May 9, 1967 J. F. RENDINA 3,318,154

SAMPLING APPARATUS

Filed Feb. 26, 1965

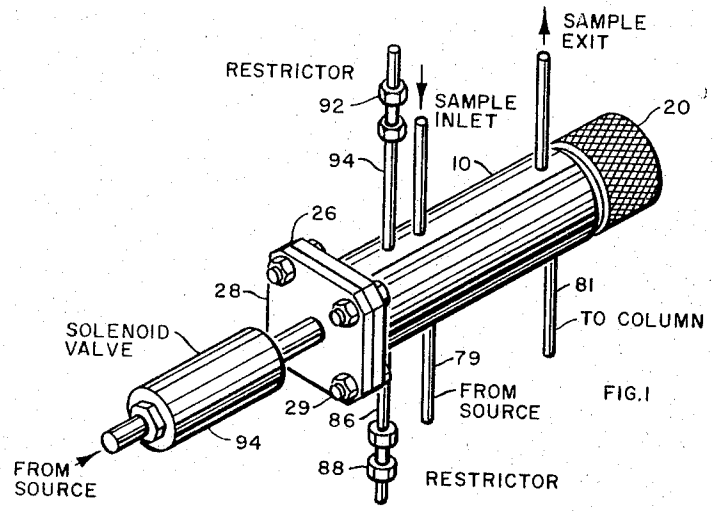


FIG. 1

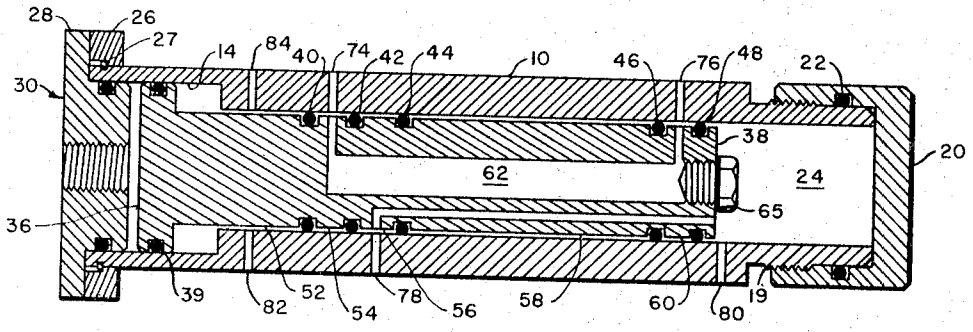


FIG. 2

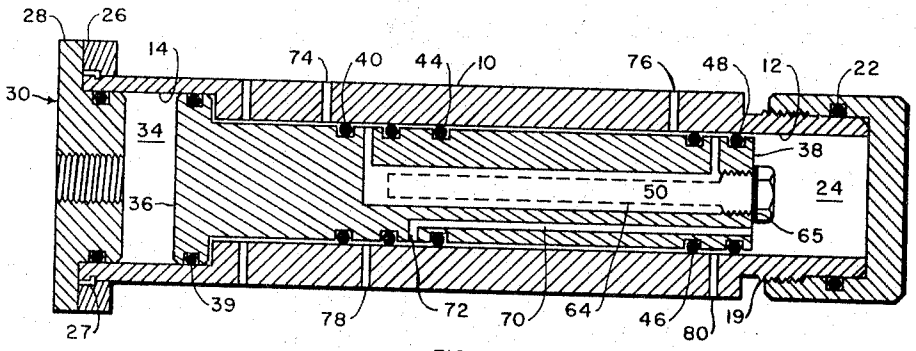


FIG. 3

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SAMPLING APPARATUS

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This invention relates to a sampling apparatus and, more particularly, to a relatively leak-free device capable of taking a reproducible sample from one fluid stream and introducing that sample into another fluid stream. Particular features of the invention are that the sample volume may be easily changed and the device itself may be actuated by the pressure of one of the fluid streams.

There are many applications in the analytical instrument industry where it is desirable to introduce samples of a known or predetermined volume into a carrier stream for conveying the sample through the instrument. One such analytical instrument is a gas chromatograph. A gas chromatograph uses a carrier fluid or gas to transport gas or vaporized liquid samples through a column for separation into its components and subsequent detection.

Various means have been employed to obtain small samples for introduction into the carrier stream. One such means is a syringe. These have not been entirely satisfactory in terms of accuracy and reliability particularly when gases are the fluid to be sampled. Gases, particularly those of low molecular weight, present the difficult problem of leakage. An additional problem with gases is encountered by reason of the sample volume being forced from the syringe into the carrier stream by depression of the plunger. This force causes changes in the temperature, pressure and volume of the gas and makes accurate reproduction of a gas sample a difficult, if not impossible, task.

Other sampling devices have been formed using various valving arrangements including variations having both rotary and linear motion. Regardless of the materials employed in rotary valves and regardless of rotational friction reducing techniques and materials employed in linear motion valves, there has generally been an undesirable leakage problem around the moving valve parts. Another problem often encountered in sampling valves is that of excessive unused volume. This excess volume, known as "dead space," tends to distort and hamper accurate analysis of the sample components.

Valve actuators have been numerous and varied—both automatic and manual. Linear motion valves typically are actuated by solenoids or pneumatic cylinders. Of the two, pneumatic cylinders have proven most satisfactory in many respects inasmuch as the same sources of compressed gas can be used for the valve actuation and the carrier gas.

It is, therefore, an object of this invention to overcome many of the disadvantages of the prior art sampling apparatus.

Another object of this invention is to provide an improved sampling apparatus that is less subject to fluid leakage than those of the prior art.

Still another object of this invention is to provide an improved sampling apparatus having reduced dead volume.

An additional object of this invention is to provide an improved sampling apparatus with a relatively low cost, reliable automatic actuator.

The improved sampling apparatus of the invention is a linear motion type valve having a housing and a piston adapted to be easily displaced along an axial bore formed in the housing. An axially disposed sample chamber of predetermined volume is formed in the interior of the

piston. Both ends of the housing bore have gas tight seals. Several spaced peripheral seals are mounted along the piston's length and are in contact with the housing bore. Carrier fluid under pressure is applied to both ends of the piston substantially continuously. This substantially reduces minute leaks around the seals and the possibility of contaminant gases being "dragged" into the valve by the sliding motion of the seals. The annular spaces left between adjacent seals, together with the radial ports formed in both the piston and housing, provide conduits by which two fluid streams are successively directed through the sample chamber.

In one form of the invention one face of the piston has a greater surface area than the other end of the piston so that carrier gas may be introduced to axially displace the piston. Gas trapped in the forward end of the housing is compressed and, when the actuating gas pressure is removed from the drive end of the piston, returns the piston to its original position by the pressure of the trapped gas acting alone.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a pictorial view of a sampling device embodying the present invention;

FIGURE 2 is a longitudinal sectional view of the device of FIG. 1 in the sample loading position; and

FIGURE 3 is a longitudinal sectional view of the device of FIG. 1 in the sample eject position.

As shown in FIG. 1 the sampling device comprises a linear motion, multi-port valve. The valve comprises a valve body or housing **10** machined typically out of a piece of stainless steel, brass, or other suitable bar stock. It may be seen more clearly in FIGS. 2 and 3 that the housing **10** has a central axial bore **12** extending through most of its length and a counter bore **14**. The central bore **12** thereby provides a cylinder adapted to slideably and sealably receive a displacement plunger or piston **16**. One end of the housing **10** (the right hand end in the drawing) is of slightly reduced outside diameter and is provided with threads **19** adapted to engage the threads of a knurled cap nut **20**. A peripheral seal in the form of an internal O-ring **22** is provided within the wall of the cap nut **20** thereby to form a sealed forward chamber **24** within the housing **10**. Cap nut **20** is formed of the same material as the housing **10**.

The other end of the housing **10** is provided with a flange **26** at its extreme end which flange may either be integral with the housing **10** or a separate piece held by a retaining ring **27** as illustrated. A sealing plug **30**, formed of the same material as the housing **10**, is machined with a mating flange **28** adapted to engage with the housing flange **26**. The two flanges may be bolted together as by bolts **29** (FIG. 1). Sealing plug **30** is formed to have a diameter slightly less than that of the counter bore **14** and may be provided with an annular peripheral seal **28** which may be an O-ring adapted to engage the inner surface of the counter bore **14**. When the term peripheral seal is used herein, it refers not only to conventional O-rings but includes any circular annular boss of a piston member particularly if used to achieve sealing. When O-rings are employed they typically are formed of an inert material that does not react chemically with the fluids with which the valve is to be used.

With the sealing plug **30** in place, there is formed within the counter bore **14** a pneumatic chamber **34**. The left hand end (in the drawing) of the piston **16** is somewhat

enlarged to have a diameter approximating that of the sealing plug 30 so as to be capable of operating in this instance as a pneumatic piston. The surface area 36 of the pneumatic piston exceeds the surface area of the forward piston face 38 in the forward chamber 24. A peripheral seal 39 on the pneumatic end of piston 16 engages the counter bore 14 to complete the pneumatic chamber 34. An axial bore is formed in the sealing plug 30 to permit the introduction of a suitable fluid such as carrier gas from a source of carrier gas which may be the same as that employed with the utilization device.

Five substantially identical, spaced peripheral seals 40, 42, 44, 46, 48, respectively, are mounted in grooves 50 formed along the piston 16. Each of the seals is adapted to sealingly engage the central bore 12. Thus positioned, the several seals 40, 42, 44, 46, 48, along with the pneumatic seal 39 form five isolated annular chambers or conduits 52, 54, 56, 58, and 60, respectively, between the piston 16 and the central bore 12. Further in accordance with this invention, the forward piston face is axially bored to provide a sample chamber 62. A removable plug 64 with a flanged cap seal 65 is adapted to be threadedly inserted into the end of the sample chamber bore. The removable plug 64 may be of varying axial lengths and of a diameter (apart from the threaded portion) less than that of the sample chamber 62. Depending upon its length and diameter, the removable plug 64 may be used to vary the volume of the sample chamber 62. Access to the removable plug 62 for cleaning the sample chamber or varying its volume may be had through the knurled cap nut 20.

Radial entrance and exit ports 66 and 68, respectively, are formed in the piston 16 to provide access to the sample chamber 62. These entrance and exit ports 66 and 68 communicate, respectively, with the second and fifth annular conduits 54 and 60. Additionally a second axial bore is formed in the piston 16 so as to provide a fluid flow path or conduit 70 to the forward chamber 24. A radial port 72 is formed in the piston to communicate the third annular conduit 56 with the axial conduit 70.

Additional radial ports are formed in the housing 10 to conduct various fluid streams to and from various of the annular conduits 52, 54, 56, 58, and 60 with the valve in the sample chamber load position illustrated in FIG. 2. Thus radial inlet and outlet ports 74 and 76 are formed to communicate with the second and fifth annular conduits 54 and 60. A sample source (FIG. 1) (typically a sample reservoir) may be connected through tubing 73 to the radial inlet port 74. Additional radial ports 78, 80 for a second fluid stream are provided to communicate with the third annular conduit 56 and the forward chamber 24. A source of carrier gas may be connected to the radial port 78 through tubing 79 (FIG. 1). In like manner the outlet radial port 80 may be connected through tubing 81 (FIG. 1) to the separating column or analytical chamber of a suitable gas chromatograph or to the utilization device (FIG. 1). Additional radial ports 82 and 84 are provided to communicate with the first annular conduit 52. Appropriate tubing 86 (FIG. 1) may be provided to connect the inlet port 82 to a carrier gas supply, a suitable flow restrictor 88 being included in this fluid stream. Additionally, a second flow restrictor 92 may be inserted in tubing 94 connected to the outlet port 84. The tubing employed typically is stainless steel which may be silver soldered to the valve housing although other suitable tubing may be employed as desired.

In the load position illustrated in FIG. 2 the piston 16 is to the extreme left end (in the drawing) of its axial travel and the forward chamber 24 is of maximum volume. A first fluid stream from a sample source, which may be, for example, a reservoir or a tap from a chemical process stream, is passed through radial port 74, second annular chamber 54, radial port 66, sample chamber 62, raidal port 68, annular conduit 60, and radial port 76 either to vent or to return to the process stream. A second

stream is maintained from the carrier gas supply through radial port 78, annular conduit 56, radial port 72, axial conduit 70, the forward chamber 24, and radial port 80 to the utilization device. Also, carrier gas from the source is passed through the flow restrictor 88, radial port 82, first annular conduit 52, radial port 84, and the second flow restrictor 92 to vent. In this manner all annular conduits including both ends of the piston, but with the exception of the fourth annular conduit 58, are filled with carrier gas or sample under pressure. Any leakage which occurs around the third and fourth seals 44 and 48 causes a pressure in the fourth annular conduit 58 from which there is no escape. Since pressure is maintained in both the first annular conduit 52 and the forward chamber 24 substantially no leakage about the O-rings can occur. Hence, contamination due to external gases being dragged into the valve by the sliding O-rings is appreciably reduced. Any contamination or leakage is by the carrier gas which produces little or no deleterious effects. Stated in another manner, there is provided a flowing fluid seal which isolates the sampling device from outside contaminants.

When it is desired to inject a predetermined volume of the sample flowing through the sample chamber 62 from the first stream into the second or carrier gas stream, one need merely open the actuator valve 94 to the pneumatic chamber 34. The pneumatic piston face 36 exceeding that of the forward chamber piston face 38, moves or displaces the piston 16 to the right (in the drawing) to the position indicated in FIG. 3. All gas in the forward chamber 24 is now sealed off by the fifth seal 48 and is compressed, thereby storing energy sufficient to return the piston 16 to its initial load position illustrated in FIG. 2 once the actuating valve is opened to release the pressure in the pneumatic chamber 34. The actuator valve 94 is a two way valve capable of connecting the pneumatic chamber 34 either to vent or to the carrier gas source.

As observed from FIG. 3 the sample flow is now from the inlet port 74 through first annular conduit 52, outlet port 84 through the flow restrictor 92 to vent. The second fluid stream now flows through the radial inlet port 78, second annular conduit 54, radial port 66, sample chamber 62, radial port 68, annular conduit 60 and radial port 80 to the utilization device. In this manner the sample volume is accurately, quickly, and reproducibly, without appreciably affecting its volume, temperature, or pressure, introduced into the carrier gas stream to be swept to the gas chromatograph. The overall sealing against leaks between rings is good since the pressure differential across any one seal is small. When the actuating valve 94 connects the pneumatic chamber to vent, the pressure on the pneumatic piston face 36 is released and the stored energy from the compressed gas in the forward chamber 24 again moves or displaces the piston 16 to the load position shown in FIG.2.

Particular advantages of the invention are seen to be that since both ends of the valve are filled with carrier gas, minute leaks are substantially reduced. There is also less tendency of contaminant gases being dragged into the valve by the sliding valve action. Additionally, a small quantity of carrier gas at reduced pressure purges the "dead space" in the first annular chamber at the open end of the valve to insure sample purity. By compressing gas with the valve actuation in the forward chamber, a simple bidirectional pneumatic actuating arrangement is obtained. Because of the reduced pressure in the first annular chamber, the valve is easily displaced in the two directions. Since the sample chamber is retained within the heart of the valve itself, its temperature and that of the carrier gas is maintained at substantially identical temperatures and are subject to relatively minute variations in temperature.

Although the valve of the invention has been described as being formed of stainless steel, it may also be formed of other suitable material. Types of such material are

chemically inert plastics such as polyamide resin sold under the trademark Zytel or acetyl resin sold under the trademark Delrin, both manufactured by E. I. du Pont de Nemours and Company.

There has thus been described an improved automatically actuated sampling valve that is relatively free from leakage and sample contamination. The valve is relatively simple to construct and yet is capable of providing accurate, reproducible samples of predetermined volume.

It will be obvious that various modifications may be made in the apparatus and in the manner of operating it. It is intended to cover such modifications and changes as would occur to those skilled in the art, as far as consistent with the state of the prior art.

What is claimed is:

1. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston in said bore,
a sample chamber of predetermined volume in said piston,
means forming a plurality of annular conduits between the periphery of said piston and said housing,
means for displacing said piston axially between first and second positions within said bore,
means for applying a fluid under pressure to the outermost ones of said conduits thereby to reduce leakage into said sampling device,
and means including radial conduits in said housing that are connectable with at least two fluid streams and radial conduits in said piston for interconnecting said sample chamber alternatively in first and second fluid streams corresponding to said first and second piston positions.

2. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston in said bore having a first end face, said piston having a sample chamber opening to said first end face, and a first fluid flow path between said first end face and the periphery of said piston,
a sealing plug positioned in said sample chamber opening at said first end face,
a plurality of spaced peripheral seals mounted on said piston in contact with said housing thereby to form a plurality of annular conduits between adjacent seals and a closed forward chamber adjacent said first end face,
means including said forward chamber and said first flow path to displace said piston axially within said housing between first and second positions,
and means including said annular conduits and radial conduits in said housing connectable with at least two fluid streams and radial conduits in said piston for interconnecting said sample chamber in the first fluid stream with said piston in said first position and in the second fluid stream with said piston in said second position.

3. The combination set forth in claim 2 which also includes means for applying a fluid under pressure to the outermost ones of said conduits thereby to reduce leakage into said sampling devices.

4. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston in said bore having first and second end faces, said piston having a sample chamber opening to said first end face and a first fluid flow path between said first end face and the periphery of said piston,
a sealing plug positioned in said sample chamber and opening at said first end face,
a plurality of spaced peripheral seals mounted on said piston in contact with said housing thereby to form a plurality of annular conduits between adjacent seals and a closed forward chamber adjacent said first end face,
means to displace said piston axially between first and second positions,

means including said annular conduits and radial conduits in said housing and said piston for interconnecting said sample chamber in a first fluid stream with said piston in said first position and in a second fluid stream with said piston in said second position,
and means for applying fluid under pressure to said forward chamber through said first flow path and to that conduit adjacent said second end face, thereby to reduce leakage about said seals into said sampling device.

5. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston in said bore having a first end face, said piston having a sample chamber opening to said first end face and a first fluid flow path between said first face and the periphery of said piston,
a sealing plug positioned in said sample chamber opening at said first end face,
a plurality of spaced peripheral seals mounted on said piston in contact with said housing thereby to form a plurality of annular conduits between adjacent seals,
means to position said piston axially between first and second positions,
first and second fluid sources and a utilization device,
means with said piston in said first position including said annular chamber and radial conduits in said housing and said piston for passing fluid from said first source through said sample chamber and fluid from second source through said first flow path to said utilization device,
and means with said piston in said second position including said annular chamber and said radial conduits in said housing and said piston for passing fluid from said second source through said sample chamber to said utilization device.

6. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston having a sample chamber of predetermined volumetric capacity positioned in said bore, said piston having first and second end faces,
a plurality of seals forming first, second, and third annular conduits between said piston and said housing bore, said first piston end face and housing together forming a sealed forward chamber,
a plurality of longitudinally spaced radial ports in said housing connectable with at least two fluid streams,
first, second, and third radial ports in said piston each connecting respectively with a corresponding one of said first, second, and third annular conduits,
means to axially displace said piston and said housing relative to each other between first and second positions thereby to select a predetermined volume of sample from one of said fluid streams and introduce said sample into another of said fluid streams,
and means for applying fluid under pressure to said forward chamber and to said housing bore adjacent said second piston face thereby to reduce the leakage of contaminants into said fluid streams and to displace said piston relative to said housing.

7. A fluid sampling device comprising:
a housing having an axially extending bore,
a piston having a sample chamber of predetermined volumetric capacity positioned in said bore, said piston having first and second end faces, wherein said second piston face has an area exceeding that of said first piston face,
a plurality of seals forming first, second, and third annular conduits between said piston and said housing bore, said first piston face and housing together forming a sealed forward chamber,
a plurality of longitudinally spaced radial ports in said housing connectable with at least two fluid streams,
first, second, and third radial ports in said piston each

connecting respectively with a corresponding one of said first, second, and third annular conduits,

means to axially displace said piston and said housing relative to each other between first and second positions thereby to select a predetermined volume of sample from one of said fluid streams and introduce said predetermined sample volume into another of said fluid streams flowing through said forward chamber,

and means for applying a fluid under pressure to said second piston face thereby to axially displace said piston to said second position and store energy by compressing the fluid of said other stream in said forward chamber, whereby upon removal of fluid under pressure from said second piston face said piston is again displaced to said first position by said stored energy.

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