474, 475, 476, 477

ABSTRACT: New and improved method for minimizing the effects of pulsations which occur during the operation of intermittent pumping systems is provided and, as disclosed, is applied to a peristaltic pump which is utilized in a fluid sample supply, treatment and analysis system and comprises the minimization of the effects of the pulsation which occurs each time a pump roller occludes the compressible pump tube, and the minimization of the effects of the pulsation which occurs each time a pump roller discontinues the occlusion of the compressible pump tube.





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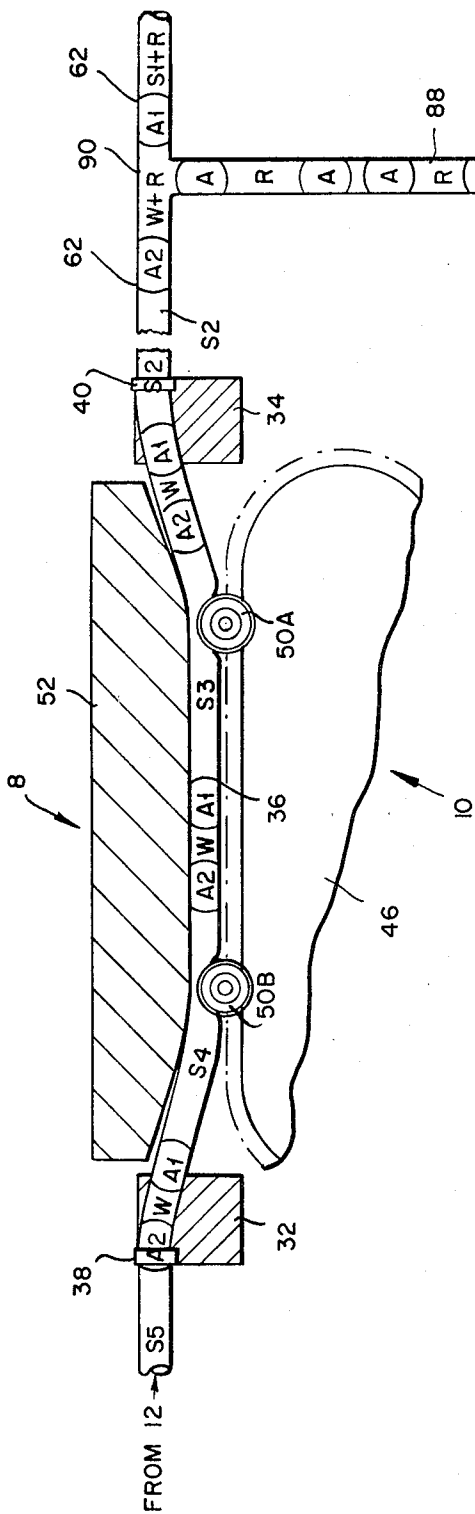


FIG. 2

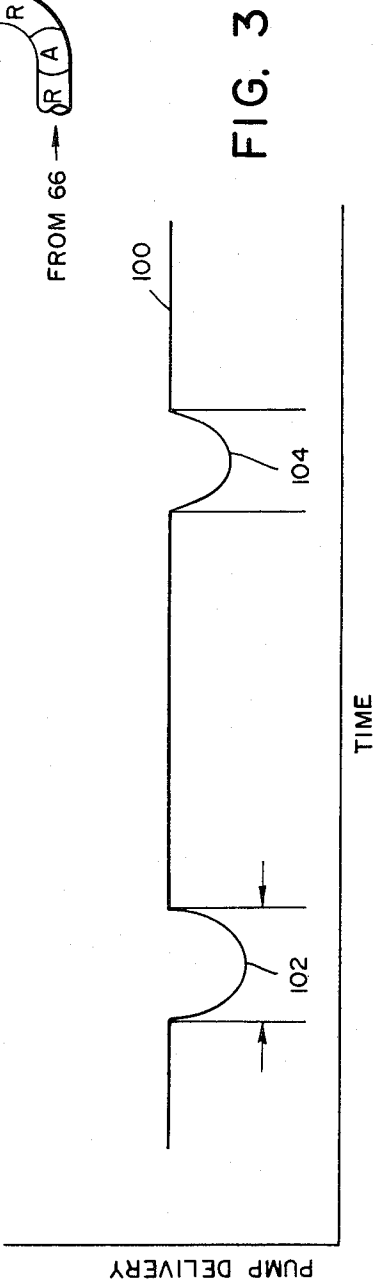


FIG. 3

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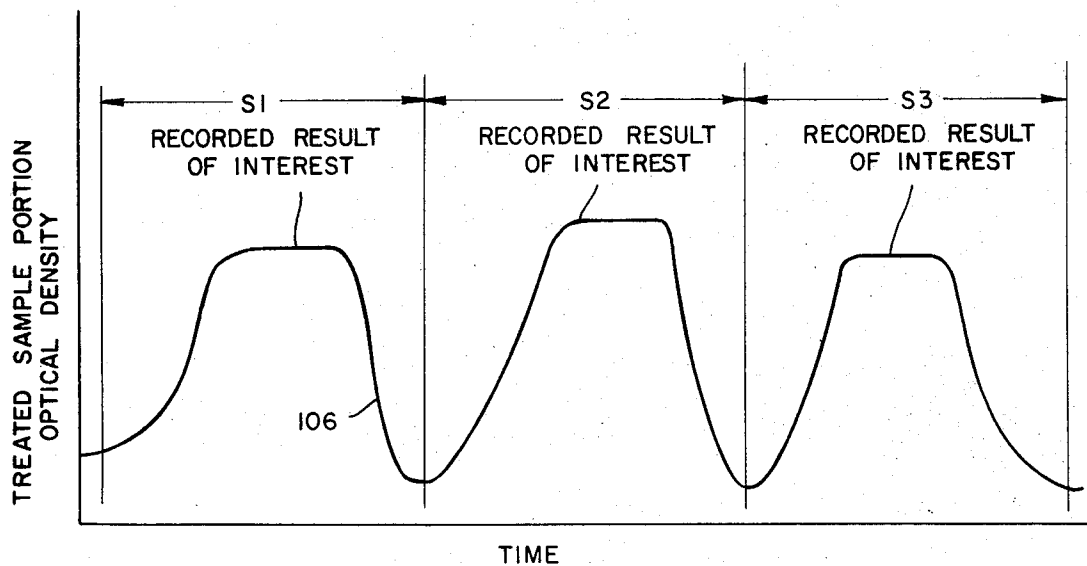


FIG. 4



FIG. 5

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METHOD FOR THE MINIMIZATION OF THE EFFECTS OF PULSATIONS IN INTERMITTENT PUMPING SYSTEMS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to new and improved method for minimizing the effects of pulsations which occur during the operation of intermittent pumping systems.

2. Description of the Prior Art

In any intermittent pumping system in the nature, for example, of a peristaltic pumping system or a pressure-pumped exchange valve and pilot fluid pumping system, it may be understood that intermittent pulsations in the provided flow rate will, of necessity, occur. For use, for example, in automatic, sequentially operable substantially constant flow rate fluid sample supply, treatment and analysis means of the nature disclosed in U.S. Pat. No. 3,241,432 issued Mar. 22, 1966 and assigned to the assignee hereof, and which are operable to supply, treat and analyze a stream consisting of successive sample portions, it may be understood that such intermittent pumping systems may be utilized without significant regard for such pulsations because of the minimization of the effects of the latter as provided by the relatively long sample portion sampling times and the relatively high flow rates and volumes of said sample portions, which, in essence, combine to function to average or spread out such effects over relatively long periods of time and throughout relatively large sample portion volumes to thereby render the same tolerable. For use of such intermittent pumping systems with newly developed and highly improved versions of such sample supply, treatment and analysis means which are operable, to significant advantage, at substantially reduced sample portion sampling times and with substantially reduced sample portion flow rates and volumes, however, it may be understood that a method must be provided to minimize the effects of such pulsations, or that unacceptable variations in the essential sample portion phasing and in the essential sample portion-sample treatment fluid proportioning will result.

OBJECTS OF THE INVENTION

It is, accordingly, an object of this invention to provide new and improved method to minimize the effects of pulsations which occur during the operation of intermittent pumping systems.

Another object of this invention is to provide method as above which may be applied to said intermittent pumping systems without structural modification of the latter.

A further object of this invention is the provision of method as above which is particularly adaptable for use in intermittent pumping systems which form part of automatically operable, substantially constant flow rate fluid sample supply, treatment and analysis means.

SUMMARY OF THE INVENTION

As specifically disclosed herein by way of illustration, the method of the invention is applied to a peristaltic pump which is operable, in a fluid sample analysis system, through the progressive occlusion of a compressible pump tube by a plurality of substantially equally spaced pump rollers to pump fluid sample portions in a precisely phased successive stream thereof from fluid sample supply means to fluid sample treatment and analysis means. A separating fluid portion which includes an air segment is provided in said fluid sample portion stream intermediate adjacent fluid sample portions. A pulsation in the pump delivery rate occurs each time a said pump roller occludes said pump tube, and each time a said pump roller discontinues the occlusion of said pump tube. Said fluid sample portions are supplied to said compressible pump tube by the aspiration thereof from sample container means through the inlet end of a connected sample offtake device which functions as pump inlet means, and each of said fluid sample portions is treated downstream of said compressible

tube pump by the mixture thereof in precisely determined proportion with a sample treatment fluid through the merger of a stream of the latter with said sample portion stream. The method of the invention minimizes the effects of the first-mentioned pulsation by insuring, through proper control of the operational timing of said pump rollers and said pump inlet means flow path length determination, that said offtake device inlet end is not exposed to the air at the time said pulsation arrives thereat to thus insure the aspiration of the separating fluid portion air segment of the required volume. The method of the invention minimizes the effects of the second-mentioned pulsation by insuring, through proper determination of the flow path length between said pump roller as the latter discontinues said occluding contact, and the point at which said sample portion stream merges with said sample treatment fluid stream, that one of said separating fluid portion air segments is disposed at said merger point at the time of the arrival thereat of said pulsation to thus minimize the extent of the change, if any caused thereby in said sample portion-sample treatment fluid proportion and, in any event, restrict the same to the beginning or end part of each of said sample portions to render the same incapable of modifying the recorded sample portion analysis results.

DESCRIPTION OF THE DRAWINGS

The above and other objects of the invention are believed made clear by the following detailed description thereof taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a flow diagram illustrating the application of the method of the invention to the operation of peristaltic pump means in a fluid sample supply, treatment and analysis system, and depicts said pump means in a first operational position thereof;

FIG. 2 is a flow diagram depicting the peristaltic pump of FIG. 1 in a second operational position thereof;

FIG. 3 is a graph depicting pump delivery plotted against time and illustrates the pump pulsations of interest;

FIG. 4 is a graph depicting treated sample portion optical density plotted against time and illustrates the minimization of the effects of one of the pulsations of FIG. 3; and

FIG. 5 is a flow diagram illustrating fluid flow through the peristaltic pump of FIG. 1 when the same is used in a somewhat differently operable fluid sample supply, treatment and analysis system.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, new and improved sample supply system constructed and operative in accordance with the teachings of this invention are indicated generally at 8, and comprise compressible tube pump means as indicated generally at 10 and operatively associated sample supply means as indicated generally at 12.

The sample supply means 12 may, for example, take the form of those shown and described in U.S. Pat. No. 3,134,263 issued May 26, 1964 to Edward B. M. DeJong, and comprise a turntable 14 upon which is disposed a generally circular array of sample containers 16. A sample offtake device is indicated generally at 18 and comprises a sample offtake tube 20 and offtake tube operating-means 22, respectively. A wash liquid receptacle 24 is disposed as shown adjacent the turntable 14, while sample supply device drive means are indicated at 26 and are operative to drive each of the turntable 14 and the sample offtake device 18 as indicated by the dashed lines extending therebetween.

In operation, the turntable 14 is intermittently rotated, or indexed, to present each of the sample containers 16 in turn to the sample offtake device 18, while the latter is operated to immerse the inlet end or offtake tube 20 in a thusly presented sample container for a predetermined period of time to aspirate (as described in detail hereinbelow) a measured volume of the sample therefrom, to then transfer the said offtake tube inlet end through the ambient air for immersion in

the wash liquid receptacle for a predetermined period of time to thus aspirate a measured volume of ambient air followed by a measured volume of said wash liquid, and to then again transfer the said offtake tube inlet and through the ambient air for immersion in the next-presented sample container 16 for a predetermined period of time to thus aspirate another measured volume of ambient air and commence the aspiration of a measured volume of the sample from said next-presented sample container.

As a result, it may be understood that a stream S consisting of successive ones of portions of said samples of substantially equal predetermined volume as spaced, in each instance, by a segment of air A, a segment of wash liquid W and a segment of air A, respectively, will be supplied to the offtake tube 20.

The compressible tube or peristaltic pump 10 may, for example, take the general form of that shown and described in U.S. Pat. No. 3,227,091 issued Jan. 4, 1966 to Jack Isreeli et al., and comprises spaced pump tube mounting blocks as indicated at 32 and 34.

A compressible pump tube 36, which is made from any suitably resilient material of appropriate strength characteristics in the nature, for example, of silicone rubber, is extended as shown between the said pump tube mounting blocks and affixed thereto by means of the placement of said pump tube in nonillustrated aligned mounting grooves formed in said pump tube mounting blocks, and the attachment of collar elements 38 and 40, as shown to opposite end portions of said pump tube, all in a manner made clear in said U.S. Pat. No. 3,227,091. The inlet end of the compressible pump tube 36 is connected as indicated at 41 to the outlet end of the sample offtake tube 20.

A pump roller assembly is indicated generally at 42 and comprises an endless chain 44 which is disposed as shown around a chain guide member 46 and is driveable therearound in the indicated clockwise direction through the driven rotation of a chain drive sprocket 48.

A plurality of substantially equally spaced pump rollers 50A, 50B, 50C and 50D are rotatably mounted in any convenient manner on endless chain 44 as shown, whereby may be understood that those of said rollers which are, at any given point in time, mounted on the upper throw of the endless chain 44 will be movable with the latter in the direction from left to right as seen in FIG. 1. Although for simplicity of illustration only one chain and drive sprocket are depicted, it may be understood that at least two of the same would be provided in spaced, general alignment, and that the respective pump rollers would, of course, extend therebetween.

A pump platen is indicated at 52 and may be understood to be movable, as by pivotal movement, from a nonillustrated "open" position thereof to the depicted "closed" position thereof wherein the pump tube 36 will be disposed as shown in firm contact with the undersurface of said platen, and will be forced to conform with the configuration of the bottom surface 54 of said groove and pressed thereby against the respective relevant rollers 50, all again as described in detail in said U.S. Pat. No. 3,227,091.

Pump drive means, which may, for example, take the form of any suitable electric motor, are indicated at 56, and are operatively connected, as indicated by the dashed line, to the chain drive sprocket 48 to drivingly rotate the latter. In addition, and for reasons described in detail hereinbelow, the operation of sample supply device drive means 26 is synchronized with the operation of the pump drive means 56, and this may be understood to be indicated in the drawings by the extension of lead 58 therebetween. Alternatively, it is believed clear that a single drive means in the nature of a suitable electric drive motor may be provided and operatively connected, as by conventional mechanical connecting means, to both the pump 10 and the sample supply device 12 to drive the same in the described synchronized manner.

With the respective pump components arranged and operative as described, it may be understood that driven, clockwise rotation of the chain drive sprocket 48 will effect movement

of the rollers 50 affixed to the upper throw of endless chain 44 from left to right as seen in FIG. 1 with the result that the compressible pump tube 36 will be progressively compressed or occluded thereby in said direction to in turn pump fluids therethrough. Accordingly, may be understood that the successive sample stream S will be supplied as indicated from the compressible pump tube 36 to a sample stream supply conduit 62, which is connected to the former as shown at 64, for supply through said sample supply conduit as indicated to the nonillustrated sample treatment and analysis means. In addition, it is reiterated that the sample portions which constitute this sample portion stream will be spaced, each from the other, by a separating fluid portion which, in this instance, will be constituted as described by a segment of air A1, a slug of wash liquid W, and a segment of air A2, arranged in that order.

Sample treatment fluid supply means are indicated generally at 66 and may be understood to function to supply a sample treatment fluid to the sample portion stream supply conduit 62 for mixture therewithin in carefully predetermined proportion with each of said sample portions being pumped therethrough.

The sample treatment fluid supply means 66 may, for example, take the general form of those shown and described in the copending application for U.S. Pat. Ser. No. 120,153 of Edward B. M. DeJong filed Mar. 2, 1971 and assigned to the assignee hereof (continuation in part of U.S. Pat. Ser. No. 712,431 filed Mar. 12, 1968, now abandoned) and, as such, will comprise a tank 68 of air at suitable pressure, as, for example, 2,200 p.s.i. connected as shown by conduit 70 through suitable pressure regulator means 72 to a T-fitting 74 to maintain the latter at substantially constant pressure in the order, for example, of 66.8 cm. Hg. For use in applications wherein the respective samples are constituted by blood serum samples from different patients, the sample treatment fluid of interest may, for example, be constituted by a color-producing reagent liquid which, when mixed with said sample portions, will enable the respective colorimetric quantitative analyses thereof with respect to a predetermined blood sample constituent, all as described in greater detail in said U.S. Pat. No. 3,241,432.

A conduit 78 extends as shown from outlet of the T-fitting 74 through the screw-on cover 80 of a reagent liquid flask 82 to thus pressurize the interior of the latter at said substantially constant pressure. An outlet conduit 84 connects the interior of the flask 82 to the inlet of a precisely calibrated high flow resistance coil 86, the outlet of which is in turn connected as shown by reagent liquid supply conduit 88 to one inlet of a T-fitting 90 which is interposed in the sample portion stream supply conduit 62.

The other outlet of the T-fitting 74 is connected as shown by conduit 92 to the inlet of a precisely calibrated high flow resistance coil 94, and the outlet of the latter is connected by air supply conduit 96 to a T-fitting 98 which is interposed as shown in the reagent liquid supply conduit 88.

For use as described in greater detail hereinbelow in automatically operable, blood serum sample treatment and analysis means, the high flow resistance coil 86 will preferably be disposed in a temperature control bath as indicated in dashed lines at 99 to maintain the temperature thereof at a suitable, substantially constant level as, for example, 37° C. to in turn maintain the temperature, and accordingly the viscosity and flow rate of the reagent liquid flowing therethrough at substantially constant, predetermined values. If necessary, and/or desired, the respective reagent liquid flask 82 and portions at least of the respective conduits 84 and 88 may also be immersed in said temperature control bath.

By this arrangement is believed made clear that the pressurized air from tank 68 will be effective to pump the reagent liquid R from the flask 82 at a substantially constant, predetermined flow rate through the high flow resistance coil 86 and therefrom, through reagent liquid supply conduit 88, to the sample stream supply conduit 62 for merger therewithin with the sample portion stream S flowing through the latter. Con-

comitantly, it may be understood that the pressurized air from tank 68 will be flowed, again at substantially constant, predetermined flow rate, through high flow resistance coil 94 and therefrom through air supply conduit 96 for merger with the reagent liquid stream flowing in reagent supply conduit 88 to air segment the same as shown to promote proper mixing thereof with the sample stream S upon the merger thereof as discussed hereinabove.

Although compressible tube proportioning pumps in the nature of the pump 10 have, to date, proven preferable for use in automatically operable, substantially constant flow rate sample treatment and analysis means of the nature disclosed in said U.S. Pat. No. 3,241,432, it may be understood that there is one operational characteristic of said pumps which must be taken in consideration for such use, and especially when applied to improved versions of said sample treatment and analysis means which are operable at substantially reduced sample volumes and substantially increased sample analysis rates. More specifically, and as seen in FIG. 3 wherein the graph 100 represents proportioning pump delivery as plotted against time for the travel of one of the compressible pump rollers 50 through one tube compressing cycle thereof, it may be understood that pulsations as indicated at 102 and 104 will respectively occur in said pump delivery rate as the said pump roller makes contact with and occludes the pump tube 36 at the commencement of the pumping cycle of interest, and as the said pump roller terminates the occluding contact thereof with said compressible pump tube at the termination of said pumping cycle.

Sample treatment and analysis means of the nature discussed may be understood to be satisfactorily operable only at substantially constant flow rate, and to further depend for satisfactory constant flow rate, and to precise proportioning between each of the sample portions and the reagent liquid which is merged therewith, and upon the substantially precise maintenance of a predetermined phase relationship between the respective sample portions. Accordingly, it becomes essential that the effects of pulsations as indicated at 102 and 104 in FIG. 3 upon such flow rate, proportioning and sample portion phase relationship be minimized, if not altogether removed.

Considering first the pulsation 102 which occurs as set forth hereinabove as a pump roller commences the occlusion of the compressible pump tube 36, it may be understood that this point in the operation of the compressible tube pump 10 as illustrated in FIG. 1 wherein the pump roller 50B is depicted as commencing the occlusion of the compressible pump tube 36. At this occurs, it may be understood that the pulsation 102 of FIG. 3 will, of course, travel in both directions from the point of roller-pump tube contact through the sample portion stream S then flowing in said pump tube. The travel of this pulsation in the direction from left to right as seen in FIG. 1, or, that is to say, the downstream direction, will be terminated at the roller 50A since the latter is, at this point in time, fully occluding the compressible pump tube 36 to thereby render substantially impossible further travel of said pulsation in this direction.

The travel of this pulsation in the direction from right to left as seen in FIG. 1 or, that is to say, the upstream direction will, however, be unrestricted to and through the inlet end of the sample offtake tube 20. As a result, it may be understood that the said offtake tube, the turntable 14 and the compressible pump tube 10 are arranged in accordance with the teachings of this invention, as through careful predetermination and control of the operational timing of the respective sample supply device drive means 26 and the pump drive means 56, to insure that the said offtake tube inlet end is not exposed to the ambient air at the time that the pulsation 102 reaches the said offtake tube inlet end. More specifically, and bearing in mind the substantial importance of proper phasing of the respective sample portions which are pumped through the compressible pump tube 36, and the obviously essential function of the respective air segments A of predetermined uniform volume

in maintaining such phasing and, in conjunction with the slug of wash liquid W, in providing for intersample portion cleansing to inhibit the contamination of a succeeding sample portion by the residue of a preceding sample portion, it is believed clear that if the inlet end of the offtake tube 20 is exposed to the ambient air at the time the said pulsation arrives thereat, the effect of the latter will, of course, be to substantially reduce, if not eliminate, the amount of air which is at that time aspirated to form an air segment A.

If the amount of air aspirated is simply reduced but is still adequate to form a leading air segment as indicated at A1 in FIG. 1 of at least the minimum volume required to occlude the nonuniform tube 36, it may be understood that the said air segment A1 will be smaller than and thus of nonuniform volume with regard to the trailing air segment as indicated at A2, whereby the essential sample portion phase relationship may be modified to obvious disadvantage. If, on the other hand, the amount of air aspirated is reduced to the extent that insufficient air is provided for the formation of an air segment A of minimum volume to fully occlude the pump tube 36—thereby resulting only in the formation of a suspended air bubble—or if no air is aspirated at all, it is believed clear that the essential inter sample portion cleansing and sample portion separating functions of the air segment A which was to have been formed will also be eliminated along with the phase relationship destruction as discussed hereinabove.

To better illustrate this, if it is assumed, for example, that a total of 12 seconds are available for the aspiration of each of the sample portions and the separating fluid portion which is constituted by the respective air segments A and slug of wash liquid W which precede the same, that only 1.5 of these 12 seconds are available for the aspiration of said air segments and wash liquid slug, that the pulsation 102 is of 1 second duration, and that the sample supply system 8 is arranged to operate to aspirate air to form segments A of the minimum volume required to occlude the compressible pump tube 36, it is believed clear that the arrival of the pulsation 102 at the inlet end of offtake tube 20 during that portion of the 1.5 seconds air-wash liquid aspiration time in which air is being aspirated will, in all probability, result in the aspiration of an air volume, if any, which is insufficient to occlude the compressible pump tube 36 to obviously unacceptable effect as discussed in detail directly hereinabove.

Preferably, the sample offtake tube 20 will be arranged as illustrated so that the inlet end thereof will be immersed in a sample container 16 generally intermediate the aspiration of a sample portion at the time of the arrival of the pulsation 102 at said inlet end, with resultant substantial absorption of said pulsation to render the effects of the latter substantially undetectable during the steady state flow rate portion of sample stream flow.

Alternatively, the sample offtake tube 20 may be arranged so that the inlet end thereof will be immersed in the wash liquid receptacle 24 at the time of arrival of the pulsation 102 thereat although this may, of course, prove unacceptable in instances as discussed hereinabove wherein the total time for wash liquid slug aspiration is so short in relation to the duration of the pulsation 102 that the former cannot accommodate the latter and still provide for the aspiration of a wash liquid slug W of suitable volume.

Considering now the effect of the pulsation 104 which occurs as set forth hereinabove as a pump roller discontinues the occlusion of the compressible pump tube 36, it may be understood that this point in the operation of the compressible tube pump 10 is illustrated in FIG. 2 wherein the pump roller 50A is depicted as discontinuing occluding contact with said pump tube. Travel of the resultant pulsation 104 in the upstream direction through the sample portion stream S will be substantially terminated at the pump roller 50B which is, at this point in time, occluding the compressible pump tube 36. Travel of this pulsation in the downstream direction through said sample portion stream to and through the T-fitting 90 wherein said stream is being merged with the stream of re-

agent liquid R from reagent liquid supply conduit 88 will, however, occur, to thus give rise to the possibility of improper sample portion-reagent liquid proportioning. This is to say that if said pulsation arrives at said T-fitting concomitantly with a sample portion and a segment R of reagent liquid, the attendant momentary reduction in the sample portion stream flow rate will, of course, result in the merger therewith of a substantially greater proportion of reagent liquid than that desired with attendant inordinate dilution of said sample portion. To prevent this from occurring or, to at least minimize the effects thereof upon sample portion analysis as discussed in greater detail hereinbelow, it may be understood that the length of the fluid flow path through the compressible pump tube 36 from the point thereon whereat the respective pump rollers discontinue occluding contact therewith as illustrated by the position of pump roller 50A in FIG. 1, and the T-fitting 90, is precisely predetermined in accordance with the fluid flow rate therethrough to insure that the arrival of the pulsation 104 at the said T-fitting will occur substantially concomitantly with the arrival of an air segment A1 or A2 thereat. As a result, it may be understood that disruptive effects, if any, of the pulsation 104 upon the requisite substantially precise sample portion-reagent liquid proportioning will be minimized and will, in any event, occur at the beginning or end of each of said sample portions so as not to interfere with the results of the analysis thereof.

More specifically—and bearing in mind that the nonillustrated sample treatment and analysis means of the type discussed include colorimeter means through which the appropriately treated sample portions which then constitute the sample portion stream S are successively flowed, and operatively connected null balance-type strip chart recorder means which provide a record of the colorimetric analysis of said sample portion, all as described in detail in said U.S. Pat. No. 3,241,432—FIG. 4 which depicts a graph 106 of treated sample portion optical density plotted against time for the successive passage of three treated sample portions through the colorimeter flow cell is believed to make clear that it is only the result of the colorimetric quantitative analysis of the respective generally central parts of said treated sample portions which are recorded to thereby make clear that any non-representative changes in sample portion optical density which might occur as a result of improper sample portion-reagent liquid proportioning at the beginning or end of each sample portion will have no effect upon the recorded results of interest.

Although disclosed in FIGS. 1 and 2 as functioning to aspirate a segment of air A, a segment of wash liquid W and a segment of air A, respectively, prior to the aspiration of each of the sample portions from the respective sample containers 16, it is believed clear that the sample portion supply means 12 could be modified by the deletion of the wash liquid reservoir 24 and the arrangement of the sample offtake means 18 to aspirate repeated small volumes of each of the samples as spaced, each from the other, by a small segment of air A, prior to the aspiration of the main body of the sample portion—with said small sample portion volumes functioning in the manner of the wash liquid in conjunction with said air segments as the separating fluid portion to remove the residue, if any, of the preceding sample portion and inhibit the contamination of the succeeding sample portion thereby—and that the teachings of the invention should be equally applicable to such system. More specifically, and as seen in FIG. 5 which illustrates the sample portion stream which would result from such operation, it may be understood that the respective turntable 14, sample offtake tubes 20, proportioning pump 10 and T-fitting 90 would respectively again be arranged as described in detail hereinabove to insure that the offtake tube inlet end would be immersed in a sample container concomitantly with the arrival thereof of the pulsation 102 for each of the pump rollers 50, and to insure that the arrival of the pulsation 104 for each of the pump rollers at the T-fitting 90 would occur substantially concomitantly with the arrival of one of said air segments A thereat.

Preferably, the apparatus of the invention are arranged as illustrated and described so that each of the pump rollers makes occluding contact with the compressible pump tube 36 generally intermediate a sample portion as shown as at S1, S2, S3, etc., rather than at a separating fluid portion, to thus prevent the breaking up of the respective air segments A by such occluding contact into air bubbles which may not reform as air segments and thus would no longer function to occlude the compressible pump tube 36 to very significant disadvantage as discussed in detail hereinabove.

Too, and although disclosed as involving one pump tube occluding contact by a pump roller per sample portion, it is believed clear that the proportioning pump 10 may alternatively be arranged to operate with one such pump tube occluding contact per two or more sample portions to, in any event, minimize the number of pump roller-compressible pump tube contacts per sample portion and thus minimize compressible pump tube wear as should be obvious.

In addition, and although disclosed by way of illustration as applied to a sample supply system which operates to supply blood serum samples for mixture with a suitable color-producing reagent liquid, it is believed clear that the teachings of this invention would be equally applicable to sample supply systems which operate to supply a wide variety of different sample treatment fluids. Further, and although disclosed in conjunction with a sample supply system which utilizes a compressible tube or peristaltic proportioning pump, it may be understood that the teachings of this invention would be equally applicable to such system wherein it utilized another and different form of pumping means which gave rise to pulsations in the nature of those discussed.

While we have shown and described the preferred embodiment of our invention, it will be understood that the invention may be embodied otherwise than as herein specifically illustrated or described, and that certain changes in the form and arrangement of parts and in the specific manner of practicing the invention may be made without departing from the underlying idea or principles of this invention within the scope of the appended claims.

What is claimed is:

1. In a method for minimizing the effects of pulsations in an intermittent pumping system having a pump which operates by the alternating intake through pump inlet means of sample fluid and separating fluid, respectively, to provide a fluid stream which comprises a series of sample fluid portions spaced by separating fluid portions, and wherein said pulsations travel in said fluid stream to said pump inlet means, the steps of, operating said pumping system to provide for the intake of said sample fluid through said pump inlet means substantially concomitantly with the arrival of said pulsations at said pump inlet means.

2. In a method as in claim 1 further comprising, the steps of, operating said pumping system to respectively provide for sample fluid portions of substantially the same volume, and to provide for separating fluid portions of substantially the same volume.

3. In a method as in claim 1 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pumping system to provide separating fluid portions of the minimum volume required to occlude said pump tube.

4. In a method as in claim 2 further comprising, the steps of, operating said pumping system to provide sample fluid portion volumes which are greater than said separating fluid portion volumes.

5. In a method as in claim 4 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pumping system to provide separating fluid portions of the minimum volume required to occlude said pump tube.

6. In a method for minimizing the effects of pulsations in an intermittent pumping system having a pump, the steps of, alternately immersing the pump inlet means in different ones of a plurality of fluids which are successively supplied thereto,

and exposing said pump inlet means to the ambient air, respectively, to provide a fluid stream which comprises a series of different fluid portions spaced, in each instance, by a separating fluid portion which comprises an air segment, and in which fluid stream said pulsations travel upstream to said pump inlet means, and operating said pump and said pump inlet means to provide for the immersion of said pump inlet means in a said fluid substantially concomitantly with the arrival of said pulsations at said pump inlet means.

7. In a method as in claim 6 further comprising, the steps of, operating said pump and said pump inlet means to respectively provide for fluid portions of substantially the same volume, and to provide for air segments of substantially the same volume.

8. In a method as in claim 6 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pump and said pump inlet means to provide air segments of the minimum volume required to occlude said pump tube.

9. In a method as in claim 7 further comprising, the steps of, operating said pump and said pump inlet means to provide fluid portion volumes which are greater than said air segment volumes.

10. In a method as in claim 9 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pump and said pump inlet means to provide air segments of the minimum volume required to occlude said pump tube.

11. In a method of minimizing the effects of pulsations on the proportionate merger of a first fluid and a second fluid at the juncture of the flow path of a first fluid stream which comprises a series of first fluid portions spaced, in each instance, by a separating fluid portion, with the flow path of a second fluid stream, wherein said first fluid stream is intermittently pumped by a pumping means to result in the occurrence of said pulsations which travel in said first fluid stream to said flow path juncture, the steps of, arranging said fluid stream flow paths to provide for the substantially concomitant arrival of said pulsations and said separating fluid portions at said flow path juncture.

12. In a method as in claim 11 wherein, the steps of arranging said fluid stream flow paths comprise the establishment of the length of said first fluid stream flow path between the outlet side of said pumping means and said flow path juncture in accordance with the flow rate through said first fluid stream flow path to provide for said substantially concomitant pulsations and separating fluid portions arrivals at said flow path juncture.

13. In a method for respectively minimizing the effects of pulsations on a first fluid stream, and on the proportionate merger of said first fluid stream and a second fluid stream at the juncture of the flow paths thereof, in an intermittent pumping system having a pump which operates by the alternating intake through pump inlet means of said first fluid and a separating fluid, respectively, to provide said first fluid stream which comprises a series of fluid portions spaced, in each instance, by a separating fluid portion, and wherein said pulsations travel in said first fluid stream to said pump inlet means and said flow paths juncture, respectively, the steps of, operating said pumping system to provide for the intake of said first fluid through said pump inlet means substantially concomitantly with the arrival of said pulsations at said pump inlet means, and arranging said fluid stream flow paths to provide for the substantially concomitant arrival of said pulsations and said separating fluid portions at said flow paths juncture.

14. In a method as in claim 13 further comprising, the steps of, operating said pumping system to respectively provide for fluid portions of substantially the same volume, and to provide for separating fluid portions of substantially the same volume.

15. In a method as in claim 13 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pumping system to provide separating fluid portions of the minimum volume

required to occlude said pump tube.

16. In a method as in claim 14 further comprising, the steps of, operating said pumping system to provide fluid portion volumes which are greater than said separating fluid portion volumes.

17. In a method as in claim 16 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pumping system to provide separating fluid portions of the minimum volume required to occlude said pump tube.

18. In a method as in claim 15 wherein, the steps of arranging said fluid stream flow paths comprise the establishment of the length of said first fluid stream flow path between the outlet side of said pumping means and said flow path juncture in accordance with the flow rate through said first fluid stream flow path to provide for said substantially concomitant pulsations and separating fluids portions arrivals at said flow path juncture.

19. In a method as in claim 17 wherein, the steps of arranging said fluid stream flow paths comprise the establishment of the length of said first fluid stream flow path between the outlet side of said pumping means and said flow path juncture in accordance with the flow rate through said first fluid stream flow path to provide for said substantially concomitant pulsations and separating fluid portions arrivals at said flow path juncture.

20. In a method for respectively minimizing the effects of pulsations on a first fluid stream, and on the proportionate merger of said first fluid stream and a second fluid stream at the juncture of the flow paths thereof, in an intermittent pumping system having a pump, the steps of, alternately immersing the pump inlet means in different ones of a plurality of fluids which are successively supplied thereto, and exposing said pump inlet means to the ambient air, respectively, to provide a first fluid stream which comprises a series of different fluid portions spaced, in each instance, by a separating fluid portion which comprises an air segment, and wherein said pulsations travel in said first fluid stream to said pump inlet means and to said flow paths juncture, respectively, operating said pump and said pump inlet means to provide for the immersion of said pump inlet means in a said fluid substantially concomitantly with the arrival of said pulsations at said pump inlet means, and arranging said fluid stream flow paths to provide for the substantially concomitant arrival of said pulsations and said separating fluid portions at said flow paths juncture.

21. In a method as in claim 20 further comprising, the steps of, operating said pump and said pump inlet means to respectively provide for air segments of substantially the same volume, and to provide for air segments of substantially the same volume.

22. In a method as in claim 20 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pump and said pump inlet means to provide air segments of the minimum volume required to occlude said pump tube.

23. In a method as in claim 21 further comprising, the steps of, operating said pump and said pump inlet means to provide fluid portion volumes which are greater than said air segment volumes.

24. In a method as in claim 23 wherein said pump comprises a progressively occludable pump tube and said method further comprises, the steps of, operating said pump and said pump inlet means to provide air segments of the minimum volume required to occlude said pump tube.

25. In a method as in claim 24 wherein, the steps of arranging said fluid stream flow paths comprise the establishment of the length of said first fluid stream flow path between the outlet side of said pumping means and said flow path juncture in accordance with the flow rate through said first fluid stream flow path to provide for said substantially concomitant pulsations and separating fluid portions arrivals at said flow path juncture.

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