

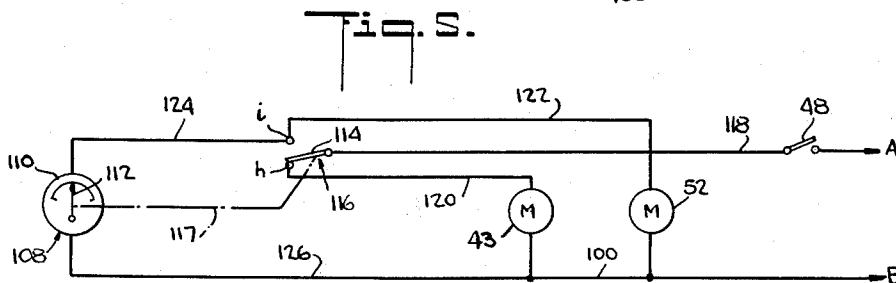
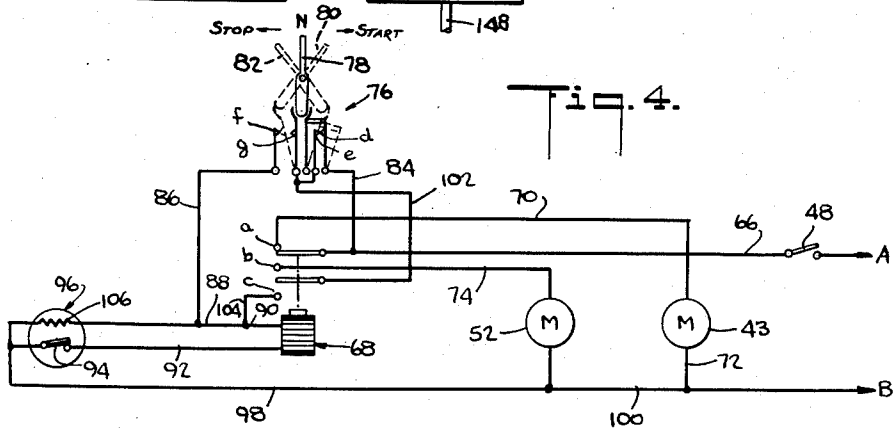
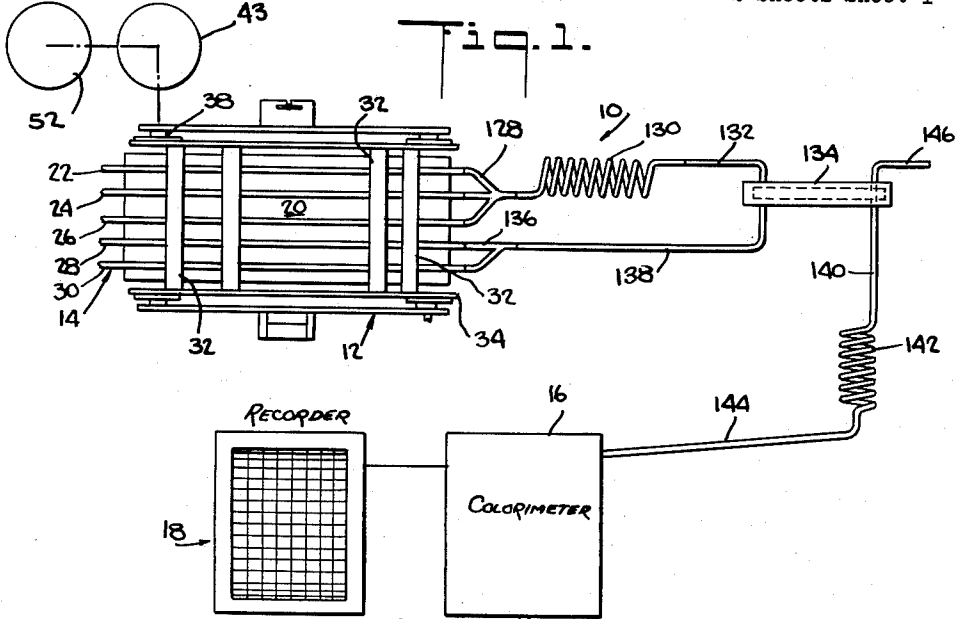
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E. C. WHITEHEAD ETAL
ANALYSIS APPARATUS AND SYSTEM

3,116,118

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2 Sheets-Sheet 1



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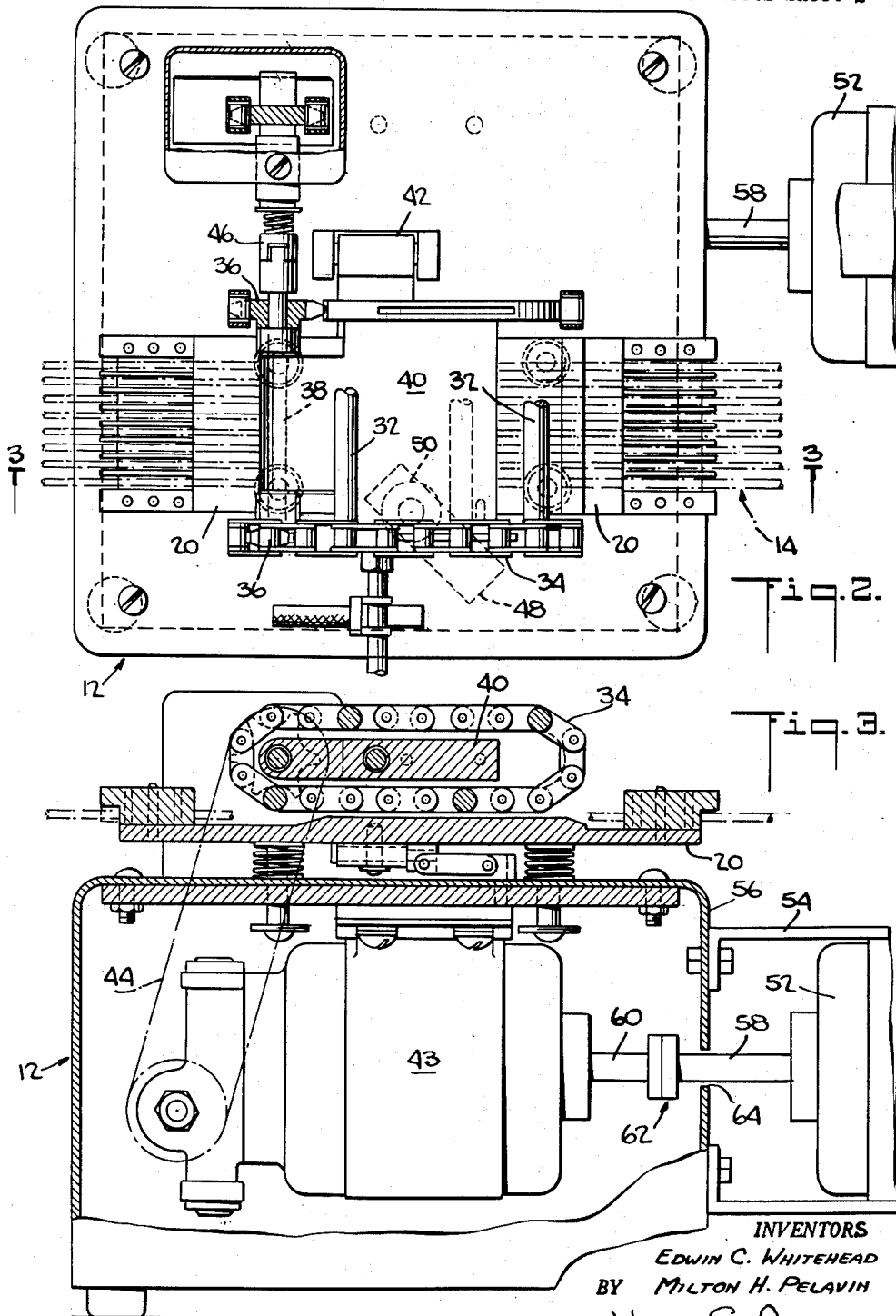
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ANALYSIS APPARATUS AND SYSTEM

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The present invention relates to automatic analysis or treatment apparatus, methods and systems wherein a liquid stream is treated for analysis or monitoring.

The invention is especially useful in its application to automatic continuous apparatus of the type described, for example, in United States Patent No. 2,797,149, of the assignee of the present application, wherein a liquid stream containing a series of samples which are to be analyzed is transmitted through the passages of the apparatus and is treated during its flow with various reagents and processing fluids in the form of individual streams flowing in other passages of the apparatus. The various streams are transmitted through the passages of the apparatus at an optimum or required rate of flow for treatment for analysis. The liquid stream and the reagent and processing fluid streams will, of course, vary depending upon the type of analysis being made so that it is necessary, between analyses, to remove fluids which may adhere to the inner walls of the passages of the apparatus from a previous analysis. This cleansing operation is accomplished by transmitting suitable cleansing fluids or wash liquids through the various passages of the apparatus and, in accordance with the invention and pursuant to the primary object thereof, the cleansing fluids are transmitted through each of the passages of the apparatus at a flow rate which is substantially higher than the optimum or required flow rate of the fluids for analysis, thereby substantially reducing the change-over time between analyses and increasing washing efficiency.

Pursuant to another object of the invention, the higher rate of flow of fluids through the passages of the apparatus is also utilized in filling the passages of the apparatus with the fluids necessary for the succeeding analysis thereby further reducing the change-over time between analyses, and when the passages are filled the apparatus is then operated to transmit the fluids at the optimum slower flow rate for treatment for analysis.

Another object is to provide the apparatus with pump means having provision for transmitting fluids through the passages of the apparatus at one flow rate for treatment for analysis and at a higher flow rate for cleaning and for filling the passages.

A further object is to provide the pump means with improved electrical means for controlling the operation of said pump means.

The above and other objects, features and advantages of the invention will be fully understood from the following description considered in connection with the accompanying drawings which are to be considered as illustrative of the invention but not in limitation thereof.

In the drawings:

FIG. 1 is a more or less diagrammatic view illustrating the method and apparatus of the present invention;

FIG. 2 is a top plan view, with parts cut-away and in section, of a pump embodying the present invention;

FIG. 3 is a sectional view, in elevation, taken on the line 3—3 of FIG. 2;

FIG. 4 is a circuit diagram of an electrical control for the pump; and

FIG. 5 is a circuit diagram of another electrical control for the pump.

Referring now to the drawings in detail, the apparatus

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10 comprises a proportioning pump 12 which has a plurality of resilient and compressible pump tubes 14 through which a plurality of fluids are transmitted for the continuous treatment of a liquid for colorimetric analysis. The treated stream flows through a flow cell in the colorimeter 16 which operates a recorder 18, in a well known manner, to record the results of the colorimetric analysis.

Proportioning pump 12 is preferably of the type described in U.S. Patent No. 2,935,028. Briefly described, this type of pump comprises a platen 20 and the flexible pump tubes 22, 24, 26, 28 and 30 which are resiliently compressible and are all simultaneously compressed progressively along their lengths against platen 20 by transverse pressure rollers 32 carried by conveyor sprocket chains 34 which are driven by sprocket wheels 36, said sprocket wheels being mounted on a shaft 38. The sprocket chains are carried by a frame 40 which is pivoted at the hinge connection 42 so that said pressure rollers can be moved to a retracted position out of engagement with the pump tubes for access to the latter when desired. Shaft 38 is actuated by a synchronous motor 43 through the sprocket-chain drive 44 and said drive is connected to the motor 43 and to shaft 38 by the clutch 46. The motor is controlled by a normally open microswitch 48 which is controlled by a switch actuating device 50, said device being operative to close the microswitch when the frame 40 is moved into operative position whereby the pressure rollers 32 engage the pump tubes. Since the details of the pump construction do not, per se, form part of the invention, it is unnecessary to describe the pump in greater detail but, if further details are desired, recourse may be had to the above mentioned patent.

In accordance with the invention, provision is made to operate pump 12 at different speeds, as required, so that a lower speed of operation may be utilized for transmitting the fluids at an optimum or required rate of flow for treatment of the sample liquids for analysis thereof while a higher speed of operation of the pump may be utilized for cleansing the inner walls of the tubular passages of the apparatus and for filling the various lines of the apparatus with fluids at the commencement of an analysis operation. This substantially reduces the time necessary for placing the apparatus in condition for another analysis after the completion of a previous analysis. Motor 43 runs at a constant speed for operating the pump at an optimum flow rate of the fluids during analysis operations. Motor 52 of any suitable type is provided to operate the pump at a higher flow rate of the fluids for rapidly cleansing and filling the tubular passages for the above stated purpose. Motor 52 is secured to a frame 54 which is bolted to the housing 56 in which motor 43 is mounted. The drive shaft 58 of motor 52 is connected to the drive shaft 60 of motor 43 by the coupling 62 and housing 56 is provided with an opening 64 through which shaft 58 extends. It will be apparent that the drive shaft of each motor rotates when either motor is energized and that motor 52, when energized, operates the pump through drive shaft 60 of motor 43. While as here shown the shafts of both motors rotate when either one of the motors is energized, it is within the scope of this invention to provide a releasable clutch in lieu of the coupling 62 so that the shaft of motor 52 rotates only when it is put into operation for the higher flow rate of the fluids.

In accordance with another aspect of the present invention in the preferred embodiment thereof, provision is made to automatically prevent the electrical energization of both motors at the same time and for automatically limiting the period of operation of the higher speed motor 52, so that it does not run longer than necessary or desirable to accomplish the tube cleansing and filling operations in the change-over operation of the apparatus

from one type of analysis to another. It will be understood however that this feature of the invention is advantageously additive to the main purpose of the invention, but is not to be considered as limitative thereof, except to the extent of its inclusion in any of the claims. The control means will now be described.

Referring now to FIG. 4, there is shown a circuit diagram for controlling the operation of motors 43 and 52 and which has provision for automatically de-energizing one of the motors when other motor is energized. In addition, a timer is provided for automatically shutting off high speed motor 52 after a predetermined period of operation.

When it is desired to operate the pump for analysis or cleansing, frame 40 is moved into its operative position wherein pressure rollers 32 engage the pump tubes 14, as previously indicated, which action closes the normally open microswitch 48. This closes an energizing circuit for motor 43 which may be traced as follows: from power line A, through closed microswitch 48 through conductor 66, through closed contact *a* of relay 68, through conductor 70, through motor 43, and through conductor 72 to power line B. High speed motor 52 is de-energized because it is in circuit, via conductor 74, with normally open contact *b* of relay 68.

A manually operable switch 76 is provided for controlling the operation of high speed motor 52. Switch 76 is of a well known type and comprises a pivoted actuating lever 78 having a center or neutral position to which it is spring biased. The switch includes a pair of normally closed contacts *d* and *e* and a pair of normally open contacts *f* and *g*. When lever 78 is moved to the right, as indicated by dotted lines 80, the normally open contacts *f* and *g* are closed, and when lever 78 is moved to the left, as indicated by dotted lines 82, the normally closed contacts *d* and *e* are opened. In each case when the lever is released, it returns to its center neutral position under the bias of the spring.

In order to operate high speed motor 52, lever 78 is moved to the right to complete an energizing circuit for motor 52 through contact *b* of relay 68. More particularly, upon movement of lever 78 to the right an energizing circuit is completed through the coil of relay 68 which may be traced as follows: from power line A, through closed microswitch 48, through conductor 66, through conductor 84, through closed contacts *d* and *e*, through the now closed contacts *f* and *g*, through conductor 86, through conductors 88 and 90, through the coil of relay 68, through conductor 92, through the normally closed switch 94 of timer 96, and through conductors 98 and 100 to power line B. Upon energization of relay 68, as just described, normally closed contact *a* of relay 68 opens to open the energization circuit for motor 43 so that said motor cannot be energized as long as the energization circuit for motor 52 is completed. The energization circuit of motor 52 may be traced as follows: from power line A, through closed microswitch 48, through conductor 66, through the now closed contact *b* of relay 68, through conductor 74, through motor 52, and through conductor 100 to power line B. A holding circuit for relay 68 is also established when lever 78 is moved to the right to initiate operation of motor 52. The relay holding circuit may be traced as follows: from power line A, through closed microswitch 48, through conductor 66, through conductor 84, through closed contacts *d* and *e*, through conductor 102, through the now closed contact *c* of relay 68, through conductor 104, through conductor 90, through the coil of relay 68, through conductor 92, through closed switch 94 of timer 96, through conductor 98, and through conductor 100 to power line B. Accordingly, even though lever 78 returns to its neutral position so that contacts *f* and *g* are opened, the energization circuit for motor 52 remains completed because relay 68 remains energized through its holding circuit.

In series with the coil of relay 68 is the previously mentioned normally closed switch 94 of timer 96 which includes a resistor 106 which is also in series with the coil of the relay. Switch 94 is of the thermal responsive type so that after a predetermined period resistor 106 will be heated to an extent which will cause the opening of switch 94 and the de-energization of relay 68, whereupon the energization circuit for motor 52 will open. In this manner the period of operation of motor 52 is automatically predetermined and at the end of said period, motor 52 automatically stops. This automatic control of motor 52 assures that the motor and the pump will not be operated at high speeds for prolonged periods of time so that the motor and the pump will not undergo excessive wear because of high speed operation for long periods of time.

In order to stop the operation of motor 52 before switch 94 of timer 96 opens, lever 78 may be moved to its left position which opens contacts *d* and *e*. Since these contacts are in the energizing circuit of relay 68, said relay is de-energized upon opening of contacts *d* and *e* and the energizing circuit for motor 52 is opened.

The electrical control shown in FIG. 5 or any other suitable control may be used instead of the control shown in FIG. 4. As shown in FIG. 5, the control includes an adjustable motor operated timer 108 in lieu of the thermal timer 96 shown in FIG. 4. The timer 108 is of a well known type and may be obtained, for example, from the Eagle Signal Corporation of Moline, Illinois. Briefly described, the timer comprises a clock motor 110 which operates a pointer 112, the pointer being adapted to move over the face of the clock motor which is provided with a time scale. A movable arm 114 of a normally closed switch 116 is operatively connected to pointer 112 of the clock motor, as indicated by line 117, and moves from contact *h* of the switch to contact *i* of the switch when pointer 112 of the timer is manually moved from its neutral position which is shown in FIG. 5.

In the neutral position of pointer 112, motor 43 will be energized when microswitch 48 is closed through an energizing circuit which may be traced as follows: from power line A, through closed microswitch 48, through conductor 118, through closed contact *h* of switch 116, through conductor 120, through motor 43, and through conductor 100 to power line B. It will be noted that since normally open contact *i* of switch 116 is in the energizing circuit of motor 52, said motor is de-energized whenever motor 43 is energized.

To operate the high speed motor 52, pointer 112 of the motor-operated timer 108 is manually moved to a predetermined time setting indicated on the face of the timer. Upon movement of said pointer, an energizing circuit will be immediately completed to motor 52 for operating said motor and simultaneously the energizing circuit for motor 43 will be opened. The energizing circuit for motor 52 may be traced as follows: from power line A, through closed microswitch 48, through conductor 118, through the now closed contact *i* of switch 116, through conductor 122, and through motor 52 to power line B. In addition, an energizing circuit is completed through the clock motor 110 of timer 108 which may be traced as follows: from power line A, through closed microswitch 48, through conductor 118, through the now closed contact *i* of switch 116, through the conductor 124, through the clock motor 110, and through conductors 126 and 100 to power line B. The clock motor is operable to move pointer 112 back to its neutral position and when it returns to its neutral position, movable arm 114 of switch 116 will move back to its normal position to open contact *i* and close contact *h*. In this position the energizing circuit for motor 52 is open.

It will be understood that the analysis apparatus may be employed for the continuous analysis of a variety of substances wherein it is desired to determine quantitatively a constituent of that substance, as fully described

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in the previously mentioned United States Patent No. 2,797,149. Briefly described, the substance to be analyzed is supplied to pump tube 22, air or other inert gas is supplied to pump tube 24, and a processing liquid is supplied to pump tube 26. The fluids are transmitted, by the action of the pump, through their respective pump tubes to fitting 128 where they join and are transmitted as a liquid-gas segmented stream to helical mixing coil 130. In the mixing coil the liquid constituents of the liquid segments of the stream are mixed together and the mixed segmented stream is transmitted, via conduit 132, through the passages of a dialyzer 134, at one side of the membrane thereof. Concurrently with the transmission of the liquid stream containing the substance undergoing analysis, a reagent is supplied to pump tube 28 and air or other inert gas is supplied to pump tube 30 and the fluids are transmitted through their respective pump tubes, by the action of the pump, to a fitting 136 where they join and flow as a liquid-gas segmented stream through conduit 138 and through the fluid passages of the dialyzer 134, at the other side of the membrane thereof. The segmented reagent stream functions as a recipient stream and receives the constituents which pass through the membrane of the dialyzer from the stream which is on the other side of the membrane. The recipient stream containing the diffused constituents is transmitted from the dialyzer, via conduit 140, to another helical mixing coil 142 and from said mixing coil through conduit 144 to the colorimeter where the stream is colorimetrically analyzed and the results of the analysis are recorded on the recorder 18, as previously indicated. The part of the stream passing through conduit 132 into the dialyzer which does not diffuse through the membrane of said dialyzer is discarded through conduit 146 and the analyzed stream is discarded from the colorimeter through outlet 148. As explained in United States Patent No. 2,797,149, air is introduced into the liquid streams to divide them into a series of successive small segments separated from each other by intervening air segments or bubbles which serve to cleanse the internal walls of the passages. With a series of individual samples, air is also introduced between successive samples of the liquids to separate the samples from each other and to provide a cleansing action of the passages between successive samples in order to prevent contamination of one sample by another, which might otherwise occur due to the fact the samples are introduced into the passages in series one after the other in a flowing stream.

While we have shown and described the preferred embodiments of the invention, it will be understood that the invention may be embodied otherwise than is 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 had without departing from the underlying ideas or principles of this invention within the scope of the appended claims.

What is claimed is:

1. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching means in a circuit for energizing and de-energizing said first motor,

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and means automatically operable under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized.

2. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching means in a circuit for energizing and de-energizing said first motor, means automatically operable under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized, and a timer in the circuit of said switching means for interrupting the operation of said second motor after a predetermined interval of time following the energization of said second motor.

3. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching means in a circuit for energizing and de-energizing said first motor, and means automatically operate under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized, said switching means including a manually operable switch normally connecting the first motor to said circuit and a relay operable under the control of said manually operable switch for disconnecting the first motor from said circuit and for concomitantly connecting said second motor to said circuit.

4. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching

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means in a circuit for energizing and de-energizing said first motor, and means automatically operable under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized, said switching means including a manually operable switch normally connecting the first motor to said circuit and a relay operable under the control of said manually operable switch for disconnecting the first motor from said circuit and for concomitantly connecting said second motor to said circuit, and a timer in the circuit of said switching means for interrupting the operation of said second motor after a predetermined interval of time following the energization of said second motor.

5. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching means in a circuit for energizing and de-energizing said first motor, means automatically operable under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized, and an automatically operable timer in the circuit of said

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switching means for interrupting the operation of said second motor after a predetermined interval of time following the energization of said second motor.

6. Automatic analysis apparatus comprising a plurality of tubular passages for the flow of specimen liquids and liquid reagents for treating said specimen liquids for quantitative analysis with respect to a known ingredient thereof, means for pumping said specimen liquids and said liquid reagents through said passages in predetermined proportions during successive analysis operations of the apparatus, a first motor having a drive shaft operatively connected to said pumping means for actuating said pumping means, and a second motor having a drive shaft operable at higher speed than the drive shaft of said first motor and operatively connected to said drive shaft of said first motor for pumping said specimen and reagent liquids into said passages at intervals between analysis operations for different liquid specimens at a higher rate of flow than the rate of flow of said liquids during the analysis operations, means including switching means in a circuit for energizing and de-energizing said first motor, means automatically operable under the control of said switching means to energize said second motor when said first motor is de-energized and to de-energize said second motor when said first motor is energized, and a manually adjustable timer in the circuit of said switching means for interrupting the operation of said second motor after a predetermined interval of time following the energization of said second motor.

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