March 13, 1956 W. F. EBERZ 2,737,978

PUMPING APPARATUS

Original Filed Oct. 6, 1946

Fig. 2

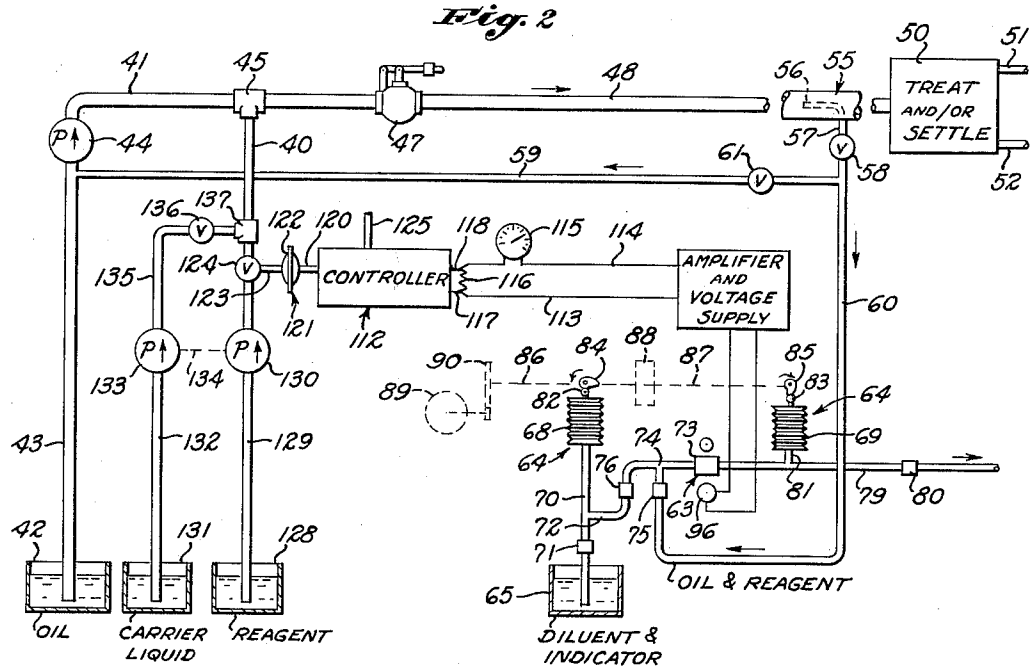


Fig. 3a

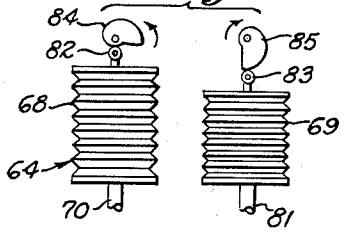


Fig. 3b

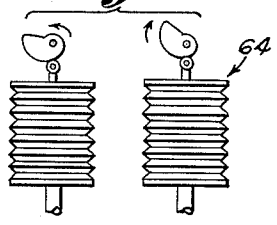
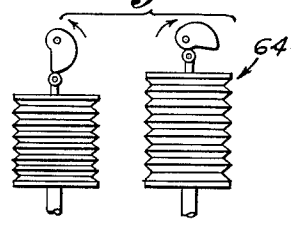


Fig. 3c



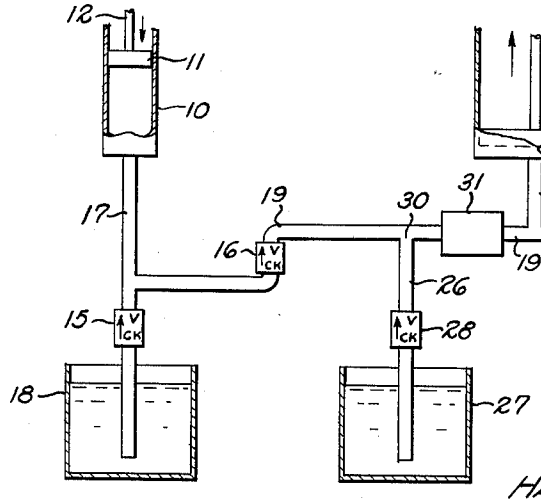


Fig. 1

INVENTOR:
WILLIAM F. EBERZ
BY HIS ATTORNEYS
HARRIS, KIECH, FOSTER & HARRIS
By Clarence F. Kiech

United States Patent Office 2,737,978 Patented Mar. 13, 1956

2,737,978

PUMPING APPARATUS

William F. Eberz, Altadena, Calif., assignor to Petrolite Corporation, Wilmington, Del., a corporation of Delaware

Original application October 6, 1946, Serial No. 778,125, now Patent No. 2,633,472, dated March 31, 1953. Divided and this application March 11, 1952, Serial No. 276,005

8 Claims. (Cl. 137—566)

This invention relates to liquid-proportioning apparatus in which a plurality of liquids are simultaneously metered or proportioned to produce a mixture of predetermined and closely controlled proportions. The present application is a division of my co-pending application Serial No. 778,125, filed October 6, 1947, now Patent No. 2,633,472, March 31, 1953, entitled "Reagent Control Method and Apparatus."

The principles of the invention are broadly applicable to the problem of proportioning a plurality of liquids and has special utility when the problem is to proportion relatively small quantities with a high degree of accuracy over relatively long periods of time. For example, the constituent volumetric rate of flow may be as low as one liter per day or less with accurate maintenance of the predetermined proportions.

The exceptional accuracy at exceedingly low rates of flow is made possible by a proportioning process in which a plurality of pumping actions are so co-ordinated that the intake phase of one pumping cycle occurs simultaneously with the discharge phase of a second pumping cycle.

The invention as employed for simultaneously metering and mixing fluids from two sources may comprise, for example, a first relatively small positive displacement pump in series with a second larger positive displacement pump with the two pumps operating synchronously but in opposite phase, in other words, with the discharge period of the smaller pump coinciding with the intake period of the larger pump. Liquid from one of the sources is fed to the smaller pump during its intake period and in the following period is discharged by the smaller pump into the intake of the larger pump. The intake capacity of the larger pump is greater than the volume discharged by the smaller pump and this difference is satisfied by placing the intake of the larger pump in communication with the second source of liquid. Thus, the liquid intake from the first source is accurately determined by the displacement volume of the first or smaller pump and the intake of liquid from the second source is accurately determined by the difference between the displacement volumes of the two pumps.

It will be apparent that the invention is adaptable to widely diverse proportioning problems and that the specific objects of the invention will vary with the specific adaptations. Thus, in different practices of the invention the primary object may pertain to the intake of liquid from the first source by the first pump, or intake from the second source by the second pump, or the intermixture of the two liquids by the action of the second pump, or the discharge of the mixture by the second pump. Moreover, as will be shown, various objects of the invention may be served by greatly prolonging either the period in which the first pump is contracting and the second pump is expanding or the other period in which the first pump is expanding and the second pump is contracting.

The objects and advantages of the invention in its various practices will be apparent from the following description taken with the accompanying drawings.

In the drawings, which are to be understood as merely illustrative:

Fig. 1 is a simpliled diagrammatic view illustrating the basic relationships in the dual pump arrangement;

Fig. 2 is a diagrammatic view illustrating the preferred elements of my flow-controlled apparatus as employed for regulating the amount of reagent supplied to an oil stream; and

Figs. 3–A, 3–B, and 3–C are enlarged diagrammatic views illustrating the co-ordinated operation of the dual pumping arrangement at various periods in its cycle.

In the simplified diagram of Fig. 1, the variable chamber for the first or smaller of the two pumps is in the form of a cylinder **10** with a coacting piston **11** operated by a suitably governed piston rod **12**. The inlet and outlet valves necessary to co-operate with this variable chamber for pumping action are in the form of simple check valves **15** and **16**, respectively, which may be in the cylinder walls or in the piping connected thereto. The inlet check valve **15** is shown in a pipe **17** leading from the cylinder **10** to communicate with liquid in a first container **18** which is one example of the first liquid source heretofore mentioned. The pipe **17** is shown as having a branch **19** on the downstream side of the inlet check valve **15**, this branch pipe being provided with the outlet check valve **16**. While the upper section of the pipe **17** serves a dual function in the embodiment shown, the pipes **17** and **19** may separately communicate with the cylinder **10** if desired.

It is apparent that expansion of the effective volume of the cylinder **10** by upward movement of the piston **11** will draw liquid from the first source through the inlet check valve **15** into the cylinder and subsequent downward movement of the piston will discharge this increment of liquid into the pipe **19** through the check valve **16**.

The second and larger pump of the dual pump arrangement has a variable chamber in the form of a cylinder **20** in which a coacting piston **21** is moved by a suitably controlled piston rod **22**. In the particular arrangement shown, the pipe **19** extends past the cylinder **20** and is connected thereto by a short branch **25** although the right and left sections of the pipe **19** may separately connect with the cylinder **20** if desired. On the downstream side of check valve **16**, a pipe **26** branches from pipe **19** and extends into a second liquid container **27** which exemplies the second liquid source heretofore mentioned. The branch pipe **26** has a suitable check valve **28** and the pipe **19** has a check valve **29** downstream from the short branch pipe **25**. It is apparent that the outlet check valve **16** of the smaller pump acts as an intake check valve for the larger pump with respect to liquid taken from the smaller pump and check valve **28** is an inlet valve for the larger pump with respect to liquid taken from the second source, the check valve **29** being an outlet valve for the larger pump.

Instead of connecting pipes **19** and **26** each directly to the large cylinder **20**, I prefer to bring these two pipes together in the manner shown to produce what may be termed a junction or mixing zone **30**. The mixing zone **30** is the juncture of the two pipes **19** and **26** where liquid from the first source **18** discharged from the cylinder **10** mingles with liquid from the second source **27**.

It is apparent that if these two pumps are operated synchronously but in opposite phase with the intake period of one pump occurring simultaneously with the discharge period of the other pump, the sequence of operation with respect to the liquids from the two sources will be as follows: First, a measured quantity of liquid from the first source **18** will be drawn into the cylinder **10** on the upward movement of the piston **11**, the inlet check valve **15** being open and the outlet check valve **16** being closed. Then the quantity of liquid isolated from

the first source in this manner will be discharged through the check valve 16 on the downward stroke of the piston 11 and as the piston 21 moves upward in the larger pump. At this same time, liquid from the second source 27 will be drawn upward through the check valve 28 to join liquid from the first source and mix therewith in the mixing zone 30 since the volumetric rate of expansion of the second pump is greater than the volumetric rate of contraction of the first pump and this difference is satisfied by the liquid from the second source. Also, during this time interval, the intermixed liquids flow into the large pump cylinder 20. On the subsequent downward movement of the piston 21, the liquid mixture is discharged through the final check valve 29.

One of the many possible specific applications of the invention which may be mentioned by way of example is to pump a corrosive liquid in a closely controlled manner without subjecting the pumping apparatus to the full corrosive effects of the liquid. In such a practice, the corrosive liquid is drawn from the second source and is mixed with the liquid from the first source as the smaller pump, serving as an auxiliary pump, discharges the liquid from the first source into the expanding second or main pump. Thus, the liquid from the first source may be of a character to dilute, neutralize, or otherwise modify the corrosive liquid before or as the corrosive liquid enters the pumping system. A non-lubricating liquid may be handled in the same way as a corrosive liquid.

As heretofore indicated, important advantages may be achieved by prolonging one or the other of the two periods of the dual pump cycle. For convenience in explaining such practices of the invention, the dual pump cycle will be referred to as consisting of a first period in which the first or smaller pump expands to draw liquid from the first source while the second and larger pump contracts, and a second period in which the smaller pump contracts to discharge its liquid into the larger pump while the larger pump expands to intake not only the discharge from the smaller pump but also the liquid from the second source. Either of these two periods may be prolonged to any desired extent for some special purpose. The disparity in time duration between the two periods may be as great or greater than a duration on the order of one hour for one period in contrast to a duration of a few seconds for the other period.

In one type of operation, the second period of the dual pump cycle is prolonged and the first period is curtailed to cause the smaller pump to draw in a predetermined quantity of liquid from the first source in a rapid manner and then to intermix this measured quantity from the first source with a measured quantity of liquid from the second source in a very gradual manner as the second pump expands, the intermixture being periodically expelled by the second pump in an abrupt manner. This dual pump cycle may have different uses. One use may be to take quick samples from the first liquid source with long intervening intervals of time for gradual intermixture of the quick samples with the liquid from the second source and rapid final expulsion from the pump system. A second use may be primarily to withdraw liquid from the second source very gradually over a prolonged period of time for gradual intermixture with a previously isolated measure of liquid from the first source. A third use may place the emphasis on the periodic short but rapid discharge of an accurately proportioned intermixture of two liquids.

In another type of operation, the first period of the dual pump cycle is greatly prolonged and the second period greatly curtailed, to cause the liquid from the first source to be drawn into the smaller pump gradually over an extended period of time and then to be quickly mixed with the second liquid in the second larger pump for final discharge of the mixture by the larger pump gradually over the next prolonged period of time. One use of this method of operation may be to accumulate and isolate in the smaller pump a quantity of liquid from the first liquid source over an extended period of time, thereby, for example, obtaining a sample representing the average character of the liquid at the source over the given period of time. These periodic samples will be automatically processed by quick mixture with liquid from the second source in the mixing zone 30 for various purposes. Another use of this dual pump cycle may be to obtain quick samples of predetermined quantity from the second liquid source at infrequent but regular times for intermixture with predetermined quantities of liquid from the first source, the emphasis being on the intake of a substantial quantity of the liquid from the second source in a minimum time interval. A third use of this dual pump cycle may be to discharge over an extended period of time a resultant mixture of the liquid from the two sources. For example, it may be desired to introduce an accurately measured mixture of two liquids into a process or system at a very gradual rate through the final check valve 29.

A feature of those practices of the invention in which one of the two periods of the dual pump cycle is prolonged in time is that the one period may be so greatly prolonged and the other period so greatly curtailed that for all practical purposes the one period is continuous. Thus, if the second period of the dual pump cycle is prolonged and the first period curtailed to the same degree, the withdrawal of liquid from the second source will be substantially continuous and the withdrawn liquid will be substantially continuously mixed with the liquid from the first source. On the other hand, if the first period of the dual pump cycle is prolonged to an hour and the second period is curtailed to a few seconds, the withdrawal of the sample stream from the first liquid source will be substantially continuous and the discharge of the intermixed liquids will likewise be substantially continuous.

It has been found that the first-mentioned practice of the invention, in which the liquid is drawn from the second source in a substantially continuous manner may be used with outstanding advantages for automatic control of a fluid system in which liquid flows constantly in a continuous process. This specific practice of the invention will be described in detail for the purpose of disclosure and to illustrate the principles involved. Those skilled in the art will find therein adequate guidance for applying the broad inventive concept to other specific purposes.

In the specific embodiment of the invention selected for disclosure, a suitable reagent is mixed with an oil in a continuous process and the object is to control the addition of the reagent to the continuous oil stream in an automatic manner to maintain the character of the intermixture substantially constant. The control procedure involves substantially continuously withdrawing a sample from the stream of oil intermixed with reagent, substantially continuously intermixing the withdrawn sample with another liquid miscible or immiscible therewith and which may be, for example, a solvent or an indicator, and continuously testing this final intermixture for automatic regulation of the rate at which the reagent is added to the oil.

One object of this particular practice of the invention is to provide the accuracy of volumetric measurement that is characteristic of a closely controlled positive displacement pumping arrangement and at the same time to provide a sampling operation that approximates continuous operation close enough for effective and stable regulation of the continuous process that is to be controlled. These objects are attained by employing the dual pump arrangement with the second period of the pumping cycle greatly prolonged.

A further object of this practice of the invention is to provide a continuous sampling arrangement for the

control of a continuous process in which the lag in time between the withdrawal of the sample liquid from the continuous process and the actual testing of the sample for detection of variations is minimized so that any departure from the desired norm in the continuous process will be automatically corrected in its incipience. This object is readily accomplished by causing the sample stream to be immediately intermixed with the liquid from the smaller pump as the smaller pump discharges into the larger pump, and by directing this intermixed stream past a test station or detecting zone on its way to the intake of the larger pump.

The test station or detecting zone may be anywhere along pipe **19** between the mixing zone **30** and the branch pipe **25**. In Fig. 1, a suitable detecting device **31** represents such a test station or detecting zone.

By causing both of the pistons **11** and **21** to move at constant rates during the discharge of the smaller pump and the simultaneous intake of the larger pump, and by greatly prolonging this period in the dual pump cycle, the volumetric rate of intake from the second liquid source, in this case the sample to be tested, and the flow of the sample liquid intermixed with the liquid from the first source will be constant during the same prolonged period of time.

To carry out this metering procedure with close accuracy at exceedingly slow rates of flow, requires positive and effective action on the part of the various check valves. Positive action on the part of the check valve **16** is especially important and it will be noted than an exceptionally high pressure differential exists across this valve during both periods of the dual pump cycle because in each period one of the two pumps is creating a vacuum on one side of the check valve while the other pump is simultaneously applying positive pressure on the other side. As to this valve and also the check valves **15**, **28** and **29**, it will be observed that these valves operate only infrequently as compared with conventional proportioning pumps which have valves operating at much higher frequency. This prolongs the life of the valves many fold.

Referring now to Fig. 2 of the drawing, the control apparatus illustrated therein is particularly adapted to regulate the amount of a reagent flowing through a line **40** which is supplied to an oil stream flowing through a line **41**. The oil, which may be a petroleum distillate such as diesel fuel, for example, may be withdrawn from a storage tank **42** through a line **43** leading to a pump **44** which forces the oil under pressure through the line **41** past the junction **45** of the lines **40** and **41** where the reagent is added to the oil stream as a continuously flowing stream controlled in volume in a manner to be described in more detail hereinafter.

Although the reagent and oil streams flowing in the lines **40** and **41** mix to some extent at the junction **45**, an additional mixing action may be provided, if desired, by a mixing means **47**, which is shown as a weight-loaded valve for illustrative purposes. In the event that the reagent is substantially immiscible with the oil, it is desirable that the mixing means **47** be capable of dispersing the reagent in the oil in the form of small droplets so as to produce an oil-continuous emulsion.

The stream of the oil-reagent mixture, hereinafter termed the "major stream," flows through a line **48** to treating, processing, or settling equipment which is indicated generally by the numeral **50**. For example, if the equipment **50** serves to separate the phases of an emulsion flowing through the line **48**, it may be equipped with an effluent line **51** for discharging the separated or treated oil and an effluent line **52** for discharging the separated reaction products resulting from a chemical reaction between the reagent and some component of the oil. In the equipment **50** any suitable aid for effecting such separation may be employed.

For the purpose of this disclosure, it is not necessary to describe the various treatments or processing steps which may be performed by the equipment **50**, the invention being primarily concerned with regulating the amount of reagent which is supplied through the line **40** to compensate for changes in some chemical characteristic of the oil stream or changes in the volume thereof. For example, the line **41** may carry a stream of a mineral oil distillate such as diesel fuel containing organic acids which vary in kind or amount from time to time. It is often desirable to neutralize such acidity to some extent by mixing an alkaline reagent with the stream of oil, the present invention, in one of its applications, being directed to controlling the amount of the alkaline reagent which is supplied to the stream of oil flowing in the line **41** through the line **40** in such a manner that the acidity or alkalinity, i. e., hydrogen ion concentration, of the oil-reagent or major stream flowing through the line **48** is maintained substantially constant within predetermined limits to aid in subsequent treatment, processing, or settling by the equipment **50**, or for other purposes.

The apparatus is provided with a sampling device **55** which withdraws a small portion of the major stream for control purposes. In its simplest form, the sampling device **55** may merely consist of a small tube **56** which is centered in the line **48** and having an open end which faces upstream to withdraw a representative small portion of the major stream. The tube **56** is connected to a line **57**, flow through which is regulated by a valve **58**.

I prefer to withdraw through the line **57** a stream of somewhat larger volume than that which is actually required for the detecting system to be described hereinafter. As indicated in Fig. 2 of the drawing, the stream flowing through the valve **58** is divided into two portions, viz., a by-passed portion flowing through a line **59**, and another portion forming a sample or minor stream flowing through a line **60** to the detecting system. Although the by-passed portion flowing through the line **59** may be discarded, it is preferably returned to the oil stream on the intake side of the pump **44**, the line **59** being shown connected to the line **43** for this purpose. The volumetric flow rate of this by-passed portion is quite small, although often substantially larger than that of the sample stream, and can be regulated manually by means of a valve **61** in the line **59**.

If the sample or minor stream flowing through the line **60** is a multiple-phase stream, it is desirable to convert it into a homogeneous stream before delivering it to the detecting system, which is indicated generally by the numeral **63** and which may, for example, be a colorimetric or electrometric cell responsive to pH or hydrogen ion concentration of the homogeneous stream. If the reaction between the reagent added to the oil stream and the desired component of the oil stream has not been completed, it is also desirable to accelerate this reaction so that it is complete, or at least substantially complete, before the sample stream is delivered to the detecting system **63**. Moreover, in aqueous systems as well as oil-continuous or non-aqueous systems, it is highly desirable that any foreign materials which tend to settle out or deposit, such as color bodies, polymers, dirt, etc., be retained in solution to prevent interference with the operation of the detecting system **63** as will be discussed in more detail hereinafter. The foregoing and other desirable functions may be performed by a suitable diluent, preferably of the alcoholic type, mixed with the sample stream, this diluent preferably being completely miscible with the oil. In addition, if the sample stream flowing through the line **60** is of a multiple-phase nature, the diluent should be of such character and used in such amount as to convert the sample stream from a heterogeneous to a homogeneous stream.

As shown in Fig. 2 of the drawing, the apparatus includes means **64** for metering the proper proportions of the diluent and the oil-reagent mixture and for bringing them together and delivering them to the detecting system **63**. Although the indicator employed in con-

nection with the detector system may be metered separately if desired, I prefer to mix the indicator with the diluent in a suitable container 65 prior to metering of the diluent by the meter means 64 so that the metering means will meter the proper amount of diluent and indicator simultaneously.

Considering the metering means 64 in more detail, since the sample stream containing the diluent and indicator, hereinafter termed the "test stream," usually cannot be returned to the major stream, in order to avoid contamination of the latter, the test stream is preferably disposed of in any suitable manner. Consequently, in order to avoid waste, the flow rate of the oil-reagent and diluent-indicator mixtures used to form the test stream are preferably held to very small values, it being contemplated that the amount of diluent used be held to approximately one liter per day as an example. Accordingly, it is necessary that the metering means 64 be capable of delivering the oil-reagent and diluent-indicator mixtures to the detecting system 63 at flow rates in the vicinity of from 0.1 to 5 ml. per minute, for example. Moreover, the metering means must be capable of operating at such flow rates while metering the amount of the oil-reagent and diluent-indicator mixtures forming the test stream accurately and without introducing any undue lag between the time that the simple stream is withdrawn from the major stream and the time that the test stream is delivered to the detecting system 63. The manner in which the metering means 64 operates to perform the foregoing functions will be evident from the description thereof in the following paragraphs.

The emphasis in the preceding paragraph is on relative rates of flow regardless of the means employed. Thus the diluent-indicator fluid is delivered in a positive manner at a given rate to the detector device and the pump 69 withdraws fluid from the detector device at a higher given rate. As a consequence, the mixture of oil and reagent flows simultaneously to the detector device at the precisely predetermined difference between the two given rates. It is also to be emphasized that immediately upon addition of the indicator, the resultant mixture enters the detector device without passing through any intervening pumping means, a very desirable result.

The time lag between the withdrawal of a sample from the main stream in pipe 48 and the response of the controller 112 should desirably be as short as possible. The omission of any pumping means between the point of entry of the indicator fluid at the mixing means 74 and the testing of the mixture at the detector device 73 minimizes this time lag not only by keeping the flow path short but also by avoiding the penalty of dead pump space. The dead space in most pumps designed for low rates of flow actually represents many minutes of through-put when the pumps are operated at their minimum rates. To minimize this penalty in time, it is necessary to increase the sampling rate and thus use more diluent with consequent increase in the cost of materials as well as in maintenance cost.

As shown diagrammatically in Fig. 2 of the drawing, the metering means 64 includes a pair of variable volume chambers typically provided by bellows pumps 68 and 69. The bellows pump 68 communicates with the container 65 for the diluent-indicator mixture through a line 70 which is provided with a check valve 71 therein for the purpose of preventing reverse flow from the pump to the container. A branch line 72 leads from the line 70 to a test zone or detecting zone represented by a detector device 73 which forms part of the previously mentioned detecting system 63, the line 60 for the sample stream of the oil-reagent mixture being connected to the line 72 at a junction upstream from the device 73 as indicated by the numeral 74, the junction representing a suitable mixing means to create a mixing zone. Check valves 75 and 76 are located in the lines 60 and 72 respectively, for the purpose of preventing back flow of the oil-reagent sample stream and of the diluent-indicator stream, respectively. The test stream resulting from mixing of the oil-reagent and diluent-indicator streams at the junction 74 flows through the detector device 73 into a discharge line 79 which is provided with a check valve 80 therein for preventing reverse flow of the test stream, the bellows pump 69 being connected to the discharge line 79 by a line 81. Any suitable auxiliary mixing device may be employed at the junction 74 or between the junction and the detector device 73 to insure a thorough mixing of the oil-reagent and diluent-indicator stream.

The bellows pumps 68 and 69 provide cam followers 82 and 83 operated by cams 84 and 85, respectively, which rotate in opposite directions as viewed in Figs. 3–A, 3–B and 3–C and as indicated by the arrows thereadjacent. The bellows may be sufficiently resilient to retain their cam followers 82 and 83 in contact with the cams and draw fluid into the bellows, or springs can be used to maintain the bellows in contact with the cams. A driving connection between the cams 84 and 85 is shown diagrammatically in Fig. 2 of the drawing and may include shafts 86 and 87 connected by a gear assembly 88 which reverses the direction of rotation of the shaft 87 with respect to that of the shaft 86. The shaft 86 may be driven by a motor 89, for example, through a suitable reduction gear system 90. Alternatively, both cams 84 and 85 may be mounted on the shaft 86 to turn therewith and in the same direction, one cam being then the mirror image of the other.

The operating cycle of the metering means 64 may conveniently be considered as comprising two parts, viz.: a first or primary period during which the cam 84 compresses the bellows pump 68 to its minimum volume while the cam 85 permits the bellows pump 69 to expand to its maximum volume; and a secondary stage during which the cam 84 permits the pump 68 to expand to its maximum volume while the cam 85 compresses the pump 69 to its minimum volume. For a reason which will be made apparent hereinafter, the cams 84 and 85 are so contoured that the pumps 68 and 69 are expanded and contracted, respectively, rather abruptly during the secondary period of the operating cycle so that only a very small portion of the duration of the entire cycle elapses during the secondary part thereof, the liquid flow through the detector device 73 being stopped during the secondary stage of the operating cycle.

Thus, at the end of the primary period of the operating cycle, the cam 84 rotates into a position such that the bellows pump 68 is permitted to expand abruptly, whereby this pump draws a quantity of the diluent-indicator mixture from the container 65 upwardly through the line 70 past the check valve 71, back flow through branch line 72 being prevented by the check valve 76. Subsequently, during the primary part of the operating cycle, the cam 84 compresses the bellows pump 68 slowly and linearly with time so as to expel the diluent-indicator mixture therefrom and to push it through the line 72 past the check valve 76 to the junction 74, reverse flow to the diluent-indicator container 65 being prevented during the primary part of the cycle by the check valve 71. The contour of the cam 84 which operates the bellows pump 68 is such that the diluent-indicator mixture is pushed through the branch line 72 at precisely the volumetric flow rate required to obtain the desired proportion of the diluent-indicator mixture in the test stream formed at the junction 74 of the lines for the diluent-indicator and oil-reagent streams.

While the bellows pump 68 is being compressed slowly by the cam 84 in this manner, the cam 85 permits the bellows pump 69 to expand at a greater volumetric rate. This not only acts to draw the test stream, formed at the junction 74, through the detector device 73, but also meters and draws into the junction 74 a proportioned

amount of the oil-reagent mixture from the line **60**, this amount being determined by the difference in volumetric rates of change of the bellows pumps **68** and **69**. During expansion of the bellows pump **69**, reverse flow in the outlet end of the discharge line **79** is prevented by the check valve **80**. It will be apparent that the rate at which the volume of the bellows pump **68** is decreased by the cam **84** during the primary part of the operating cycle will determine the rate at which the diluent-indicator mixture is delivered to the junction **74**, and the increased rate at which the volume of the bellows pump **69** increases as it is permitted to expand by the cam **85** will determine the rate at which the test stream is drawn through the detector device **73** and also the rate at which the oil-reagent mixture is delivered to the junction **74**. Correspondingly, the rate of volume decrease of the bellows pump **68** must be equal to the desired volumetric flow rate of the diluent-indicator mixture, and the rate of volume increase of the bellows pump **69** must be equal to the volumetric rate of flow of the diluent-indicator mixture plus that of the oil-reagent mixture comprising the test stream, the difference between the rate of volume increase of the pump **69** and the rate of volume decrease of the pump **68** being equal to the volumetric flow rate of the oil-reagent mixture. It will be understood that this difference may be obtained by making the difference between the maximum and minimum lengths of the bellows pump **69** greater than that of the pump **68** if the pumps are of the same diameter or by using pumps of the same maximum length but of different diameter or by using pumps which differ both in such maximum lengths and in diameter.

At the end of the primary period of the cycle, the cam **85** abruptly compresses the bellows pump **69** to its minimum volume so that the test mixture inhaled thereby is expelled through the discharge line **79** through the check valve **80**, back flow being prevented during this expulsion process by the check valves **75** and **76**. At the same time, the cam **84** permits the bellows pump **68** to expand quickly to its maximum volume so as to draw in a fresh charge of the diluent-indicator mixture past the check valve **71**. Subsequently, the cam **84** gradually decreases the volume of the bellows pump **68** and the cam **85** gradually permits the volume of the pump **69** to increase so as to meter the diluent-indicator and oil-reagent mixtures during a repetition of the primary part of the operating cycle.

It will be apparent that the metering means **64** thus delivers the test mixture consisting of the proper proportions of the diluent-indicator and oil-reagent mixtures to the detector device **73** in the form of a stream which flows continuously except for the brief interval taken up by the secondary part of the operating cycle, which interval is preferably made very small by properly contouring the cams **84** and **85** as previously discussed. The operating cycle of the metering means **64** is preferably relatively long, e. g., one hour more or less, so that pressure pulsations in the system are created only at infrequent intervals. Consequently, the check valves **71** and **80** must be maintained in proper operating condition since any appreciable leakage past these valves would affect the accuracy of the metering means to some extent.

I have found that the metering means **64** will meter and mix fluids accurately at flow rates as low as 0.1 to 5 ml. per minute, for example, and will operate satisfactorily for extended periods of time. The metering means thus permits using only very small quantities of the oil-reagent and diluent-indicator mixtures, the use of only one liter of diluent per day, for example, being entirely practicable, which is an important feature of the invention.

The detecting device **73** and the detecting system **63** may include any suitably responsive detecting element **96** that is connected to an amplifier and voltage supply as shown in Fig. 2. The output side of the amplifier circuit may be connected to a suitable controller indicated generally by the numeral **112**, the connection being made by conductors **113** and **114**. The controller **112** is adapted to regulate the amount of reagent added to the stream of oil flowing through the line **41** in a manner well understood in the art. If desired, the output potential may be supplied to a meter **115**, which may be a milliammeter calibrated in suitable units for the purpose of giving test readings. The meter **115** is shown diagrammatically as being connected in series with an impedance **116** across the output leads **113** and **114**. The controller **112** receives the test-derived potential from conductors **117** and **118** tapped across a portion of the impedance **116**. If desired, the controller **112** may include an additional amplifier, the output of which may be employed to control the amount of reagent added to the oil stream flowing through the line **41**.

Although the controller **112** may be of any suitable type, I have shown a controller of the so-called pneumatic type in the drawing for the purpose of illustration. The output of the controller amplifier, if such an amplifier is employed, is delivered to an electrically operated valve (not shown) which controls the flow of air through a line **120** to and from a diaphragm unit **121** to control the pressure applied to the right side of a diaphragm **122**, the latter being connected to a stem **123** of a control valve **124** which varies the flow of the reagent through the line **40**. Compressed air is supplied to the controller **112** through a line **125**, the pressure of the air delivered to the diaphragm unit **121** being controlled by the previously mentioned valve in the controller. It will be understood that the pneumatic type controller **112** used with the meter **115** is merely illustrative of one of a number of means for actuating the control valve **124** in response to variations in the electrical potential developed by the detecting system **63**.

The amount of reagent added to the stream of oil may be regulated by the controller **112** in various ways, two different ways being suggested in Fig. 2. In the first place, a reagent of a predetermined concentration may be withdrawn from a container **128** through a line **129** by a pump **130** which delivers it at substantially constant pressure to the control valve **124** and thence to the line **40**. In this system the volumetric flow rate of a reagent of a constant, predetermined concentration is controlled in such a manner as to maintain the hydrogen ion concentration of the oil-reagent stream flowing through the line **48** substantially constant.

In the second place, the volumetric flow rate of the reagent delivered to the line **40** may be maintained relatively constant while the concentration thereof is varied by means of the detecting system **63** and controller **112**. This system is particularly suited to installations in which the reagent includes two components, e. g., an acid or alkali and a carrier such as water, alcohol, etc. In such a system, a relatively concentrated acid or alkaline solution may be present in the container **128** and may be withdrawn therefrom by the pump **130** under the control of the valve **124** as previously discussed. In addition, the carrier liquid, e. g., water, alcohol, etc., may be stored in a container **131** and may be withdrawn therefrom through a line **132** by a pump **133**, the pumps **130** and **133** preferably being interconnected as indicated diagrammatically by the dotted line **134** and being connected to a suitable drive means (not shown). The pump **133** delivers the stream of carrier liquid withdrawn from the container **131** through a line **135** and a valve **136** to the line **40** at a junction **137** downstream from the control valve **124**, where it mixes with the stream in the line **40** to form the reagent which is continuously mixed with the oil stream in the line **41**. In this system, a reagent of variable concentration is delivered to the oil stream while the volumetric flow rate thereof may be substantially constant, the concentration of the reagent

being regulated by the control valve 124 under the influence of the controller 112 and the detecting system 63.

As an example of the operation of my flow control apparatus, it will be assumed that a stream of a mineral oil distillate such as diesel fuel, one of the many fluids which may be processed in accordance with the invention, is to be partially or completely neutralized. Diesel fuel usually contains naphthenic acids so as to form corresponding naphthenates. These can be separated from the distillate stream in the equipment 50, a soap stock effluent being discharged through the line 52 and a diesel fuel effluent being discharged through the line 51. In order to insure a complete separation of the soap stock as well as to perform other desirable functions, the amount of reagent added to the stream of diesel fuel should be correlated accurately with the naphthenic acid content of the fuel, which content may change from time to time. The present invention is particularly well suited for such processing of diesel fuels and its operation in this connection is explained in the following paragraphs.

The diesel fuel is pumped along the line 41 by the pump 44 and an alkaline solution, typically an aqueous solution of about 0.25 to 1.0 N, is drawn from the container 128 by the pump 130 and is delivered to the junction 45 under the control of the valve 124, the valve 136 being closed in this example of the operation of the apparatus. The alkaline solution mixes with the oil stream at the junction 45 to some extent, but it is often desirable, both for the purpose of the present invention and for the effectiveness of the naphthenic acid recovery process, to mix the resulting oil-reagent or major stream additionally through the action of the mixing means 47. The mixing means produces a non-aqueous, multiple-phase stream which comprises an external phase of the diesel fuel and an internal phase of minutely dispersed droplets of the alkaline reagent reacting with the naphthenic acids in the oil to form dispersed reaction products which include particles of aqueous soap stock. In the example under consideration, the major stream flowing through the line 48 represents a heterogeneous system, usually an emulsion, and the reaction between the alkali and any acids contained in droplets dispersed in the oil (e. g., sulfonic acids from a sulfuric acid treatment) takes place only as fast as the alkali diffuses to the interfaces of such acid droplets. In such an installation, the heterogeneous stream is preferably sampled shortly after the emulsion is formed and even before the reaction between the alkali and the acids is complete.

In sampling the major stream flowing through the line 48, the valves 58 and 61 are preferably set to withdraw a stream which is larger than the sample stream to be delivered to the metering means 64 in order to insure a representative sample stream. The excess withdrawn by the sampling means 55 is preferably returned to the system at the inlet side of the pump 44 via the line 59 as previously discussed. The metering means 64 accurately meters the oil-reagent mixture from the line 60 and the diluent-indicator mixture from the container 65 in the proper proportions, the metered quantities of the oil-reagent and diluent-indicator mixtures being brought together and delivered to the detecting system 63 in the form of a test stream. In the particular application of my invention which is under consideration, the diluent is preferably secondary butyl alcohol and the volumetric ratio of the diluent to the oil-reagent mixture is preferably approximately 2:1. Various indicators may be employed in connection with the particular mineral oil distillate under consideration, the indicator preferably being mixed with the diluent preliminarily as previously discussed.

It will be apparent that my invention may be employed for controlling the hydrogen ion activity of the stream of diesel fuel by varying the amount of alkaline reagent added to the stream in accordance with continuous testing of the mixed stream containing the indicator liquid. In a similar way, the invention may be applied to neutralizing or partially neutralizing other animal, vegetable, or mineral oils containing acids, which are either naturally present or which are present because of prior processing. In other instances, the invention is applicable to the acid treatment of such oils wherein acids are added either for the purpose of reacting with alkaline materials which may be present or for the purpose of reacting with other acid-reactable components which may be present, as in the acid refining of mineral oil distillates.

Since various changes, modifications, and substitutions can be made without departing from the spirit of the invention, I hereby reserve the right to all such changes, modifications, and substitutions as properly come within the scope of the appended claims.

I claim as my invention:

1. In an apparatus for proportioning and mixing first and second fluids from first and second sources of supply, the combination of: a pipe means providing a discharge portion, a first intake portion and a second intake portion opening on the pipe means at a position between said first intake portion and said discharge portion, said second intake portion being connected to said second source of supply; a first pump means including a first variable volume chamber connected to said first source of supply to receive an increment of said first fluid from said first source of supply when said chamber expands and to expel such fluid increment into said first intake portion when said chamber contracts; a second pump means including a second variable volume chamber communicating with said discharge portion for respectively receiving and expelling a mixture of said fluids upon expansion and contraction of said second variable volume chamber; operation means including means for slowly contracting said first chamber at one volumetric rate and simultaneously slowly expanding said second chamber at a large volumetric rate to draw said second fluid into said pipe means through said second intake portion in amount determined by the difference in said volumetric rates, said operating means including means for quickly expanding said first chamber to draw in a new charge of said first fluid and for simultaneously quickly contracting said second chamber to expel a mixture of said two fluids therefrom.

2. In an apparatus for mixing a first liquid from a first source with a second liquid from a second source in predetermined proportions, the combination of: a first pumping means having a first variable volume chamber; a second pumping means having a second variable volume chamber; and operating means to operate said two pumping means synchronously in opposite phase with the volumetric rate of change of said second chamber greater than the volumetric rate of change of the first chamber, said first pumping means having its inlet in communication with said first source, said second pumping means having its inlet connected with said first pumping means and also in communication with said second source whereby the difference between the volumetric rate of expansion of the second chamber and the volumetric rate of contraction of the first chamber is satisfied by liquid from said second source, said operating means including means producing a cycle of operation characterized by a relatively long period in which one of said chambers gradually contracts while the other gradually expands followed by a relatively short period in which said one chamber quickly expands and said other chamber quickly contracts.

3. An apparatus as set forth in claim 2 in which said first chamber gradually expands during said relatively long period whereby the liquid from the first source is drawn into said first chamber in a substantially constant manner, interruption occurring infrequently by quick contraction of said first chamber.

4. In an apparatus for mixing a liquid from a first source with a liquid from a second source in predetermined proportions and for moving the mixture in a sustained stream through a detecting zone to ascertain changes in the character of the mixture, the combination

therewith of: means providing a mixing zone; a test cell connected to receive a mixture from said mixing zone, said test cell providing said detecting zone; a first pumping means having a first variable chamber communicating both with said first source and through said mixing means with the inlet side of said detecting zone to pump the first liquid toward the detecting zone; unidirectional passage means from said second source communicating with said mixing zone and thence with the inlet side of said detecting zone, said passage means including a check valve preventing reverse flow therein; a second pumping means having a second variable chamber in communication with the outlet side of said detecting zone; and operating means for mechanically connecting said two pumping means, said operating means synchronizing the contraction of said first chamber with the expansion of said second chamber, the volumetric rate of contraction of said first chamber being the predetermined proportionate rate of flow of the first liquid, the volumetric rate of expansion of the second chamber exceeding the volumetric rate of contraction of the first chamber, the difference between the two rates being equal to the predetermined rate of flow of the second liquid.

5. An apparatus as set forth in claim 4 in which said operating means includes means producing an operating cycle consisting of a short period during which said operating means expands and contracts said second chamber and a long period during which said operating means contracts said first chamber and expands said second chamber whereby liquid is drawn from said second source through said detecting zone substantially continuously.

6. An apparatus for proportioning and mixing first and second fluids obtained respectively from first and second sources of supply, said apparatus including in combination: means providing a mixing zone; a first reciprocatory pump including a first variable-volume chamber; check-valve-equipped intake means communicating between said first source of supply and said first chamber for supplying first fluid to said first chamber upon expansion of said first chamber but preventing reverse flow; a pair of pipes communicating with said mixing zone and comprising a first pipe communicating with said first chamber for conducting an increment of said first fluid therefrom to said mixing zone upon contraction of said first chamber, said pair of pipes including a second pipe communicating between said second source of supply and said mixing zone to supply thereto a stream of said second fluid; check valves in said first and second pipes preventing reverse flow therethrough in a direction away from said mixing zone; a conduit conducting a mixture of said fluids from said mixing zone; a test cell in said conduit; a second reciprocating pump providing a second variable-volume chamber and having an inlet communicating with said mixing zone through said conduit and said test cell to receive said mixture of said fluids upon expansion of said second chamber, said second pump having a discharge for conducting said mixture from said second chamber upon contraction thereof; a valve in said discharge preventing reverse flow of said mixture to said second chamber; and operating means for operating said first and second pumps in step with each other but in opposite phase to expand said second chamber concurrently with the contraction of said first chamber but at a volumetric expansion rate in excess of the volumetric contraction rate of said first chamber during one portion of an operational cycle to draw said second fluid through said second pipe at a rate equal to the difference in said volumetric rates, said operating means including means for contracting said second chamber concurrently with the expansion of said first chamber during another portion of said operational cycle to expel said mixture from said second chamber through said discharge and draw an increment of said first fluid into said first chamber through said intake means, said one portion of said operational cycle being extremely long as compared with said other portion of said operational cycle.

7. In an apparatus for sampling and testing a liquid stream in such way as to minimize the time elapsed between the withdrawal of a small sample stream therefrom and the testing of said sample stream and also to minimize the volume of the liquids required for testing, the combination of: means providing a mixing zone; a test cell providing a test zone; a first pump connected to deliver a test liquid at a given rate to said mixing zone; means providing a path of flow for said sample stream to said mixing zone; means providing a path of flow of the mixed test liquid and sample stream from said mixing zone to said test cell; and a second pump for withdrawing the mixture from said test cell at a rate greater than said given rate so as to draw a predetermined amount of the liquid of said sample stream into said mixing zone and through said test zone.

8. An apparatus as defined in claim 7 in which said first and second pumps are positive displacement pumps having pumping chambers and including means for driving such pumps in step with each other, said last named means including means for rapidly expanding and contracting the respective pumping chambers of said first and second pumps in a short period of time and for extremely slowly contracting and expanding the respective pumping chambers of said first and second pumps in a long period of time, the sum of such short and long periods representing one cycle of said apparatus.

References Cited in the file of this patent

UNITED STATES PATENTS

94,746	Holly	Sept. 14, 1869
190,902	Remsen	May 15, 1877
595,942	Diehl et al.	Dec. 21, 1897
1,121,488	Ford	Dec. 15, 1914
1,428,204	Barnickel	Sept. 5, 1922
1,908,924	Schaeffer et al.	May 16, 1933
1,919,981	Le Sur	July 25, 1933
1,977,171	Clithero et al.	Oct. 16, 1934
2,009,622	Kennedy	July 30, 1935
2,074,883	Ziebolz et al.	Mar. 23, 1937
2,400,298	Jones et al.	May 14, 1946
2,529,028	Landon	Nov. 7, 1950
2,532,856	Ray	Dec. 5, 1950
2,607,718	Suthard	Aug. 19, 1952