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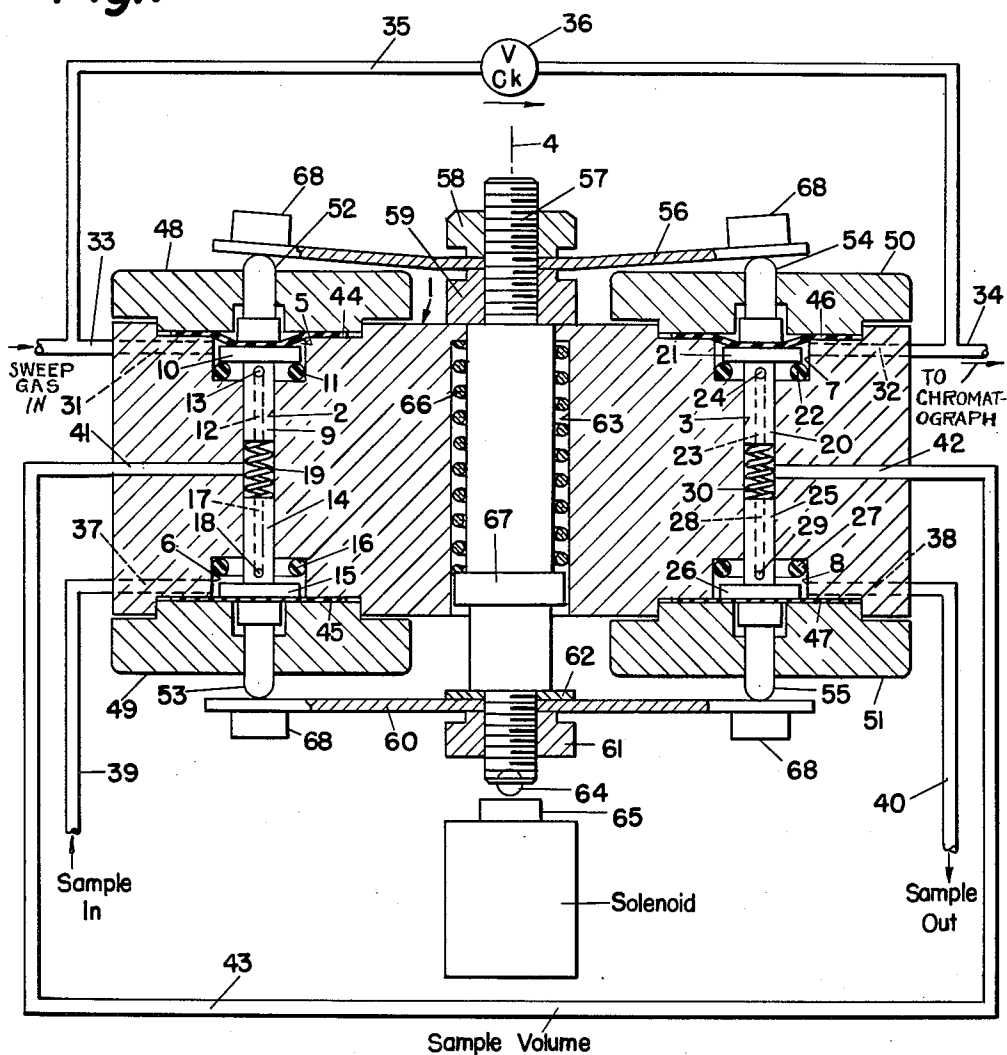
J R. WRIGHT
FLUID SAMPLING VALVE

3,021,713

Filed July 27, 1959

2 Sheets-Sheet 1

Fig. 1



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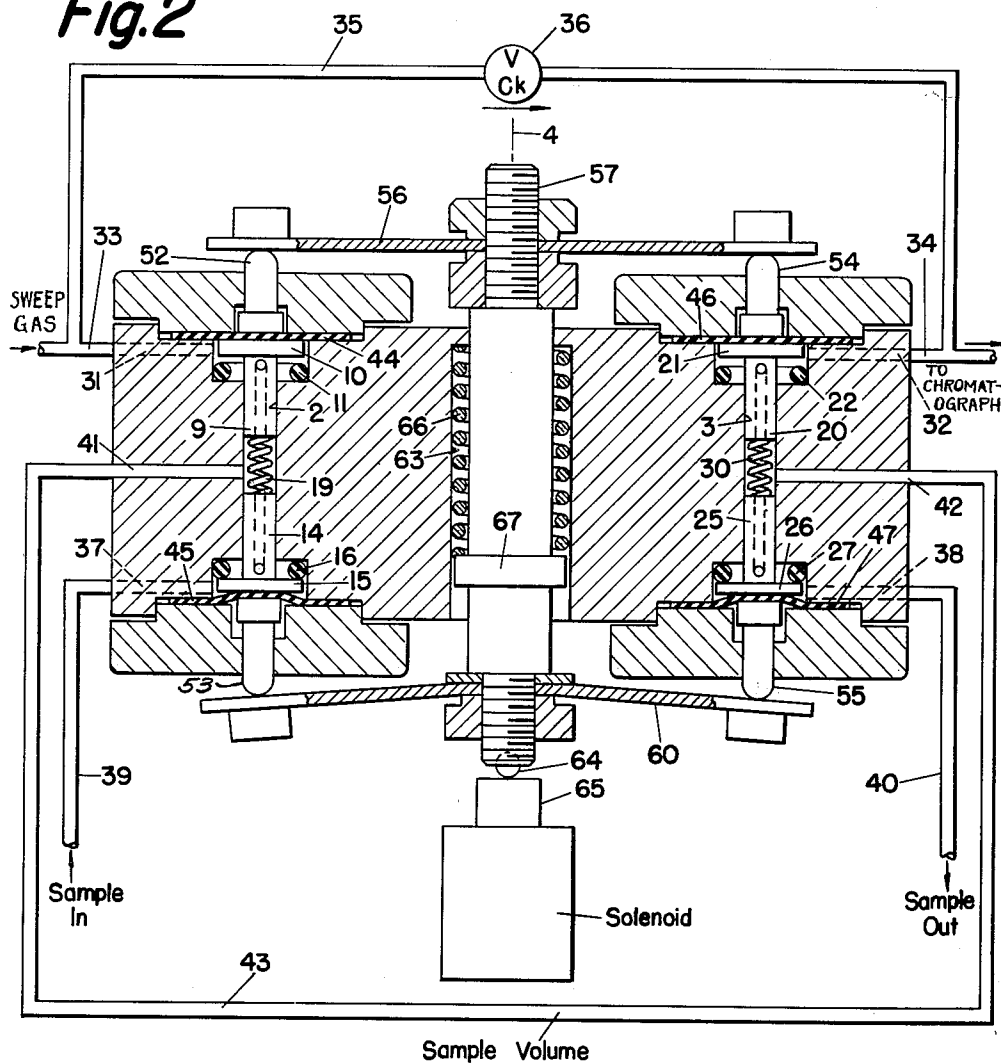
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2 Sheets-Sheet 2

Fig. 2



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3,021,713

FLUID SAMPLING VALVE

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16 Claims. (Cl. 73-422)

This invention relates to apparatus for transferring to a main fluid stream a quantity of fluid from an auxiliary fluid stream, and more particularly to an improved valve construction for intermittently injecting into a continuously flowing main fluid stream a predetermined volume of fluid (i.e., a sample) from an auxiliary fluid stream.

Valves of the type aforesaid, known as fluid sampling or sample injecting valves, are commonly utilized in connection with apparatus for analyzing gasses and vapors by the technique of gas chromatography, which technique lends itself to the accurate measurement of both major and minor components of complex mixtures. Gas chromatography essentially is a process for separating these complex mixtures into their components. In order to accomplish the separation, a so-called partitioning or separating column is used. In gas chromatography, an inert sweep or carrier gas (such as helium or nitrogen) flows continuously through the separating column. This is the main fluid stream, usually having a flow rate of between 50 and 100 cc./minute. A small sample of a mixture to be analyzed (called the sample) is injected into the sweep or carrier gas stream, prior to the column. The chromatogram may be developed by elution, the different components of the sample having different retention times in the separating column.

In automatic operation of the above apparatus, the gaseous mixture or simple gas is flowing in an auxiliary fluid stream. Periodically, a sequence timer closes a circuit to cause operation of the fluid sampling valve. The latter then operates to automatically inject a predetermined volume (e.g., 0.5 cc.) from the sample or auxiliary fluid stream into the main or carrier gas stream. The sample volume normally is swept (by the carrier gas) out of the valve in about two seconds, although the valve may be left in the "operated" position for five to ten seconds. Under normal conditions, the sweep gas stream is passed through the chromatographic apparatus until equilibrium conditions are reached, whereupon a sample is injected into the stream. The apparatus may require from two to thirty minutes to complete one cycle, of analysis.

In the design of such a fluid sampling valve, it is desired to achieve certain ends. The valve should be as quick and smooth acting as possible, so that the uniform flow through the partitioning column is disturbed as little as possible. It should be as small and compact as possible, so that it can be used where space is limited. The parts of the valve should all be long wearing, to reduce to a minimum the cost and inconvenience of making repairs. The force required for operating the valve should be small.

A valve construction which eminently realizes the aforesaid desired ends is disclosed in my copending application, Serial No. 756,927, filed August 25, 1958. The present invention, which constitutes an improvement over the construction disclosed in my prior application, utilizes a construction which is smaller, and simpler to manufacture (and therefore less costly); also, the present construction has a smaller amount of "dead space," the necessary dead space presently being kept very small as compared with the sample volume.

The fluid sampling valve of this invention comprises two chambered valve body sections in each one of which a pair of on-off valve members is arranged to operate, the two pairs of valve members being operated by a single

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operating force. One valve member of each pair is normally "off" or closed, and the other valve member of each pair is normally "on" or open, the positions of all four valve members being reversed from normal when a sample is to be taken. Mechanical operating force is applied to each of the valve members by way of a respective weak diaphragm or cover which seals off a corresponding end of the respective chamber. Separate springs are provided in each chamber for biasing the respective valve members therein toward their "on" or open positions.

A detailed description of the invention follows, taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a section through a valve constructed in accordance with this invention, the parts being shown in one position of operation and certain parts being shown somewhat schematically; and

FIGURE 2 is a view similar to FIGURE 1, but showing the parts in another position of operation.

Referring now to the drawings, a valve body 1, whose outer configuration is substantially that of a rectangular prism, has therein two longitudinal cylindrical bores or chambers 2 and 3 which are parallel to each other and which are located respectively on opposite side of a longitudinal center line 4. The center lines or axes of the bores are spaced equidistantly from the center line 4, and the axes of the bores lie in the same plane (the plane of the paper) as the center line 4. The bores or chambers 2 and 3 extend entirely through the body or block 1, in a vertical direction. The chamber 2 has a constricted or small-diameter central portion, and is counterbored to provide a larger-diameter upper end portion 5 and a larger-diameter lower end portion 6. Similarly, chamber 3 has a constricted or small-diameter central portion, and is counterbored to provide a larger-diameter upper end portion 7 and a larger-diameter lower end portion 8.

A first valve member, having a cylindrical stem or shank 9 depending from an upper disk 10, is slidably mounted in chamber 2. The shank 9 has a diameter such as to slide freely in the central portion of chamber 2, while being guided thereby. The disk 10 has a diameter somewhat smaller than the diameter of chamber end portion 5, to provide an annular space between the outer edge of the disk and the chamber wall, through which space gas can flow. The shank or guide 9 terminates somewhat above the horizontal midplane of body 1. An O-ring 11 is mounted on the lower circular end face of chamber end portion 5, in such a position as to surround shank 9. O-ring 11 is adapted to make sealing contact with the lower face of disk 10, and also with the lower end face of chamber portion 5.

For proper valve action, it is necessary that free and unrestricted communication be established at certain times (depending upon the valve operation, as will later be described) between the lower end of valve stem 9 and the upper end of chamber end portion 5. While this might be effected by way of the annular space between stem 9 and the cylindrical wall which defines the central portion of bore 2, this space may become obstructed by grease or other lubricant used on the valve stem. Therefore, a central longitudinally-extending bore 12 of small diameter is provided in stem 9. Bore 12 extends from the lower end of stem 9 to a point just below the lower face of disk 10, and the upper end of this bore communicates with one or more radial holes 13 provided in stem 9, the holes 13 opening into chamber end portion 5, just below the lower face of disk 10.

The valve member 9, 10 described comprises a simple on-off valve controlling a fluid flow path between the lower end of valve stem 9 (i.e., between a region of the central portion of chamber 2 which is located adjacent the horizontal midplane of body 1) and the upper end of chamber portion 5. This valve member is closed or

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turned "off" (in which position it is illustrated in FIGURE 1) by forcing the disk 10 downwardly into snug contact with the O-ring 11, thereby providing seals at both the upper and lower surfaces of the O-ring. In this position, the controlled fluid flow path referred to is broken or blocked. The valve member is opened or turned "on" by lifting the disk 10 away from O-ring 11, in which case the controlled fluid flow path is open and may be traced as follows, beginning at the lower end of bore 12: bore 12, hole or holes 13, over the top of O-ring 11, and around the outside of disk 10 to the upper end of chamber portion 5.

A second valve member, which is preferably a duplicate of the first valve member 9, 10, has a cylindrical stem or shank 14 integral with or attached to a disk 15, and is slidably mounted in chamber 2. The stem 14 slides freely in the central portion of chamber 2, and the upper end of this stem is spaced from the lower end of stem 9. There is an annular space between disk 15 and the wall of chamber end portion 6, through which space gas can flow. Stem 14 terminates somewhere below the horizontal midplane of body 1. An O-ring 16 is mounted on the upper circular end face of chamber end portion 6, surrounding stem 14. If desired, an adhesive may be used to fasten the O-ring 16 in place in chamber end portion 6. O-ring 16 is adapted to make sealing contact with the upper face of disk 15, and also with the upper end face of chamber portion 6.

Communication is provided, at certain times, between the upper end of valve stem 14 and the lower end of chamber end portion 6, by means of a longitudinally-extending bore 17 which communicates at its lower end with one or more radial holes 18, the latter being located just above the upper face of disk 15; the bore 17 and hole 18 are both provided in stem 14.

The valve member 14, 15 comprises a simple on-off valve controlling a fluid flow path between the upper end of valve stem 14 (i.e., between a region of the central portion of chamber 2 which is located adjacent the horizontal midplane of body 1) and the lower end of chamber portion 6. This valve member may be closed or turned "off" by forcing the disk 15 upwardly into snug contact with the O-ring 16, thereby to provide seals at both the upper and lower surfaces of this O-ring. The controlled fluid flow path referred to would then be broken or blocked. The valve member 14, 15 is opened or turned "on" (in which position it is illustrated in FIGURE 1) by moving disk 15 downwardly, away from O-ring 16. The fluid flow path controlled by valve member 14, 15 (when open) may be traced as follows, beginning at the upper end of bore 17: bore 17, hole or holes 18, below the lower side of O-ring 16, and around the outside of disk 15 to the lower end of chamber portion 6.

A compression spring 19 "floats" in the space between the lower end of stem 9 and the upper end of stem 14, one end of spring 19 engaging the lower end of stem 9 and the other end of this spring engaging the upper end of stem 14. Spring 19 comprises a resilient means in chamber 2 which urges or biases both the upper and the lower valve members in this chamber toward their open or "on" positions.

A third valve member, similar in all respects to the first valve member 9, 10, is slidably mounted in chamber 3. The structure here comprises a valve stem 20 having a longitudinal bore 23 and one or more radial holes 24 therein; a disk 21, and an O-ring 22. The valve member 20, 21 comprises an on-off valve controlling a fluid flow path between the lower end of valve stem 20 (i.e., between a region of the central portion of chamber 3 which is located adjacent the horizontal midplane of body 1) and the upper end of chamber portion 7. This valve member is illustrated in the closed or "off" position, in FIGURE 1. Disk 21 is forced downwardly into snug contact with O-ring 22 to close or turn "off" this valve, and is lifted away from O-ring 22 to open or turn "on"

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the valve. The fluid flow path controlled by valve member 20, 21, when open, may be traced as follows, beginning at the lower end of bore 23: bore 23, hole or holes 24, over the top of O-ring 22, and around the outside of disk 21 to the upper end of chamber portion 7.

A fourth valve member, similar in all respects to the second valve member 14, 15, is slidably mounted in chamber 3. The structure here comprises a valve stem 25 having a longitudinal bore 28 and one or more radial holes 29 therein; a disk 26, and an O-ring 27. The valve member 25, 26 comprises an on-off valve controlling a fluid flow path between the upper end of stem 25 (i.e., between a region of the central portion of chamber 3 which is located adjacent the horizontal midplane of body 1) and the lower end of chamber portion 8. This valve member is illustrated in the open or "on" position, in FIGURE 1. Disk 26 is forced upwardly into snug contact with O-ring 27 to close or turn "off" this valve, and is moved downwardly away from O-ring 27 to open or turn "on" the valve. The fluid flow path controlled by valve member 25, 26 may be traced as follows, beginning at the upper end of bore 28: bore 28, hole or holes 29, below the lower side of O-ring 27, and around the outside of disk 26 to the lower end of chamber portion 8. An adhesive may be used to fasten the O-ring 27 in place in chamber end portion 8.

A compression spring 30 "floats" in the space between the lower end of stem 20 and the upper end of stem 25, one end of spring 30 engaging the lower end of stem 20 and the other end of this spring engaging the upper end of stem 25. Spring 30 comprises a resilient means in chamber 3 which urges or biases both the upper and the lower valve members in this chamber toward their open or "on" positions.

Valve body 1 is provided with a port 31 which extends from the exterior of the body to the upper end of chamber portion 5. The inner end of port 31 opens into chamber portion 5, while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto. The inner end of port 31 is preferably located above the O-ring 11. In the drawings, the port 31 is shown somewhat schematically. Actually, in a practical embodiment of the invention, the outer end of this port may be located in the horizontal midplane of the valve body and aligned laterally with the axis of chamber 2, but 90° angularly from the plane of the paper; from this point, the port may extend inwardly or horizontally toward the axis of chamber 2, then upwardly (vertically) just beyond or outwardly of the vertical wall of chamber portion 5, then horizontally into the upper end of chamber portion 5. A similar and completely analogous port 32 extends from the exterior of the body 1 to the upper end of chamber portion 7. The inner end of port 32 opens into chamber portion 7, while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto. The inner end of port 32 is preferably located above the O-ring 22.

One end of a conduit or tube 33 is connected to the fitting provided at the outer end of port 31, and the opposite end of this conduit is connected to a suitable source (not shown) of carrier or sweep gas, preferably by way of a suitable flow regulator (also not shown). The carrier or sweep gas should be some inert gas, such as helium or nitrogen. This sweep gas may be thought of as comprising a main fluid.

One end of a conduit or tube 34 is connected to the fitting provided at the outer end of port 32, and the opposite end of this conduit is connected to the partitioning or separating column (not shown) of a chromatograph. The partitioning column is of course conventionally followed by a suitable detector, etc.

A by-pass or alternate path for the sweep gas (main fluid) is provided, between conduits 33 and 34. This by-pass path is provided by a conduit or tube 35, one end of

which is connected to conduit 33, between the carrier gas source and port 31, and the other end of which is connected to conduit 34, between port 32 and the chromatograph. A check valve 36 is inserted into conduit 35, between the ends of such conduit. The check valve 36 is preferably of a commercially-available type utilizing a spring-loaded ball. Such a check valve requires a small pressure differential to open it and, when open, it permits fluid (gas) to flow through conduit 35 in the direction of the arrow (i.e., from the source to the chromatograph). Check valve 36 will automatically open to permit the flow of sweep gas as described when no alternate flow path for such gas is open or presented, since in this case the required pressure differential (for opening the check valve) is made to appear; however, when an alternate flow path is opened up, the pressure differential disappears and check valve 36 closes, thereby stopping the flow of gas through conduit 35.

The valve conduit 35 may be thought of as a main conduit, to which chamber portions 5 and 7 are directly connected, by way of the respective ports 31 and 32.

Valve body 1 is also provided with a port 37 which extends from the exterior of the body to the lower end of chamber portion 6. The inner end of port 37 opens into chamber portion 6, while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto. The inner end of port 37 is preferably located below the O-ring 16. In the drawings, the port 37 is also shown somewhat schematically. Actually, in a practical embodiment of the invention, the outer end of this port may be located in the horizontal midplane of the valve body and aligned laterally with the axis of chamber 2, but 90° angularly from the plane of the paper (and 180° angularly from the outer end of port 31); from this point, the port 37 may extend inwardly or horizontally toward the axis of chamber 2, then downwardly (vertically) just beyond or outwardly of the vertical wall of chamber portion 6, then horizontally into the lower end of chamber portion 6. A similar and completely analogous port 38 extends from the exterior of the body 1 to the lower end of chamber portion 8. The inner end of port 38 opens into chamber portion 8, while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto. The inner end of port 38 is preferably located below the O-ring 27.

One end of a suitable conduit or tube 39 is connected to the fitting provided at the outer end of port 37, and the opposite end of this conduit is connected to a suitable source (not shown) of sample gas (the gaseous mixture to be chromatographically analyzed), preferably by way of a suitable sample treater (not shown). A typical sample treater which can be used is disclosed in my copending application, Serial No. 7,626, filed February 9, 1960. This sample gas may be thought of as comprising an auxiliary fluid. Thus, the chamber portion 6 is connected, via port 37, to an upstream section 39 of the auxiliary conduit.

One end of a suitable conduit or tube 40 is connected to the fitting provided at the outer end of port 38, and the opposite end of this conduit goes to a "sample out" connection, for example a vent. Thus, the chamber portion 8 is connected, via port 38, to a downstream section 40 of the auxiliary conduit.

Valve body 1 is also provided with a horizontally-disposed port 41 which extends from the exterior of the body to the horizontal midplane region of chamber 2. The inner end of port 41 opens into this horizontal midplane region (i.e., the region wherein spring 19 is located, between the lower end of valve stem 9 and the upper end of valve stem 14), while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto. Valve body 1 also has therein a horizontally-disposed port 42 which

extends from the exterior of the body to the horizontal midplane region of chamber 3. The inner end of port 42 opens into this horizontal midplane region (i.e., the region wherein spring 30 is located, between the lower end of valve stem 20 and the upper end of valve stem 25), while the outer end of this port is provided with a fitting (not shown), by means of which a conduit or pipe may be connected thereto.

Interconnecting the fittings at the outer ends of ports 41 and 42 is an auxiliary conduit or tube intermediate section 43, this latter conduit comprising a "sample volume" and having its opposite ends connected respectively to the fittings previously referred to.

The normal position of the fluid sampling valve of this invention is illustrated in FIGURE 1. In this position, the top pair of valve members (to wit, valve members 9, 10 and 20, 21) are closed or "off," and the bottom pair of valve members (to wit, valve members 14, 15 and 25, 26) are open or "on." When the valve is in this position, the sample gas flows in at port 37, through the (now open) fluid flow path controlled by valve member 14, 15, and out the port 41 into the "sample volume" conduit 43. Flowing through the conduit 43 from left to right, the sample gas flows back into the valve body via port 42, from whence it flows through the (now open) fluid flow path controlled by valve member 25, 26 and out the port 38 to "sample out" conduit 40. Thus, with the sampling valve in its normal position, there is sample gas (auxiliary fluid) flowing continuously through the external "sample volume" 43.

The sample gas cannot flow upwardly into chamber portion 5, nor can it flow into chamber portion 7, because valve members 9, 10 and 20, 21 are both now closed or "off," disk 10 being in sealing contact with O-ring 11 and disk 21 being in sealing contact with O-ring 22. Since the top pair of valve members is closed, the spring-loaded check valve 36 is forced open, and the carrier or sweep gas (main fluid) flows through conduit 35 and through this check valve to the chromatographic column, by way of conduit 34. The sweep gas may thus be made to pass through the chromatographic apparatus until equilibrium conditions are reached. An important feature of this invention resides in the manner of producing the necessary motion, by means of a single operating force, for operating the sampling valve to its "sampling" or injecting position, together with the manner of sealing the valve against leaks to the outside. This will now be described.

Four flexible (weak) sealing diaphragms 44, 45, 46, and 47, one for each of the four chamber portions 5, 6, 7, and 8, respectively, are utilized to seal off the outer ends of these chamber portions from the atmosphere. These diaphragms may be made of any rubber-like (flexible) material which is inert to the sweep and sample gases. Sheet "Teflon" (tetrafluoroethylene) 4 mils (0.004 inch) thick has been found quite satisfactory. The diaphragms 44-47 comprise flexible imperforate covers for the respective chamber ends, and seal against flat (annular) sealing surfaces provided on the surface of valve body 1, at both ends of each of the chambers 2 and 3.

A more or less cylindrical stepped cover (one step of which provides a flat surface adapted to engage the outer surface of the respective diaphragm) is utilized for each respective one of the four chamber ends, to maintain the respective diaphragms in position for sealing, and also to provide bearing surfaces for a purpose which will appear hereinafter. Each of the four covers is mounted to overlie the outer surface of a respective diaphragm, and also an adjacent area of the outer face of the valve body. The metal covers are secured to the valve body 1 in any suitable manner, for example by means of screws (not shown) which pass through holes provided near the periphery of the covers and thread into matching tapped holes provided in the valve body 1.

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Cover 48 overlies the outer surface of diaphragm 44 and is secured to the valve body adjacent the periphery of this diaphragm, cover 49 overlies the outer surface of diaphragm 45 and is screwed to the valve body adjacent the periphery of this diaphragm, cover 50 overlies the outer surface of diaphragm 46, is positioned above the outer end of chamber portion 7, and is fastened to the valve body adjacent the periphery of diaphragm 46, while cover 51 overlies the outer surface of diaphragm 47 and is secured to the valve body adjacent the periphery of this diaphragm. It should be apparent that the longitudinal axes of both cylindrical covers 48 and 49 should coincide with the axis of chamber 2, while the longitudinal axes of both cylindrical covers 50 and 51 should coincide with the axis of chamber 3.

A metal plunger 52, having an upper shank portion and an enlarged lower head portion, is mounted for vertical sliding movement in cover 48, at the center of this cover. The shank portion of this plunger slides freely in a central hole drilled through cover 48, this hole providing a bearing and guiding surface for the plunger shank. The diameter of the plunger head is smaller than the diameter of the chamber end portion 5, and the lower end of the plunger head is adapted to engage the central area of the outer surface of diaphragm 44. When the plunger 52 is moved downwardly (inwardly with respect to the valve body), the diaphragm will be flexed as shown in FIGURE 1, transmitting the force to disk 10 (whose upper face will be engaged by the inner surface of the imperforate diaphragm 44) to urge the disk into snug contact with O-ring 11, the force exerted by plunger 52 through the diaphragm 44 being sufficient to cause disk 10 to seal against its O-ring 11. This closes or turns "off" valve member 9, 10.

When the plunger 52 is moved upwardly (outwardly with respect to the valve body), the downwardly-acting force previously operative on diaphragm 44 and valve member 9, 10 will be removed, permitting this valve member to move upwardly (under the urging of spring 19, which biases this valve member toward open or "on"), disk 10 then lifting away from O-ring 11 to open or turn "on" this valve member. As disk 10 moves upwardly, the diaphragm 44 follows it, returning to a substantially flat, horizontal position.

The inner side of cover 48 is counterbored with a diameter such as to allow the head of plunger 52 to fit loosely in the counterbore, the depth of the counterbore being sufficient to allow the plunger to move upwardly far enough to permit complete opening of valve member 9, 10.

A metal plunger 53, preferably of the same dimensions as plunger 52, is mounted for vertical sliding movement in cover 49, but in a reversed position as compared to plunger 52. Plunger 53 operates valve member 14, 15 through the imperforate diaphragm 45, in a manner analogous to the operation (previously described) of valve member 9, 10 by plunger 52. That is to say, when plunger 53 moves downwardly (i.e., outwardly) to the position illustrated in FIGURE 1, the disk 15 is permitted to move downwardly (under the urging of spring 19), away from O-ring 16, thus opening or turning "on" valve member 14, 15. Diaphragm 45 is then substantially flat and horizontal. When plunger 53 moves upwardly (inwardly with respect to the valve body), the diaphragm 45 will be flexed, transmitting the force to disk 10 and moving the latter upwardly into snug contact with O-ring 16, thereby closing or turning "off" valve member 14, 15.

The inner side of cover 49 is counterbored to permit the required movement of the head of plunger 53.

A metal plunger 54, similar in every respect to plunger 52, is mounted for vertical sliding movement in cover 50. Plunger 54 operates valve member 20, 21 through the imperforate diaphragm 46, in a manner exactly similar to that in which plunger 52 operates valve member 9, 10. In FIGURE 1, diaphragm 46 is flexed and valve mem-

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ber 20, 21 is closed or "off." Cover 50 is counterbored to permit the required movement of the head of plunger 54.

A metal plunger 55, similar in every respect to plunger 53, is mounted for vertical sliding movement in cover 51. Plunger 55 operates valve member 25, 26 through the imperforate diaphragm 47, in a manner exactly similar to that in which plunger 53 operates valve member 14, 15. In FIGURE 1, diaphragm 47 is shown flat, valve member 25, 26 then being open or "on." Cover 51 is counterbored to permit the required movement of the head of plunger 55.

The shanks of all four plungers are long enough so that the outer ends thereof project outwardly beyond the outer faces of the respective covers, even when these plungers are pushed inwardly to their maximum extents. In order to apply a single operating force to all of the plungers, thereby to operate the respective valve members through the corresponding sealing diaphragms, leaf springs are employed as a part of the operating mechanism. An upper leaf spring 56, made of a suitable material such as Phosphor bronze, is positioned so that its opposite ends engage, respectively, the outer ends of plungers 52 and 54. The midportion of spring 56 is rigidly fastened to a shaft 57 which is positioned so that the shaft longitudinal axis coincides with the center line 4 of the valve body. The fastening of spring 56 to shaft 57 can be effected in any suitable manner; as illustrated, the threaded upper end of the shaft passes through a central hole in spring 56 and upper and lower nuts 58 and 59, respectively, are threaded on the shaft and bear respectively against the upper and lower faces of spring 56. The lower side of nut 59 can contact the upper face of valve body 1 (as illustrated in FIGURE 1), to limit the downward movement of shaft 57 with respect to the valve body.

The shaft 57 passes freely through an enlarged central bore 63 in valve body 1, and the midportion of a lower leaf spring 60 (similar in construction to spring 56) is fastened to shaft 57, near the lower end of this shaft. This fastening may be by means of a lower nut 61 which threads onto the threaded lower end of shaft 57 and bears against the lower face of spring 60, and a flat washer 62 which bears against the upper face of spring 60 and also against a shoulder provided on shaft 57. The opposite ends of spring 60 engage, respectively, the outer ends of plungers 53 and 55.

At the extreme lower end of shaft 57, and integral therewith, there is a cup or socket (not shown), and a hardened steel ball 64 (for example, $\frac{1}{8}$ inch in diameter) is swaged in place in this socket, so that a portion thereof projects slightly below the lower end of the socket. The plunger 65 of a solenoid is aligned axially with shaft 57 and is located just below the ball 64, with a very small clearance (about 10 mils) between the upper end of the plunger and the lowermost point of the ball. The solenoid may be a small commercially-available type of rotary solenoid which, although primarily designed to give rotary motion, does have an axial motion of about 60 mils, with a force of about 20 pounds; this is enough axial motion to operate the valve even deducting the aforementioned clearance, since the force required to operate the latter is about 10 pounds and the length of stroke required is about 50 mils. When the solenoid is energized, its plunger 65 moves upwardly, engaging ball 64 and moving the shaft 57 upwardly. This will be explained further hereinafter.

If desired, the bracket which suspends the solenoid below the valve of the invention may have a portion (not shown) which surrounds the lower end of shaft 57, in a region substantially vertically coextensive with lower covers 49 and 51, to provide a sliding bearing at the lower end of this shaft.

The upper end of bore 63, near the top of valve body 1, has a constricted portion which provides a sliding bearing at the upper end of shaft 57. The lower edge of this

constricted portion also provides a fixed abutment (integral with valve body 1) against which bears the upper end of a compression spring 66. The lower end of spring 66 bears against a collar 67 which is integral with or is rigidly secured to shaft 57. It may be seen that spring 66 urges shaft 57 downwardly, toward the normal position illustrated in FIGURE 1. Thus, if shaft 57 has been moved upwardly by the solenoid plunger (working against the force of spring 66), deenergization of the solenoid returns the plunger 65 to its normal position, releasing the shaft 57, which then returns to its normal or FIGURE 1 position under the influence of return spring 66.

In the drawings, the springs 56 and 60 are shown schematically as each comprising a single spring. Actually, in a practical embodiment of the invention, these may each comprise two springs, an inner and an outer spring, placed back-to-back, and means for separately adjusting the spring force at each of the four plungers. Thus, taking spring 56 as an example (the description now to be given applying equally well to spring 60), and remembering that it may comprise an inner and an outer spring mounted in "two-ply" fashion, a separate internally-threaded and outwardly-extending bushing 68 may be rigidly secured to each end of the outer spring. Threaded into each of these bushings is a respective set screw (not shown), the inner end of which engages the outer face of the inner spring. By turning these set screws, the effective "normal" force exerted at the two ends of the leaf spring 56 may be independently adjusted.

Assuming that the fluid sampling valve is in its normal or FIGURE 1 position, the sweep gas stream is passed through the chromatographic apparatus, in the manner previously described, until equilibrium conditions are reached, at which time it is desired that a sample of predetermined, known volume be injected into the gas stream going to said apparatus. To do this, the solenoid is energized (this may be conveniently done, automatically and periodically, by means of a sequence timer), causing the plunger 65 to move upwardly to apply (by means of the ball 64) an upwardly-directed force to the central shaft 57. This shaft will then move upwardly, against the opposing force of spring 66.

During the first half of the upward motion of shaft 57, the center and ends of spring 60 all move upwardly, more or less as a unit (the spring tending to remain flat). In this connection, it will be remembered that the midportion of spring 60 is fixedly secured to shaft 57, as is also the mid portion of spring 56. Plungers 53 and 55 thus are both moved upwardly by the ends of spring 60, forcing both disks 15 and 26 upwardly (via the flexible diaphragms 45 and 47) to close or turn "off" the lower valve members 14, 15 and 25, 26. This closes off both ends of the "sample volume" conduit 43, by closing the connection between conduit 39 and one end of conduit 43 (this being done by operating valve member 14, 15 to "off"), and by closing the connection between conduit 40 and the other end of conduit 43 (this latter being done by operating valve member 25, 26 to "off"). Closing off both ends of conduit 43 traps a fixed, predetermined volume of sample gas in the "sample volume."

During this first half of the upward motion of shaft 57, the midportion of spring 56 (attached to shaft 57) tends to move upwardly without moving the ends of this spring any appreciable amount, since this spring, when released, tends to first return to a flat position, from the upwardly-bowed position illustrated in FIGURE 1. As a result, during this first half of the movement, valve members 9, 10 and 20, 21 both remain closed or "off."

During the second half of the upward motion of shaft 57, the disks 15 and 26 are in engagement with the respective O-rings 16 and 27 and thus cannot move any further upwardly. The plungers 53 and 55, and the ends of spring 60, therefore cannot move any further upwardly. The midportion of spring 60, however, moves upwardly

with shaft 57, causing spring 60 to become bowed, so that it finally reaches the position illustrated in FIGURE 2.

During this same second half of the motion, after spring 56 has attained a more or less flat position, the ends of spring 56 move upwardly along with the midportion thereof, these ends moving away from plungers 52 and 54, so that the latter can move upwardly and release disks 10 and 21 for movement upwardly, as urged by the springs 19 and 30, respectively. This causes the upper pair of valve members 9, 10 and 20, 21 to open or turn "on."

The fluid sampling valve has now been brought to the "sampling" position, which is illustrated in FIGURE 2. In this position, spring 56 is essentially flat, spring 60 is bowed outwardly at its ends, shaft 57 has moved upwardly from its FIGURE 1 position, the lower pair of valve members is closed, and the upper pair of valve members is open.

With the lower pair of valve members closed and the upper pair of valve members open, the sweep gas enters the valve body through port 31, flows through the fluid path (now open) controlled by valve member 9, 10, and into "sample volume" conduit 43 by way of port 41. The sample gas trapped in conduit 43 is now swept by the sweep gas through port 42, through the fluid path (now open) controlled by valve member 20, 21, and through the port 32, into conduit 34, by means of which it is carried out to the chromatographic column.

When the flow path for carrier gas through the sampling valve (the path delineated in the preceding paragraph) is opened up, check valve 36 automatically closes, so that the by-pass conduit 35 is no longer open, and all of the carrier or sweep gas flow takes place through the sampling valve, as just described.

The valve operation described (i.e., the operation from the FIGURE 1 position to the FIGURE 2 position) takes place very rapidly, so that the time during which all four valve members are closed or "off" is only a very small fraction of a second. Thus, the interruption of flow of the sweep gas is only slight, and insignificant.

The solenoid is kept energized (so that the valve is in the FIGURE 2 position) long enough for the carrier or sweep gas to carry the entire sample volume into the sweep gas stream, which leads to the chromatograph. Then, the solenoid is deenergized and plunger 65 moves downwardly, releasing shaft 57 for downward movement under the influence of return spring 66. Then, an action essentially the reverse of that previously described takes place, to return the valve to the normal position of FIGURE 1. The shaft 57, moving downwardly, causes the ends of spring 56 to move downwardly, thereby closing or turning "off" the upper pair of valve members 9, 10 and 20, 21. Further downward movement of shaft 57 bows the spring 56, causing it to attain the position illustrated in FIGURE 1. When the upper pair of valve members closes, blocking off the flow path for sweep gas through the sampling valve, check valve 36 automatically opens, opening up the conduit 35, through which the sweep gas then flows to the chromatograph.

As shaft 57 moves downwardly from the FIGURE 2 position, spring 60 first tends to flatten out, following which the ends of this spring move downwardly to release the lower pair of valve members 14, 15 and 25, 26 for movement to the open or "on" position, under the urging of springs 19 and 30, respectively.

The valve has now been brought back to the "normal" position illustrated in FIGURE 1, wherein sweep gas flows continuously to the chromatograph by way of conduit 35, and sample gas flows continuously from conduit 39 to conduit 38 via conduit 43, thus filling this latter "sample volume" conduit.

It is pointed out that the sampling valve of this invention is rather simple to manufacture. The only critical machining operations are those for the surfaces involved

in the O-ring seals. Also, as previously stated, the power required to operate the valve is very small.

The valve of this invention is very small in size. By way of example, the dimensions of a practical embodiment of the valve may be: Height, from the outer face of cover 49 to the outer face of cover 48, one inch; overall width of the valve body, $2\frac{1}{2}$ inches; depth of the valve body (the dimension perpendicular to the plane of the paper), one inch.

The gas conducting paths through the valve of this invention are made small, due largely to the fact that the valve actuating or operating mechanism (which produces the valve operating force) is sealed off from the gas flow paths, by means of the diaphragms 44-47. As a result of the gas conducting paths being so small, any necessary dead space (e.g., bore 17, radial hole 18, etc.) is kept very small, compared with the sample volume.

The volume of sample injected when the valve is operated to the FIGURE 2 position, from the FIGURE 1 or "normal" position, is determined primarily by the size of the tubing or conduit 43 used to connect the opposite valve ports 41 and 42. The sample volume can be made as large as desirable. The minimum volume is about $\frac{1}{4}$ cc., and a typical operating volume is $\frac{1}{2}$ cc.

The invention claimed is:

1. Apparatus for injecting into a stream of fluid in a main conduit a predetermined fluid volume from a stream of fluid in an auxiliary conduit, comprising a pair of chambered valve body sections each connected directly into said main conduit, and connected respectively into upstream and downstream sections of said auxiliary conduit, a pair of opposed valve members reciprocable substantially independently of each other in the elongated chamber of one of said valve body sections, the two valve members being positioned respectively adjacent the two opposite end walls of said chamber, sealing means interposed between each end wall of the chamber and the respective cooperating face of the adjacent valve member, a pair of opposed valve members reciprocable substantially independently of each other in the elongated chamber of the other of said valve body sections, the two valve members of the last-mentioned pair being positioned respectively adjacent the two opposite end walls of the last-mentioned chamber, sealing means interposed between each end wall of the last-mentioned chamber and the respective cooperating face of the adjacent valve member, an intermediate section of said auxiliary conduit communicating at one end with one of said chambers at a location between the two valve members therein and between the connections to said one chamber of said main conduit and of said auxiliary conduit, and at its other end with the other of said chambers at a location between the two valve members therein and between the connections to said other chamber of said main conduit and of said auxiliary conduit; and means for applying an operating force to said valve members to move them to positions wherein both ends of said intermediate conduit section are sealed off from said auxiliary fluid stream, thereby trapping a predetermined volume of auxiliary fluid therein, and wherein the ends of said intermediate conduit section are placed in communication with said main fluid stream, thereby directing said main fluid stream through said intermediate conduit section for sweeping said trapped fluid into said main fluid stream.

2. Apparatus as defined in claim 1, wherein one member in each of the two pairs of valve members is moved by said operating force to a closed position for sealing off the two respective ends of the intermediate conduit section from the auxiliary fluid stream.

3. Apparatus as defined in claim 1, wherein one member in each of the two pairs of valve members is moved in response to the application of said operating force to an open position for placing the two respective ends of

the intermediate conduit section in communication with the main fluid stream.

4. Apparatus as set forth in claim 1, including a separate flexible imperforate cover sealed to each end of each of the two chambers, the operating force being applied to each valve member by way of its respective cover.

5. Apparatus as set forth in claim 1, including separate resilient means in each chamber for biasing the valve members therein toward their open positions.

6. Apparatus in accordance with claim 5, characterized in that each resilient means comprises a compression spring positioned between the two corresponding valve members and having its opposite ends respectively engaging the two corresponding valve members.

7. Apparatus as set forth in claim 1, including a separate flexible imperforate cover sealed to each end of each of the two chambers, and individual plungers mounted to engage the outer surfaces of the respective covers; the operating force being applied to said plungers to move said valve members by way of their respective covers.

8. Apparatus in accordance with claim 7, including separate resilient means in each chamber for biasing the valve members therein toward their open positions.

9. A fluid sampling valve comprising a pair of chambered valve body sections, a first on-off valve member positioned in the first chamber for selectively placing one end of said first chamber in fluid communication with an intermediate portion thereof, a second on-off valve member positioned in the first chamber for selectively placing the other end of said first chamber in fluid communication with said intermediate portion thereof, a third on-off valve member positioned in the second chamber for selectively placing one end of said second chamber in fluid communication with an intermediate portion thereof, a fourth on-off valve member positioned in the second chamber for selectively placing the other end of said second chamber in fluid communication with said intermediate portion thereof, means connecting said one of said first chamber and said one end of said second chamber directly into a main fluid conduit, means connecting said other end of said first chamber into an upstream section of an auxiliary fluid conduit, means connecting said other end of said second chamber into a downstream section of said auxiliary conduit which is separate from said upstream section thereof, means connecting together the intermediate portions of said first and second chambers, thereby to provide an interconnection between the upstream and downstream sections of said auxiliary conduit, and means for applying a common operating force to all four of said valve members.

10. A valve in accordance with claim 9, wherein the first and third valve members are normally "off" and the second and fourth valve members are normally "on," and wherein the application of the operating force reverses the position of the valve members from normal.

11. A valve as defined in claim 9, including a separate flexible imperforate cover sealed to each end of each of the two chambers, the operating force being applied to each valve member by way of its respective cover.

12. A valve as set forth in claim 9, including resilient means in said first chamber for biasing the first and second valve members toward their "on" positions, and resilient means in said second chamber for biasing the third and fourth valve members toward their "on" positions.

13. A valve in accordance with claim 12, characterized in that each resilient means comprises a compression spring positioned between the two corresponding valve members and having its opposite ends respectively engaging the two corresponding valve members.

14. A valve as defined in claim 9, including a separate flexible imperforate cover sealed to each end of each of the two chambers, and individual plungers mounted to engage the outer surfaces of the respective covers; the

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operating force being applied to said plungers to move said valve members by way of their respective covers.

15. A valve in accordance with claim 14, including resilient means in said first chamber for biasing the first and second valve members toward their "on" positions, and resilient means in said second chamber for biasing the third and fourth valve members toward their "on" positions. 5

16. A valve in accordance with claim 14, including a compression spring positioned between the first and second valve members and having its opposite ends respectively 10

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engaging the first and second members, and a compression spring positioned between the third and fourth valve members and having its opposite ends respectively engaging the third and fourth members.

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