Sept. 15, 1970 J. PLUCKER III 3,528,440

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 1

FIG. 1

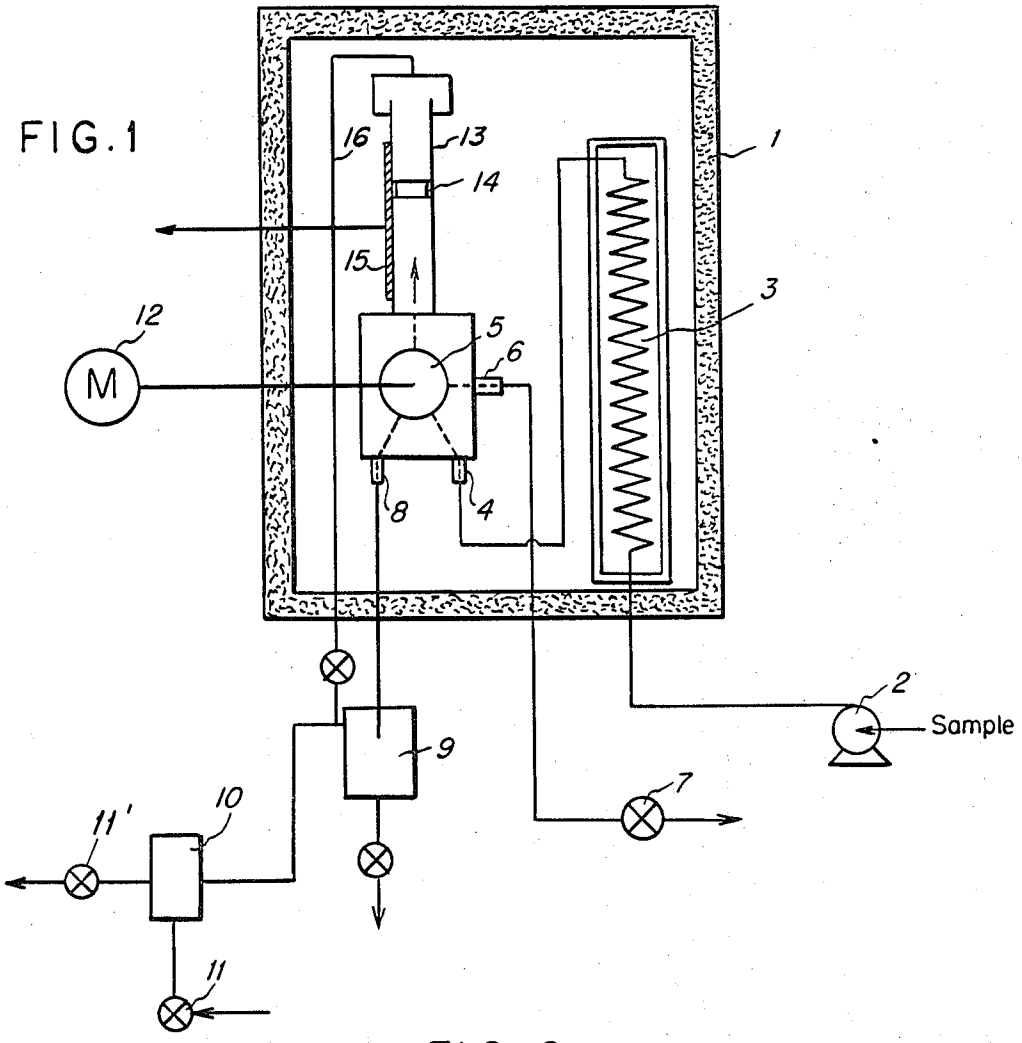
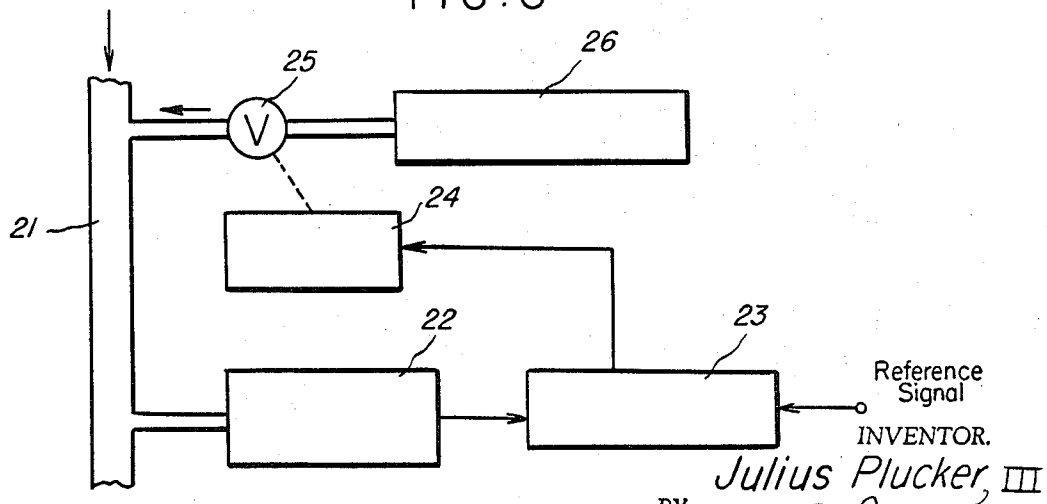


FIG. 6



INVENTOR.
Julius Plucker, III
BY James F. Powers Jr.
Attorney

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 2

FIG. 2

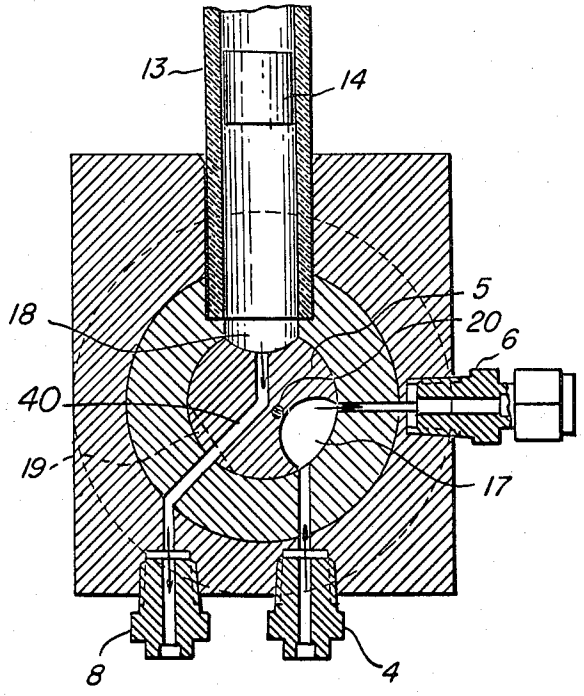
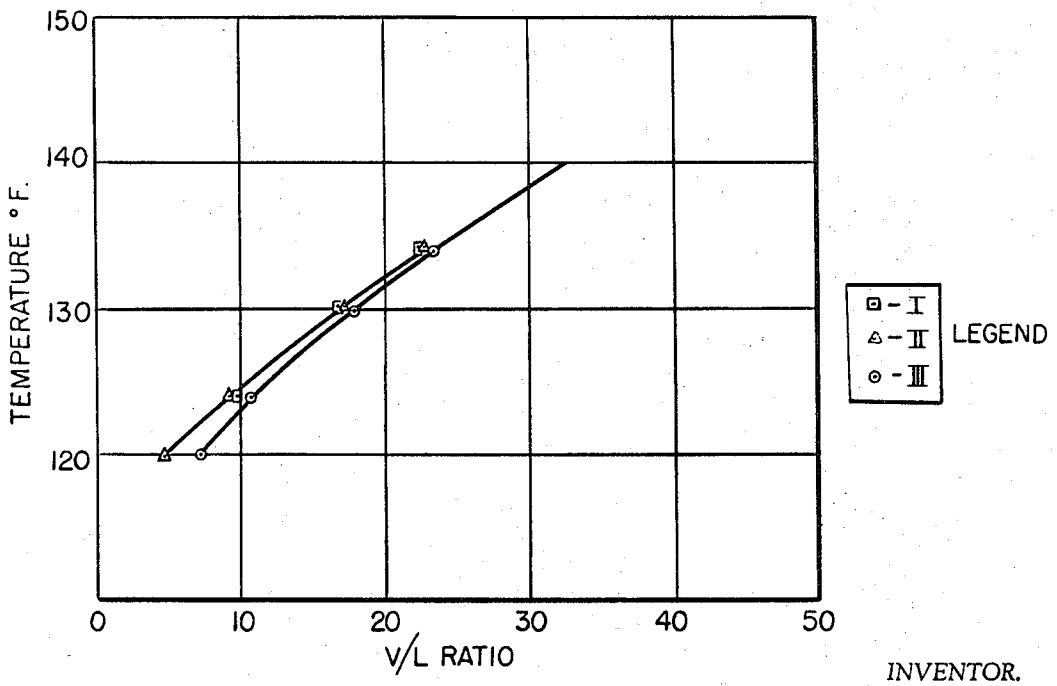


FIG. 7



INVENTOR.
Julius Plucker, III
BY
James F. Powers Jr
Attorney

Sept. 15, 1970 J. PLUCKER III 3,528,440

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 3

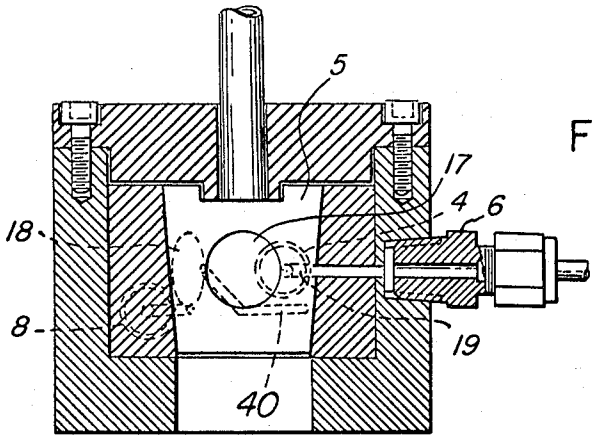


FIG. 5

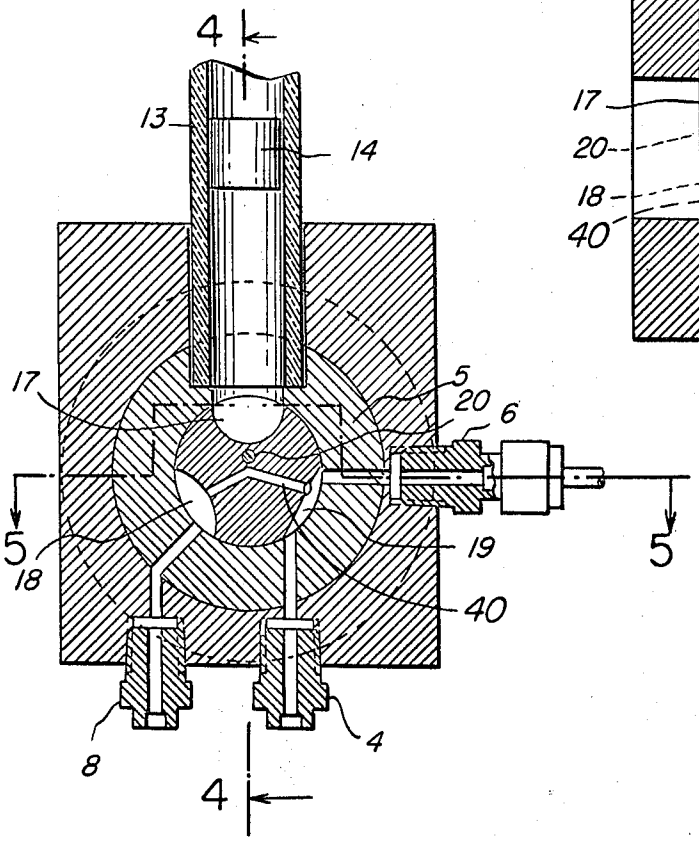


FIG. 3

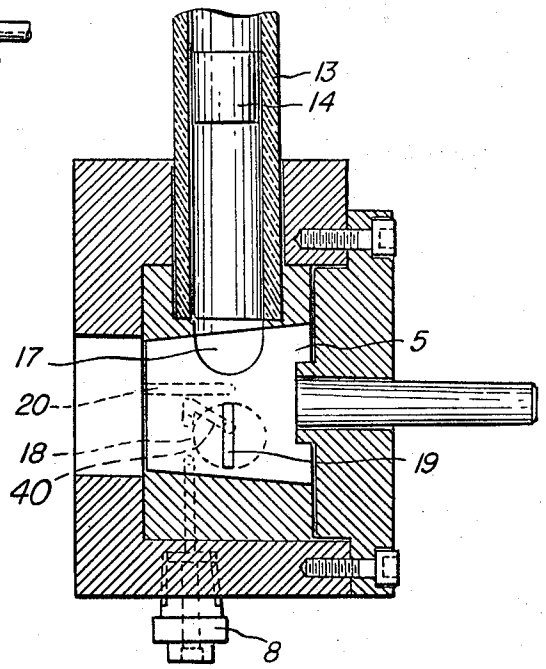


FIG. 4

INVENTOR.
Julius Plucker, III
BY
James F. Powers Jr
Attorney

Sept. 15, 1970 J. PLUCKER III 3,528,440

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 4

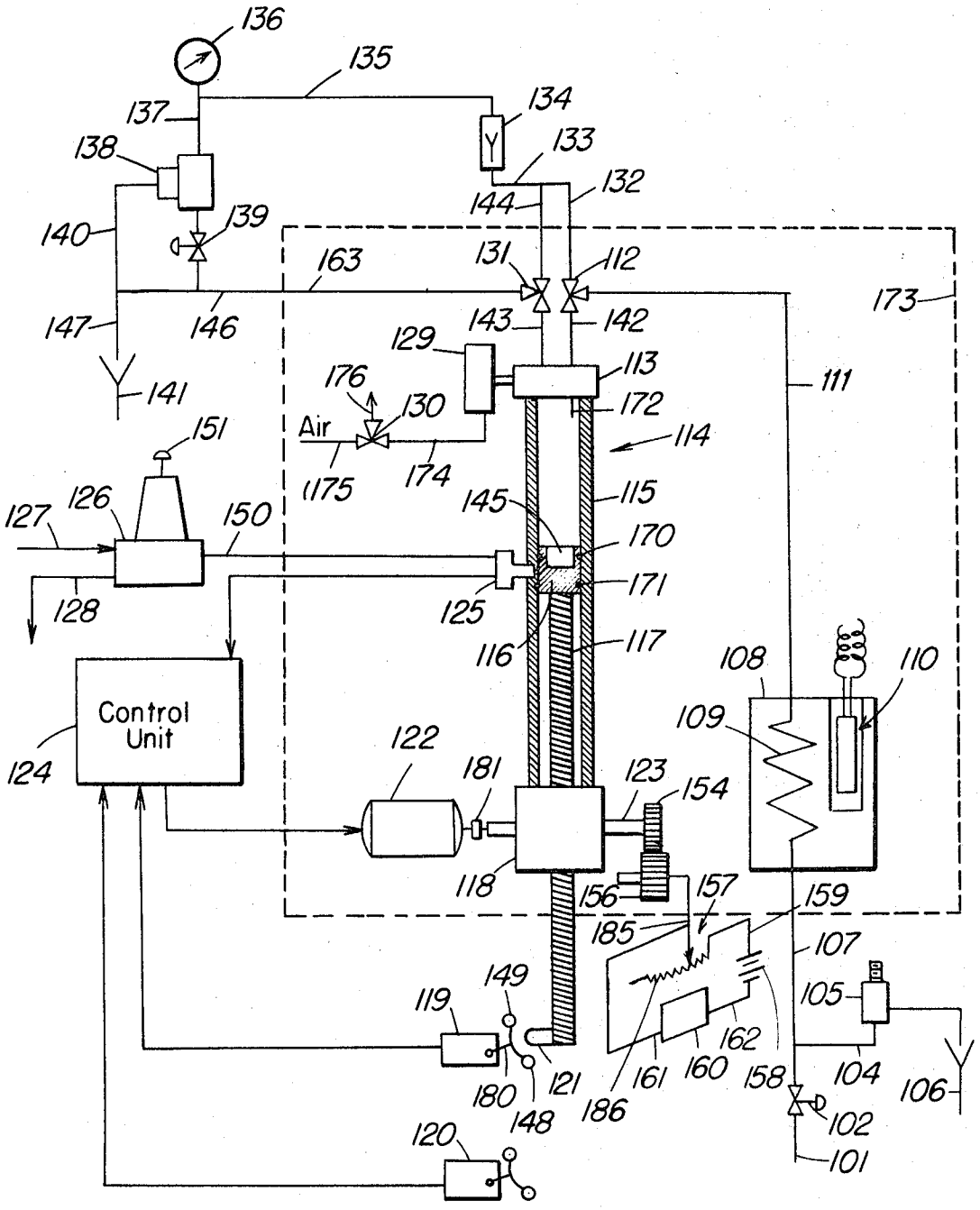


FIG. 8

INVENTOR.
Julius Plucker, III
BY James F. Lawrence
Attorney

Sept. 15, 1970 J. PLUCKER III 3,528,440

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 5

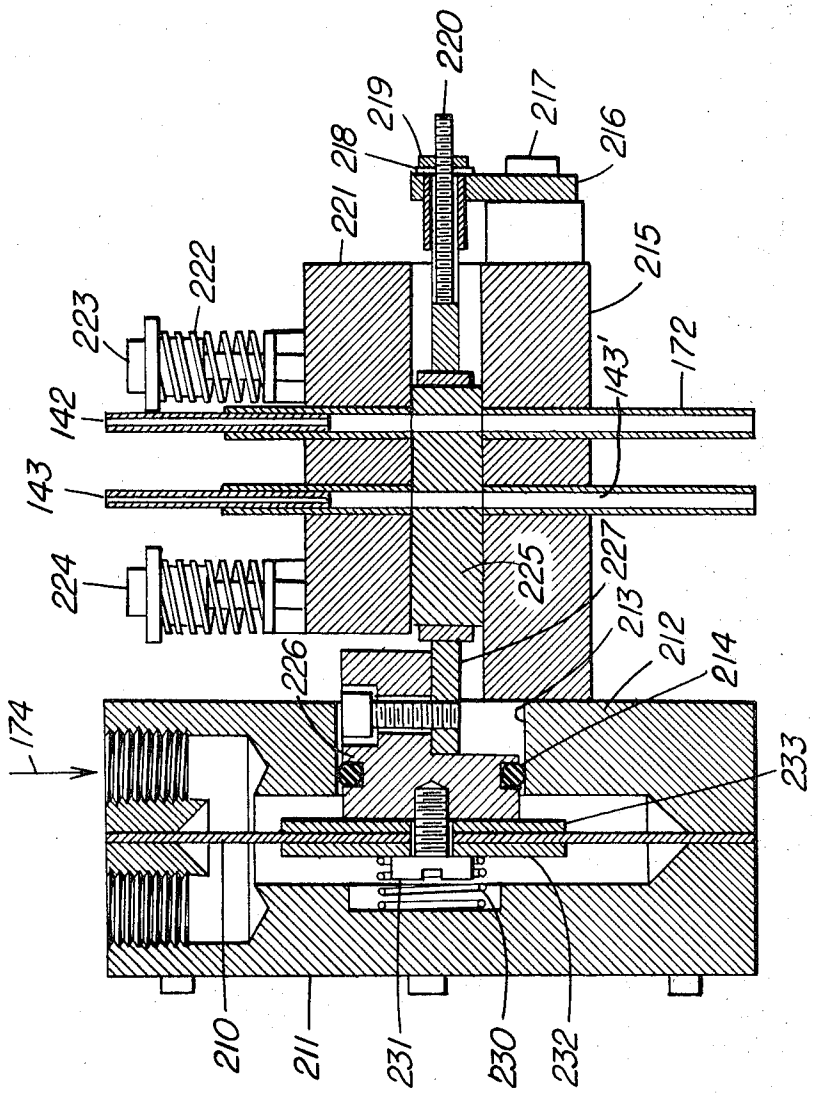


FIG. 9

INVENTOR.
Julius Plucker, III
BY
James F. Powers Jr
ATTORNEY

VAPOR-LIQUID RATIO MONITOR

Filed Oct. 20, 1969 6 Sheets-Sheet 6

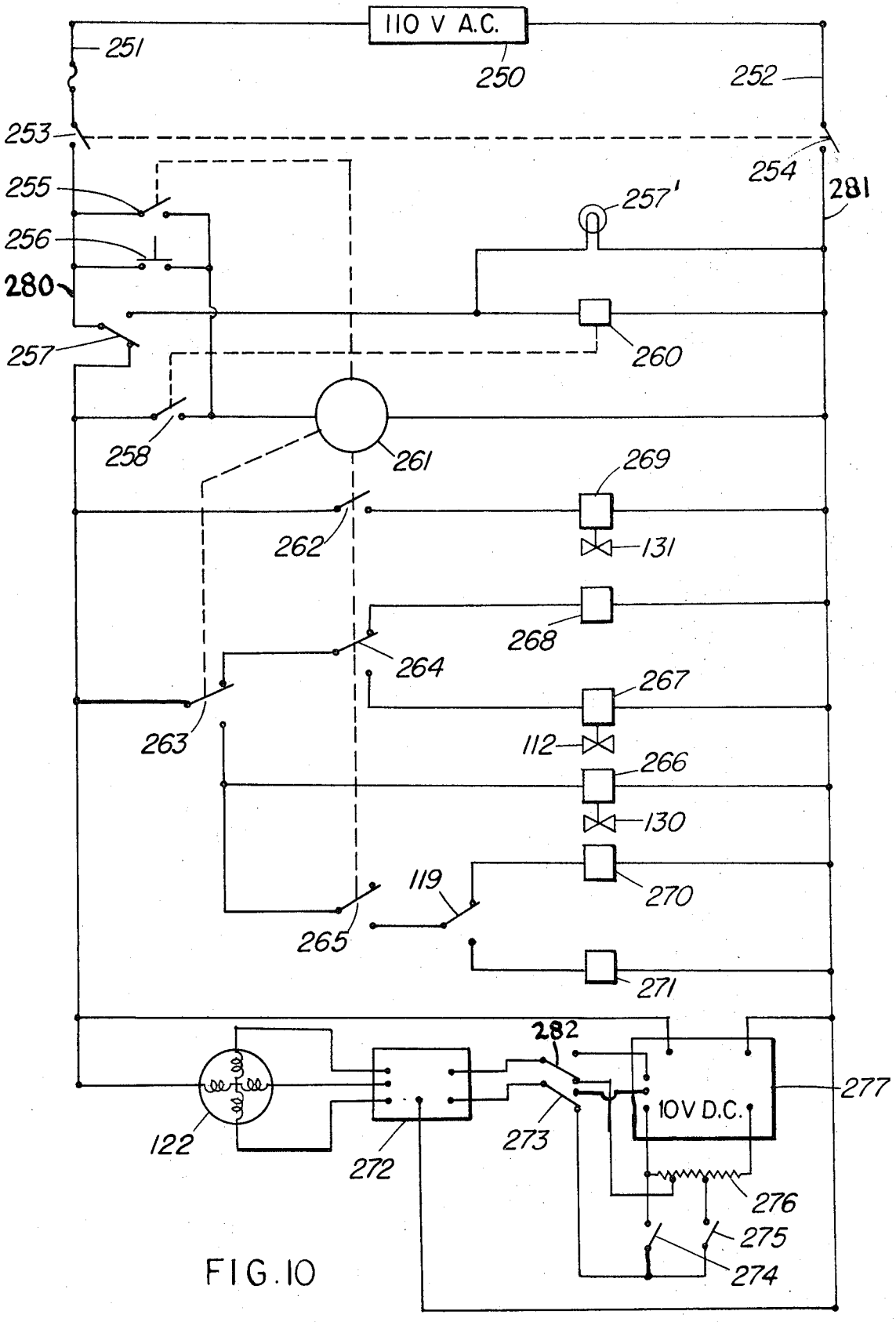


FIG. 10

United States Patent Office 3,528,440 Patented Sept. 15, 1970

3,528,440

VAPOR-LIQUID RATIO MONITOR

Julius Plucker III, Pitman, N.J., assignor to Mobil Oil Corporation, a corporation of New York

Continuation-in-part of application Ser. No. 861,211, July 23, 1969, which is a continuation of application Ser. No. 562,621, July 5, 1966. This application Oct. 20, 1969, Ser. No. 867,544

Int. Cl. G01n 7/14

U.S. Cl. 137—3 11 Claims

ABSTRACT OF THE DISCLOSURE

A vapor-liquid ratio monitor is disclosed which comprises valve means for feeding a predetermined volume of a motor fuel to a chamber. Vertically movable means within the chamber is adapted to move in response to the vapor pressure of the fuel until a predetermined pressure is present above the sample within the chamber. The amount of the vertical movement of the movable means provides an indication of the vapor-liquid ratio of the sample.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of copending application Ser. No. 861,211, filed July 23, 1969, which is a continuation of application Ser. No. 562,621, filed July 5, 1966, and now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

This invention is directed to a method and apparatus for determining the vapor-liquid ratio characteristics of petroleum products. More particularly, this invention is directed to the automatic determination of the vapor-liquid ratio of gasoline.

Description of the prior art

The vapor-liquid ratio of gasoline is a measure of the amount of light ends present in a given fuel. This has been further defined by the ASTM as follows: Vapor-liquid ratio of a gasoline, at any specified temperature and pressure is the ratio, at that temperature and pressure of the volume of vapor in equilibrium with liquid to the volume of sample charged, as a liquid, at 32° F.

The volatility characteristic of motor gasoline is recognized as an important property, from the standpoint of proper engine operation. Too large a proportion of light ends can result in a vapor-lock and other hot weather problems in engine fuel systems. Too little an amount of the light ends can adversely affect the engine starting and warm-up characteristics of the gasoline. A further important factor results from the favorable economics of blending in light products where feasible. For example, butane, a relatively low cost component, is economically upgraded by use in gasoline which is sold for a higher price. Butane has a high octane number; however, its use in gasoline is limited because of its high volatility. Therefore, a device which accurately and continuously monitors the vapor-liquid ratio of a gasoline would be of great value in producing a product of good quality at the lowest price. Such a device would also be of value as a control element for blending in the maximum amount of light products within an acceptable limit for the vapor-liquid ratio.

Even though a great need has existed for the determination of the vapor-liquid ratio of gasoline, one of the most prevalent tests for this characteristic is still its indirect measurement by the Reid Vapor Pressure method, normally in conjunction with one or more ASTM distillation point measurements. In some cases, however, it was recognized that these tests did not provide sufficient information or that the empirical correlation of the measured parameters with the actual vapor-liquid ratio was not satisfactory.

Considerable work has been done on new methods to measure the actual vapor-liquid ratio of gasoline. Data obtained by these procedures are considered to be more closely related to engine performance aspects of volatility than that obtained by the Reid Vapor Pressure and ASTM distillation. The principal drawbacks to most of these methods are the complexity of the apparatus or the procedure and the length of time necessary to obtain results. These drawbacks are particularly acute in any attempt to determine the vapor-liquid ratio continuously.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an apparatus for determining the vapor-liquid ratio of a motor fuel comprising an expansion chamber having a top and a bottom and means for supplying a predetermined volume of a sample of said motor fuel to said expansion chamber. Means are also provided which are vertically movable in sealing engagement with the internal walls of said chamber in response to the vapor pressure of said sample for indicating the vapor-liquid ratio of said sample.

In accordance with another aspect of the invention there is provided a method of determining the vapor-liquid ratio of a motor fuel, wherein fuel is supplied to an elongated chamber having a top and a bottom and means vertically movable in sealing engagement with the interior of said chamber for indicating the vapor-liquid ratio. The method comprises the steps of supplying a predetermined volume sample of the motor fuel at a pressure sufficient to prevent vaporization of the fuel, to one of said top and said bottom when said indicating means is positioned at said one of said top and said bottom, and controlling the vertical movement of said indicating means to provide a predetermined pressure in the portion of said chamber in fluid communication with said sample. Then the amount of vertical movement of said indicating means from said one of said top and said bottom is determined to provide an indication of the vapor-liquid ratio of the sample.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts the overall arrangement of the apparatus used in an embodiment of this invention.

FIG. 2 is a sectional view of the rotary valve and connected portions in a filling and draining position.

FIG. 3 shows the rotary valve in a vaporizing position, rotated 120° from the position of FIG. 2.

FIG. 4 is a section through 4—4 of FIG. 3.

FIG. 5 is a section through 5—5 of FIG. 3.

FIG. 6 depicts the use of the vapor-liquid ratio monitor as a control element in the blending of motor fuels.

FIG. 7 is a graph which shows the vapor-liquid ratio of a gasoline at several temperatures, as determined by the methods and apparatus of this invention and the prior art.

FIG. 8 is a schematic representation of another embodiment of the present invention.

FIG. 9 is a sectional view of a valve and valve actuator used in the embodiment of FIG. 8.

FIG. 10 is a schematic representation of a control unit for the embodiment of FIG. 8.

DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring to FIG. 1, the apparatus of this invention is contained within an insulated housing 1. A sample stream of motor fuel is delivered by a pump 2 through a tempera-

ture controlled coil 3, preferably located within the housing, to the sample inlet 4. The sample stream flows to the rotary valve 5, described in detail below, and then to the outlet connector 6 and to the drain apparatus 7, including a back pressure regulator. At this position the valve 5 is positioned so that the previous sample leaves through drain connector 8 to the liquid trap 9 and drain means comprising pressure regulator 10, air regulator 11 and vacuum source 11'. The pressure of the sample stream between the pump 2 and the drain apparatus 7 is sufficiently high to prevent vaporization of the fuel in the stream. The temperature controlled coil 3 preheats the fuel in the stream to a specified temperature which may be the sum of the mean high average temperature for a particular locality and a predicted temperature of an engine under the hood of a car during normal operation.

When the rotary valve is driven by the motor 12 to the vaporizing position, a predetermined volume of the sample is directed into a gas flow calibrator tube 13 which contains vapor-liquid ratio indicating means shown as an piston or mercury sealed float 14. Electrical or photoelectric sensing means 15 generates a signal representative of the position of the float 14. The tube 13 has a constant internal diameter and is calibrated in volumetric units which are equal to the predetermined volume of the sample to provide a visual readout of the float position and thus a representation of the vapor-liquid ratio of the sample.

The pressure on either side of the float 14 is equalized in the drain position by the conduit 16. The conduit 16 may be connected to conventional pressure and air regulators 10, 11, which maintain the pressure above the float 14 constant as the float 14 rises in response to the vapor pressure of the sample. For example, the pressure below the float 14 may be maintained at a value of one standard atmosphere when the rotary valve 5 is in the sample vaporizing position. The pressure above the float 14 would be equal to one atmosphere minus an amount determined by the weight of the float 14.

FIGS. 2, 3, 4 and 5 show the rotary valve 5 in greater detail. The valve 5 contains a sample reservoir 17, a drain cup 18 and bypass slot 19. The sample reservoir 17 should be of a known volume to provide the predetermined volume of the sample, or its volume relative to the volume of the expansion chamber 13 should be ascertained.

In FIG. 2, the drain cup 18 is positioned beneath the calibrator tube 13. At this point the sample will drain through drain means shown as the cup 18 and its associated conduit 40, through sample outlet means shown as the drain connector 8, as indicated by the arrows. The rate at which the sample is drained can be controlled by the pressure differential created across the seal 14 by the pressure and air regulator 10 and 11. Simultaneously, with the draining of cup 18 the sample reservoir 17 is being flushed and filled by a sample stream flowing through the sample inlet 4, and associated conduits, to sample reservoir 17 and through stream outlet means shown as the outlet connector 6 and associated conduits as indicated by the arrows.

As depicted in FIG. 3, after a predetermined interval, the motor 11 will turn the valve 5 a suitable distance, illustrated as 120°, to position the sample reservoir with the predetermined volume of the sample beneath the calibrator tube 13. At this point the sample will vaporize, and the piston or sealed float 14 will rise in the tube 13 to indicate the volume of the vapors to that of the liquid. Simultaneously, the bypass slot 19 will provide a channel for the flow of the sample stream from the inlet connector 4 to the outlet connector 6. Of course, alternative means may be provided to cut off the supply of sample stream when the valve 5 is in the sample vaporizing position. However, as depicted, the heated sample will help maintain the temperature of the valve 5 and housing 1.

A further feature of the rotary valve 5 is the provision for a thermowell 20 for housing a thermocouple (not shown) for controlling a heating element (not shown) in the vicinity of the coil 3 such that the temperature of the valve 5 and the sample may be maintained at the specified level.

Thus, by this invention a constant-volume sample of motor fuel, such as gasoline, at a controlled temperature is periodically delivered by the rotary valve 5 to the calibrated tube 13. The sample partially vaporizes within the tube 13 to a height indicated by the piston or float 14. The float 14 can actuate electrical sensing means 15 which provides a direct readout of vapor-liquid ratio. After a reading is obtained, the valve 5 is rotated to a position at which the tube 13 is drained and the sample reservoir 17 is flushed and filled with a succeeding sample.

FIG. 6 shows an automatic monitoring and blending system in accordance with the invention. A fluid such as a motor fuel flows in a conduit 21 and is monitored by a vapor-liquid ratio monitor 22 as described above. A signal representative of the vapor-liquid ratio of the fluid is applied to a subtractor 23. The signal is generated by conventional electrical (or photoelectrical) sensing means 15 activated by the piston or float 14. Also applied to the subtractor 23 is a reference signal representative of the vapor-liquid ratio at which it is desired to maintain the fluid. This reference signal may be generated by methods well known in the art.

The output signal from the subtractor 23 then is representative of the deviation of the vapor-liquid ratio of the fluid from that desired. This signal is applied as an error signal to servo motor 24 which is used to control the setting of a valve 25 that meters the flow of a component, such as butane, for example, for a component source 26 that is allowed to flow into the conduit 21. The valve 25 is varied until the error signal is reduced to zero, and in this fashion the fluid is continuously monitored and is combined with the component to meet a predetermined specification regarding vapor-liquid ratio.

In a specific example, the liquid metering device was a tapered stainless steel plug, one and one-quarter inch in diameter at the center of its longitudinal axis. A half inch diameter hemispheric cup of approximately 0.7 cc. capacity was milled into the plug on the one and one-quarter inch diameter center line. A drain cup was milled into the plug on the same center line at a 120° angle, counter-clockwise from the sample cup as viewed from the small end of the tapered plug. A drain line was drilled from the bottom of the cup through the plug. A bypass slot for the liquid sample was milled into the plug on the same center line at 120° counter-clockwise from the drain cup and drain line. The tapered stainless steel plug was inserted into a Teflon sleeve with a matching taper. These were then positioned in a brass lock which mated with the precision bored gas flow calibrator. The metering device was flushed and filled from the position indicated in FIG. 2. The metering device was then rotated 120° to the position indicated in FIG. 3. The pressure below the mercury sealed float was maintained at 760 mm. Hg with a nullmatic pressure regulator. The sample used was a premium grade commercial gasoline. The above procedure was followed in a test of several samples which were held at temperatures ranging rom 120° F. to 134° F. by conventional temperature control apparatus. The position of the float is indicated on the abscissa of the graph in FIG. 7 at each of the respective temperatures indicated on the ordinate of said graph. In the legend these points are indicated as I.

To verify the accuracy of the method and apparatus of this invention portions of the gasoline sample referred to above were analyzed for their vapor-liquid ratio by two other methods referred to as the ASTM and Calculated methods (respectively indicated in the legend of FIG. 7 as II and III). In the ASTM method a measured volume of liquid fuel at 32–40° F. is introduced through a rubber septum into a glycerine-filled burette. The charged burette is placed in a temperature controlled

water bath. The volume of vapor in equilibrium with liquid fuel was measured at each of the temperatures used above and at the same pressure, 760 mm. Hg. The vapor-liquid ratio was then calculated from the volume displaced by the vapor in the burette and from the initially measured volume of the liquid used. In the calculated method the Reid vapor pressure and the 10, 20 and 50% distillation points were determined for the given sample at each of the above temperatures. The vapor-liquid ratio was estimated from this volatility data by correlations set forth in the prior art, see 1946 CRC Handbook, pages 154 and 155. The results of these tests as indicated in FIG. 7 show that the method and apparatus of this invention may be used to obtain the vapor-liquid ratio of a gasoline sample which correlates well with prior art methods.

Another embodiment of the present invention is schematically shown in FIG. 8. With reference to this figure, a sample stream of the motor fuel, for example gasoline, to be analyzed for vapor-liquid ratio is applied to the system by a sample inlet line **101**. The inlet line **101** may be connected to a process line such as line **21** of FIG. 6. The sample stream flows from inlet line **101** through a metering valve **102** and to a line **107** for application to a temperature controlled coil **109** of a sample preheater **108**. The preheater **108** includes an electrical heating element **110** for preheating the sample stream to a predetermined temperature, As described hereinabove with reference to the embodiment of FIG. 1, the predetermined temperature may be determined by the sum of the mean high average temperature for a particular locality and a predicted temperature of an engine under the hood of a car during normal operation.

A seperate heater (not shown) may be provided as a source of heat for the elements within an insulated housing **173** to maintain the elements at the predetermined temperature.

From the preheater **108** the sample stream flows through a line **111** to a three-way solenoid valve **112**. The three-way solenoid valve **112** is connected by a line **142** to a chromatograph-type sliding plate valve **113** mounted on top of an expansion chamber **114**. The expansion chamber **113** comprises a cylinder **115** having a constant internal diameter. A vertically movable piston **116**, shown in cross-section, having a sample cup **145** formed in the top thereof is positioned within the cylinder **115**. The piston **116** has a pair of O-rings **170**, **171** for frictionally engaging the inner surface of the cylinder to ensure that fluids do not pass between the piston **116** and the inner surface of the cylinder **115**. The piston **116** and is fixedly secured to the top of a lifting screw **117** of a worm gear screw jack **118** which is mounted at the bottom of the cylinder **115**. A suitable jack screw is Simplex Model JMO5, manufactured by Templeton Kenly & Company, Simplex Division, Broadview, Ill.

At the beginning of a vapor-liquid ratio analyzing cycle, the piston **116** is positioned at the top of the cylinder **115** such that the top surface of the piston **116** is flush against the underside of the valve **113**. In this position, a line **172** extends from the underside of the valve **113** and into the sample cup **145**.

The three-way solenoid valve **113** is actuated such that the sample stream flows line **111** through the solenoid valve **112** to the line **142**, through the opened plate valve **113**, and through the line **172** into the sample cup **145**. From the sample cup **145**, the sample stream flows back through the plate valve **113** to a line **143**, and another three-way solenoid valve **131** positioned such that the sample stream flows through lines **144**, **133**, a rotometer **134**, lines **135**, **137** and to a flow regulator **138**. The rotometer **134** is provided to monitor the flow rate of the sample stream. The flow rate of the sample stream is adjustable by the flow regulator **138**, which may be a Moore Model 63–SD, manufactured by Moore Products Co., Philadelphia, Pa. The flow regulator **138** has a reference pressure applied thereto by lines **140**, **147**. In the embodiment of FIG. 8, the reference pressure is atmospheric pressure as schematically represented by line **147** being opened at the lower end thereof. The sample stream of fuel passes through the flow regulator, through an adjustable valve **139**, and lines **146**, **147** to a drain **141** or to a monitored process line such as conduit **21** of FIG. 6. The flow rate of the sample stream of fuel is maintained at a predetermined level by adjusting the valve **139** to provide a predetermined pressure drop across the flow regulator **138**.

The pressure of the sample stream of fuel is maintained at a sufficiently high value to avoid vaporization of the fuel in the stream. A relief valve **105** is connected to line **107** by a line **104** for bypassing a portion of the sample stream to a drain **106** or to return the bypassed portion to a process line such as conduit **21** of FIG. 6. The relief valve **105** is set to maintain the pressure in the sample stream at a predetermined level as indicated by a pressure gauge **136**. For example, the predetermined pressure may be approximately 20 p.s.i.g.

At the end of a predetermined time sufficiently long to ensure that pressurized fuel has filled the sample cup **145**, a control unit **124** provides a signal for actuating a three-way solenoid valve **130** to connect a source of pressurized air **175** to a valve actuator **129** by a line **174**. The actuator **129** acts to close the sliding plate valve **113** such that lines **142** and **143** are no longer in fluid communication with the sample cup **145**. Shortly after actuation of the actuator **129**, the control unit **124** provides a signal to the three-way solenoid valve **112** to actuate it to a position such that the sample stream flows from the line **111** through the solenoid valve **112**, and to the lines **132**, **133**, the rotometer **134**, the lines **135**, **137**, and to the flow regulator **138**.

At this time, the sample cup **145** has a predetermined volume of pressurized sample therein. The control unit **124** then actuates a stepping motor **122** which powers the worm gear screw jack **118** to move the lifting screw **117** downwardly. The lifting screw **117** continues its downward movement until a boss **121** at the lower end thereof engages an arm **148** of a lever **180** to actuate a limit switch **119**. The limit switch **119** is positioned a sufficient distance below the screw jack **118** to ensure that the piston **116** is below a sensing element **125**. Upon actuation of the limit switch **119**, a signal is applied to the control unit **124** which causes the control unit to control the stepping motor **122** in response to the sensing element **125**.

The sensing element **125** is a pressure transducer in fluid communication with the interior of the cylinder **115**, and may be a transducer model 8503, manufactured by Endevco Laboratories, Mountain View, Calif. The sensing element **125** is positioned a distance down the cylinder to avoid severe flexing of the sensing element **125** in response to the pressurized sample of fuel in the sampling cup **145**. By the time the piston **116** moves by the sensing element **125**, the pressure above the piston **116** has decreased to a value which does not endanger the sensing element **125**.

The Endevco transducer model 8503 is capable of providing a signal output which indicates whether the sensed pressure is above or below a reference pressure. The reference pressure is applied to the sensing element **125** through a line **150** which is connected to a pressure regulator **126**. The pressure regulator **126** may be Moore Model 43–20, manufactured by Moore Products Co., Philadelphia, Pa. The Moore Model 43–20 has a source of pressurized air **127** applied thereto which is above the reference pressure. Another source of pressure **128** is also connected to the regulator **126** which is below the reference pressure. The reference pressure is preferably 760 mm. and a suitable value for the pressure source **127** is 5 p.s.i.g. and the pressure source **128** may be a vacuum source. The Moore Model 43–20 has an adjust-

able control **151** for providing the predetermined reference pressure in line **150**.

In response to signals from the sensing element **125**, the control unit acts to cause the stepping motor **122** to drive the lifting screw **117** downwardly if the sensing element senses a pressure above the reference pressure, or to drive the lifting screw **117** upwardly if the sensing element **125** senses a pressure below that of the reference pressure. In this mode, the control unit **124** controls the movement of the lifting screw **117** until the sensing element **125** senses a pressure within the cylinder **115** equal to that of the reference pressure. At this point, the sensing element **125** is at a null point and does not provide an output signal to the control unit **124**.

When the sensing element **125** is at its null point, the volume of the space within the cylinder **115** above the piston **116** measured in units equal to the volume of the sampling cup **145** is the vapor-liquid ratio of the fuel in the sampling cup **145**. The cylinder **115** may be transparent in whole or in part and graduated in units of volume equal to the volume of the sample cup **145** to provide a visual readout of the vapor-liquid ratio of the fuel in the sample cup **145**.

The vapor-liquid ratio of the fuel in the sampling cup **145** may also be recorded or a signal representative of the vapor-liquid ratio will be used to control a process. For example, a gear **154** fixedly secured to the outer end of a drive shaft **123** of the screw jack **118** drives a gear **156**. The gear **156** in turn positions a movable arm **185** of a potentiometer **157**. One end of the resistor portion **186** is connected to a power supply **158** by a line **159**, and the movable arm **185** is connected to a recorder **160** by a line **161**. The recorder **160** is connected to the power supply **158** by a line **162** to complete the circuit. Thus, the position of the movable arm **185** relative to the resistor **186** is a function of the position of the piston **116** with respect to the underside of the sliding plate valve **113**, and thereby is a function of the volume of the space within the cylinder **115** above the piston **116**. Therefore, the resistance of the potentiometer **157** as reflected on the recorder **160** is representative of the vapor-liquid ratio of the fuel in the sampling cup **145**.

Alternatively, a counter (not shown) may be used to count the number of revolutions of the lifting screw **117**, and thus provide a representation of the vertical movement of the piston **116**. Further, the potentiometer **157** circuit may provide a signal representative of the vapor-liquid ratio of the fuel in the sampling cup **145** to the subtractor **23** of FIG. 6 to thereby control a process.

At the end of a predetermined period of time sufficiently long to ensure that the sensing element **125** is at its null point, the control unit provides a signal to the three-way solenoid **131** which places line **143** in fluid communication with lines **163**, **146** and **147**. The control unit also controls the operation of the three-way solenoid valve **130** to connect the source of air **175** with a vent line **176** to thereby remove air from the actuator **129** and permit the sliding plate valve **113** to open. As the lifting screw **117** rises the boss **121** at the lower end thereof engages arm **149** of the lever **180** to actuate the limit switch **119** to remove control of the stepping motor **122** from signals from the sensing element **125**. Since the space above the piston **116** is opened to atmosphere via line **143**, solenoid valve **131**, and lines **146**, **147**, the liquid in the sampling cup **145** tends to vaporize. The lifting screw continues to rise until the piston **116** is again positioned at the top of the cylinder **115** such that the top surface of the piston **116** flush against the underside of the valve **113**. A slip clutch **181** is provided between the motor **122** and the worm gear screw jack **118** to prevent damage to the piston **116** and the valve **113** when the piston has been driven to its uppermost position. At this time, the sampling cup **145** is in a position to receive a new sample from line **111** for test in accordance with the foregoing sequence of events.

A fail safe switch **120** is provided to remove power from the motor **122** when the lifting screw is driven to an extreme downward position and the boss **121** engages the lever arm of the switch **120**.

FIG. 9 shows a valve actuator and sliding plate valve suitable for use as the actuator **129** and valve **113** of FIG. 8. The actuator and valve are available from the Bendix Greenbrier Instruments, Ronceverte, W. Va., and identified by PN 5501334. The reference numerals of FIG. 9 which are identical to those of FIG. 8 identify items corresponding to those schematically shown in FIG. 8.

The actuator portion comprises a diaphragm **210** secured between plates **211**, **212**. The diaphragm **210** is biased to the right by a spring **230** which is mounted about a bolt **231**. The bolt **231** secures plates **232**, **233** and the center portion of the diaphragm **210** to a movable block **226**. The movable block **226** has an O-ring **214** to fluidly seal the block **226** and the plate **212**. The block **226** is secured to a movable plate **225** by an extension bar **227**. The movable plate **225** is preferably composed of Teflon and includes two parallel ports therethrough for providing a fluid path between lines **142** and **172**, and **143** and **143'**. The lines **142**, **172**, **143** and **143'** pass through a pair of plates **215** and **221** which are held together by a bolt and spring arrangement **222–224**. The sliding plate is secured to a bolt **220** and nut **219**. The bolt is movable within a conduit formed in an extension arm **216** which is secured to the plate **215** by a nut **217**. The bolt **219** is movable about the bolt **220** to provide a space **218** between the nut **219** and the arm **216**.

As described with reference to FIG. 8, pressurized air from conduit **174** enters a chamber to exert a force along the right hand side of the diaphragm **210** to move it to the left against the spring **230**. This action causes the plates **226**, **225** and nut and bolt **219**, **220** to move as an integral unit to the left and thereby close the valve. When the source of pressurized air is vented as described with reference to FIG. 8, the spring **230** causes the diaphragm **210**, the plates **226**, **225** and nut and bolt **219**, **220** arrangement to move as an integral unit to the right and thereby open the valve.

FIG. 10 is a schematic representation of a control circuit which is suitable to carry out the functions of the control unit **124** described hereinabove with reference to FIG. 8. With reference to FIG. 10, power is supplied from a source **250** by lines **251**, **252** to a pair of ganged switches **253**, **154**. When the switches **253**, **254** are closed power is supplied to the control circuit.

A timer motor **261** is provided to actuate a plurality of switches in a predetermined sequence. A suitable speed for the motor is $\frac{1}{10}$ r.p.m.

To begin the cycle with the piston **116** (FIG. 8) flush against the underside of the valve **113** (FIG. 8), the timer motor **261** actuates a switch **262** to provide power to a solenoid **269** via lines **280**, **281**. Actuation of the solenoid **269** moves the three way solenoid valve **131** to the position which provides a fluid path between lines **143** and **144** (FIG. 8). At this time switches **263**, **264**, **265**, and **119** are in the position shown in FIG. 10 and the sliding plate valve **113** (FIG. 8) is in the open position. The timer motor then actuates switch **264** to the position not shown in FIG. 10. This closes a circuit which includes line **280**, switch **263**, a solenoid **267**, and line **281**. Actuation of the solenoid **267** causes the three-way valve **112** to provide a fluid path between lines **111** and **142** (FIG. 8). Thus, fluid flows to the sampling cup as described with reference to FIG. 8.

After a predetermined time sufficiently long to insure that the sampling cup is filled with pressurized liquid, switch **263** is moved to the position not shown in FIG. 10 and thereby apply power to a solenoid **266** which actuates the three-way valve **130** to connect the source of pressurized air **175** to the valve actuator **129** (FIG. 8)

to thereby close the sliding plate valve **113**. Movement of the switch **263** to the position not shown in FIG. 10 also removes power from the solenoid **267** to thereby operate the three-way valve **112** to connect line **111** with line **132** of FIG. 8.

The timer motor **261** then actuates a switch **265** to the position not shown in FIG. 10 to apply power through the limit switch **119** (FIG. 8) to a relay **270**. Actuation of the relay **270** closes a drive down switch **274** which completes a circuit to an amplifier **272** which consists of switch **282** in the position shown, a resistor **276** and a switch **273** in the position shown. Completion of this circuit causes the motor **122** of FIG. 8 to drive the lifting screw **117** (FIG. 8) downwardly.

As described with reference to FIG. 8, the limit switch **119** is actuated by the boss **121** to the position not shown in FIG. 10. This actuation of switch **119** applies power to a relay **271** which in turn causes the switches **273** and **282** to move to the position not shown in FIG. 10. This places the motor **122** under the control of the sensing element **125** (FIG. 8) which includes the block circuit **277**. As described hereinabove, the sensing element may be Endevco Model 8503. The circuit portion **277** of the sensing element **125** (FIG. 8) has power applied thereto by lines **280** and **281**. The circuit portion **277** then controls the motor **122** until the sensing element **125** (FIG. 8) is at a null point.

At the end of a predetermined time sufficiently long to insure that the sensing element **125** is at a null point, the timer motor **261** actuates switch **262** to the position shown in FIG. 10 to thereby deenergize the solenoid **269** and move the three-way valve **131** to a position which connects line **143** to line **163** of FIG. 8. The timer motor **261** then operates switches **263** and **264** to the position shown in FIG. 10. This removes power from the solenoid **266** which causes the three-way valve **130** to vent the source of pressurized air **175** by line **176** (FIG. 8). Thus, the sliding plate valve **113** (FIG. 8) is opened.

Movement of switch **263** to the position shown in FIG. 10 also removes power from the relay **271** to thereby cause the switches **273**, **282** to move to the position shown in FIG. 10. When switches **263** and **264** are in a position shown in FIG. 10, power is supplied to a relay **268** which operates to close a drive up switch **275**. Closure of the drive up switch **275** completes a circuit to the amplifier **272** which includes switch **282**, resistor **276**, switch **275** and switch **273**. This circuit causes the amplifier **272** to provide an output signal which operates the motor **122** to drive the lifting screw upwardly. As the lifting screw moves upwardly, the limit switch **119** is actuated by the boss **121** at the end of the lifting screw (FIG. 8) to move the limit switch **119** to the position shown in FIG. 10.

The timer motor **261** also operates to move the switch **265** to the position shown in FIG. 10. This mode is continued for a sufficiently long time to insure that the lifting screw returns the piston **116** to a position flush against the underside of the valve **113** (FIG. 8). Since the sample in the sampling cup **145** is in fluid communication with the atmosphere by way of the opened sliding plate valve **113**, the line **143**, the three-way solenoid valve **131**, and lines **163**, **146** and **147**, (FIG. 8), the sample tends to vaporize as the piston **116** rises. The slip clutch **181** (FIG. 8) is provided to avoid damage to the apparatus after the piston **116** engages the underside of the valve **113**.

At this time the system is ready to repeat the foregoing sequence of events to determine the vapor-liquid ratio of a new sample.

The circuit of FIG. 10 also includes a fail-safe network which comprises a bottom limit switch **257** which corresponds to the bottom limit switch **120** of FIG. 8 and which is normally in the position shown in FIG. 10. However, should the boss **121** (FIG. 8) at the lower end of the lifting screw **117** actuate the bottom limit **257** it is moved to the position not shown in FIG. 10. Movement of the switch **257** to the position not shown applies power to a relay **260** which opens the normally closed switch **258** and applies power to a lamp **257'** to give an indication of the problem. This action removes the power at line **280** from the timer motor **261**. Further, movement of the switch **257** to the position not shown removes power from the motor **122** and thereby stops the movement of the lifting screw **117** (FIG. 8). An interrupt switch **255** is closed for a substantial portion of the cycle under the control of the timer motor **261**. Thus, power is applied to the timer motor **261** even though the switch **258** has been opened. This permits the timer motor **261** to continue operation until it reaches a predetermined point in the program, at which time the interrupt switch **255** is opened.

A reset button **256** is provided to restart the timer motor **261** after the system has been stopped as a result of actuation of the bottom limit switch **257**. The reset button **256** is depressed to provide a circuit therethrough to the timer motor **261** until at least the timer motor **261** causes he interrupt switch **255** to close, and preferably, until the lifting screw **117** is driven upwardly until the boss **122** actuates the bottom limit switch **120** to move the switch **257** to the position shown in FIG. 10. This causes the relay **260** to deactivate and to close switch **258** to provide power from line **280** to the timer motor **261**.

Thus, there have been described specific embodiments for determining the vapor-liquid ratio of a fuel, and for controlling a blending operation in response to the monitored vapor-liquid ratio. It will be understood by those skilled in the art that the above-described embodiments are merely exemplary and that they are susceptible to modification and variation without departing from the spirit and scope of the invention.

What I claim is:

1. Apparatus for determining the vapor-liquid ratio of a motor fuel comprising:

an elongated expansion chamber having a first end and a second end opposite said first end,

means for supplying a predetermined volume of a sample of said motor fuel to one of said first end and said second end,

means longitudinally movable in sealing engagement with the internal walls of said chamber for indicating the vapor-liquid ratio of said sample, and

means connected to said indicating means for moving said indicating means in response to the vapor pressure of said sample.

2. Apparatus for determining the vapor-liquid ratio of a motor fuel comprising:

an expansion chamber having a top and a bottom,

means including a sample receptable for positioning a predetermined volume of a sample of said motor fuel in sealing engagement with said top, and

means vertically movable in sealing engagement with the internal walls of said chamber in response to the vapor pressure of said sample for indicating the vapor-liquid ratio of said sample.

3. The apparatus of claim **2** further comprising means for sensing the position of said vapor-liquid ratio indicating means and for generating a signal representative of the vapor-liquid ratio of said sample.

4. Apparatus for determining the vapor-liquid ratio of a motor fuel comprising:

an elongated expansion chamber having a top and a bottom,

receptacle means vertically movable within said chamber and in sealing engagement with said chamber for receiving a predetermined volume of said fuel,

valve means for supplying a pressurized sample of said fuel into the top of said chamber to said receptacle means, and for exhausting said sample from said chamber,

means for sensing the pressure within said chamber, and

control means responsive to said sensing means for vertically moving said receptacle means until the pressure within said chamber above said receptacle means is at a predetermined value.

5. The apparatus of claim 4 wherein said sensing means is positioned a sufficient distance from the top of said chamber to prevent damage thereto by the pressurized sample, and wherein said control means sequentially performs the following functions:

(a) vertically move said receptacle means to the top of said chamber,

(b) actuate said valve means to supply a pressurized sample of said fuel to said receptacle means,

(c) actuate said valve means to seal the top of said chamber,

(d) vertically move said receptacle means downwardly to a position below said sensing means,

(e) vertically move said receptacle means in response to said sensing means until the pressure within said chamber is at the predeterminde value,

(f) actuate said valve means to provide an exhaust for said sample, and

(g) vertically move said receptacle means upwardly to exhaust said sample through said valve means.

6. The apparatus of claim 5 further comprising means for determining the distance between the top of said chamber and said receptacle means when the pressure within said chamber is at the predetermined value to provide an indication of the vapor-liquid ratio of said sample.

7. Apparatus for blending a motor fuel having a predetermined vapor-liquid ratio, wherein a plurality of components including at least one component which affects the vapor-liquid ratio of the motor fuel are combined in blending means, comprising:

the apparatus of claim 4,

means for generating in response to the vertical movement of said receptacle means a signal representative of the vapor-liquid ratio of said sample,

means for generating a signal representative of said predetermined vapor-liquid ratio,

means for generating an error signal representative of the difference between the sample vapor-liquid ratio signal and the predetermined vapor-liquid ratio signal, and

means for controlling the relative amount of said one component in the blending means in accordance with the magnitude of said error signal.

8. Apparatus for blending a motor fuel having a predetermined vapor-liquid ratio, wherein a plurality of components including at least one component which affects the vapor-liquid ratio of the motor fuel are combined in blending means, comprising

an expansion chamber having a top and a bottom,

valve means for positioning a sample of predetermined value of said motor fuel in sealing engagement with said expansion chamber top,

conduit means for delivering a stream of the motor fuel from the blending means to said valve means,

means vertically movable in sealing engagement with the internal walls of said chamber in response to the vapor pressure of said sample for indicating the vapor-liquid of said sample,

means for generating in response to the vertical movement of said vapor-liquid ratio indicating means a signal representative of the vapor-liquid ratio of said sample,

means for generating a signal representative of said predetermined vapor-liquid ratio,

means for generating an error signal representative of the difference between the sample vapor-liquid ratio signal and the predetermined vapor-liquid ratio signal, and

means for controlling the relative amount of said one component in the blending means in accordance with the magnitude of said error signal.

9. A method of determining the vapor-liquid ratio of a motor fuel, wherein fuel is supplied to an elongated chamber having a first end and a second end opposite said first end, and means longitudinally movable in sealing engagement with the interior of said chamber for indicating the vapor-liquid ratio, comprising the steps of:

supplying a predetermined volume sample of the motor fuel, at a pressure sufficient to prevent vaporization of the fuel, to one of said first end and said second end when said indicating means is positioned at said one of said first end and said second end,

controlling the longitudinal movement of said indicating means to provide a predetermined pressure in the portion of said chamber in fluid communication with said sample, and

determining the amount of longitudinal movement of said indicating means from said one of said first end and said second end to provide an indication of the vapor-liquid ratio of the sample.

10. A method of determining the vapor-liquid ratio of a motor fuel comprising the steps of:

conveying a sample of predetermined volume of the motor fuel to means for determining vapor-liquid ratio,

moving said sample to the top of an elongated expansion chamber of said vapor-liquid ratio determining means thereby causing vertically movable means in sealing engagement with the internal walls of said chamber to move in response to the vapor pressure of said sample for indicating the vapor-liquid ratio of said sample.

controlling the vertical movement of said vapor-liquid ratio indicating means to provide a predetermined pressure above said vapor-liquid ratio indicating means, and

measuring the vertical movement of said vapor-liquid ratio indicating means to determine the vapor-liquid ratio of said sample.

11. A method of blending a motor fuel having a predetermined vapor-liquid ratio, wherein a plurality of components including at least one component which affects the vapor-liquid ratio are combined in blending means, comprising the steps of:

at least substantially continuously flowing a stream of the motor fuel from the blending means to means for determining vapor-liquid ratio;

obtaining a sample of predetermined volume from the motor fuel stream;

moving said sample to the top of an elongated expansion chamber of said vapor-liquid ratio determining means thereby causing vertically movable means in sealing engagement with the internal walls of said chamber to move in response to the vapor pressure of said sample for indicating the vapor-liquid ratio of said sample;

controlling vertical movement of said vapor-liquid ratio indicating means to provide a predetermined pressure above said vapor-liquid ratio indicating means;

generating, in response to vertical movement of said vapor-liquid ratio indicating means, a signal representative of the vapor-liquid ratio of said sample;

generating a signal representative of said predetermined vapor-liquid ratio;

generating an error signal representative of the difference between the sample vapor-liquid ratio signal and said predetermined vapor-liquid ratio signal; and

controlling the relative amount of said one component in the blending means in accordance with the magnitude of said error signal.

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13

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14

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WILLIAM F. O'DEA, Primary Examiner

D. J. ZOBKIW, Assistant Examiner

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,528,440 Dated September 15, 1970

Inventor(s) JULIUS PLUCKER III

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, at line 60, for "11" read --12--. Column 5, at line 43, for "113" read --114--; at line 62, for "113" read --112--; at line 63, after "flows" insert --from--. Column 7, at line 68, after "116" insert --is--. Column 8, at line 49, for "154" read --254--. Column 10, at line 20, for "he" read --the--; at line 52, for "receptable" read --receptacle--. Column 11, at line 20, for "predeterminde" read --predetermined--; at line 56, for "value" read --volume--; at line 63, after "liquid" insert --ratio--.

SIGNED AND
SEALED
NOV 24 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents