United States Patent [19]

Harris, Sr. et al.

[11] **3,754,443**

[45] **Aug. 28, 1973**

[54] **AUTOMATIC FLUID INJECTOR**

[76] Inventors: **Rano J. Harris, Sr.**, 1945 Carolyn Sue Drive; **Rano J. Harris, Jr.**, 9880 South Riveroaks Drive, both of Baton Rouge, La. 70815

[22] Filed: **Feb. 4, 1972**

[21] Appl. No.: **223,663**

[52] **U.S. Cl.** .... **73/422 GC**, 73/423 A

[51] **Int. Cl.** **G01n 1/14**

[58] **Field of Search** .... 73/421 R, 421 B, 73/422 GC, 423 A

[56] **References Cited**

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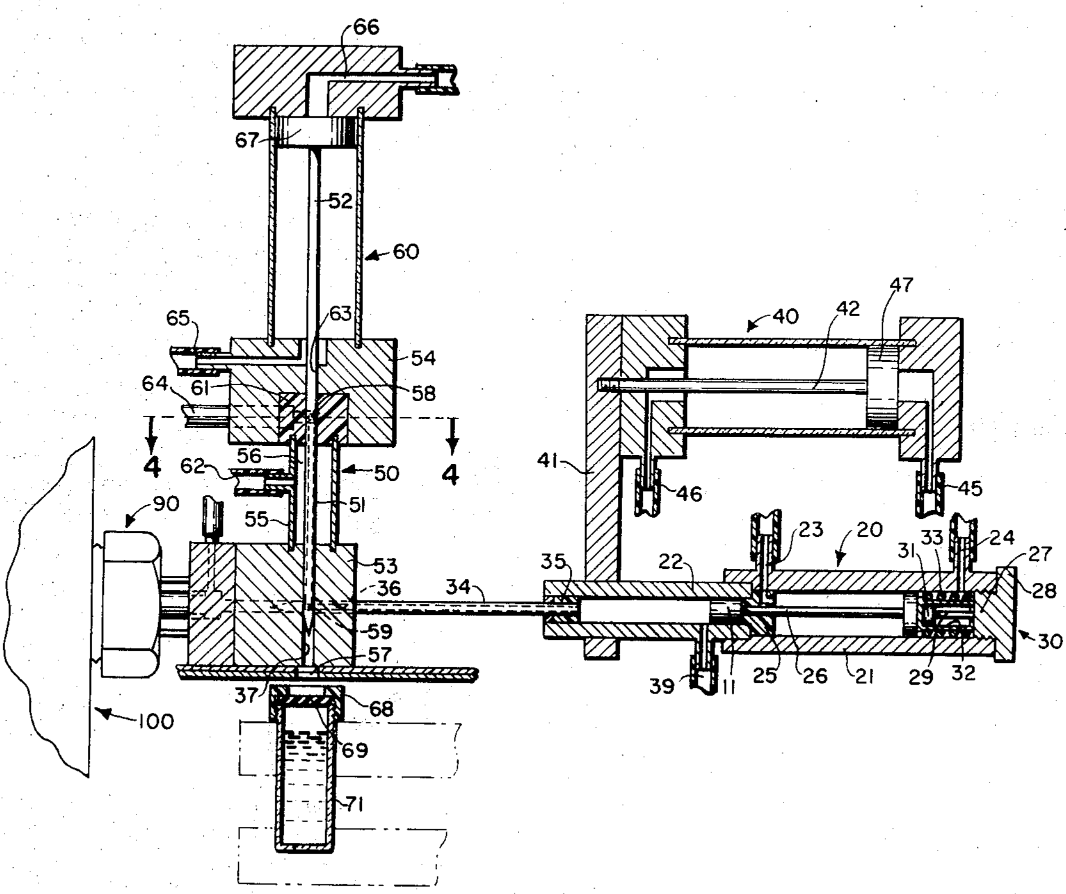
Primary Examiner—S. Clement Swisher
Attorney—Llewellyn A. Proctor

[57] **ABSTRACT**

An apparatus for automatically accurately measuring and injecting quantities of fluid specimens, or samples, into various media, e.g., a receptacle or inlet of a modern analytical instrument. The automatic fluid injector includes generally a housing within which is mounted a needle syringe, or sample injector unit, and an injector feed unit or unit for automatically filling the said syringe, or sample injector unit. The housing is provided with an opening through which the needle portion of the syringe can be projected. The housing is located adjacent, and the opening thereof is aligned upon, the inlet of an analytical instrument within which fluid specimens are to be automatically periodically injected. Means are provided for movement of the syringe along a straight path for insertion and withdrawal of the needle from the opening. A reciprocable hollow probe associated with the injector feed unit picks up a fluid specimen from a fluid-containing vial delivered by a carrousel feed tray, or other type of feed tray, and conveys the fluid to the sample injector unit. A predetermined portion of the fluid specimen is trapped and accurately measured within the syringe, the syringe is carried forward to insert the needle portion thereof through the opening of the housing and into the inlet to the analytical instrument, and the sample is injected. The needle is then withdrawn. Automatic controls provide for cyclically cleaning and purging the syringe, and for filling and injecting fluid specimens.

9 Claims, 19 Drawing Figures



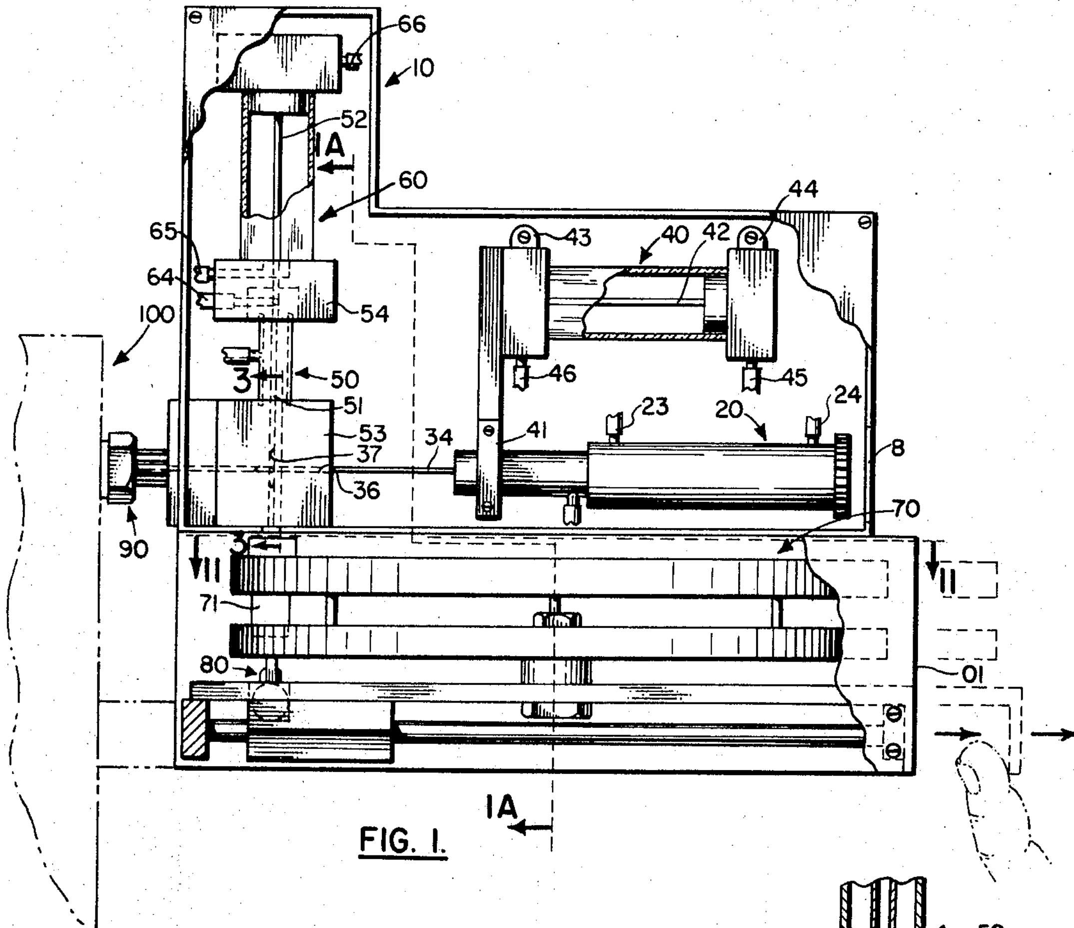


FIG. 1.

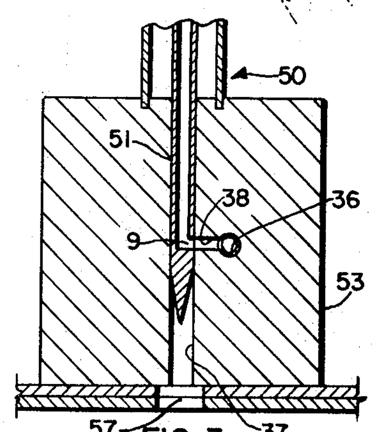


FIG. 3.

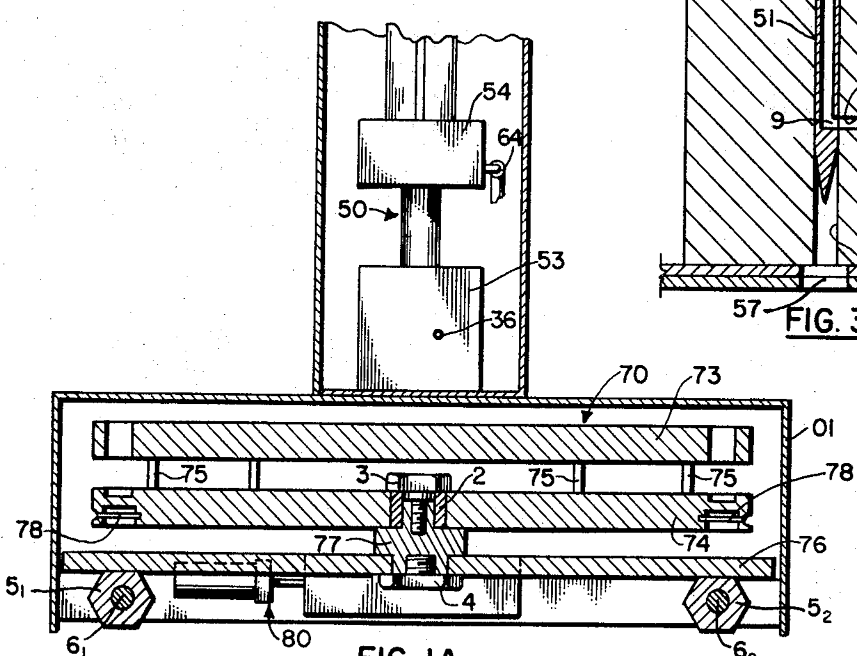


FIG. 1A.

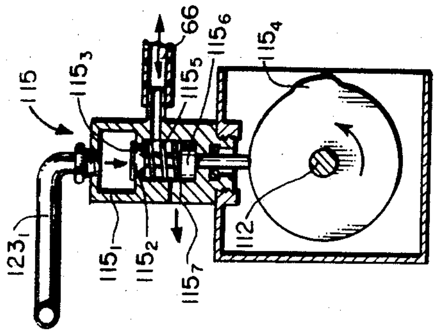


FIG. 17.

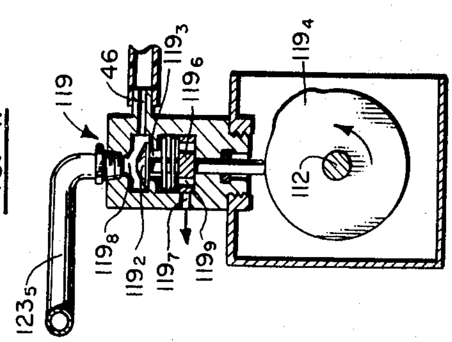


FIG. 18.

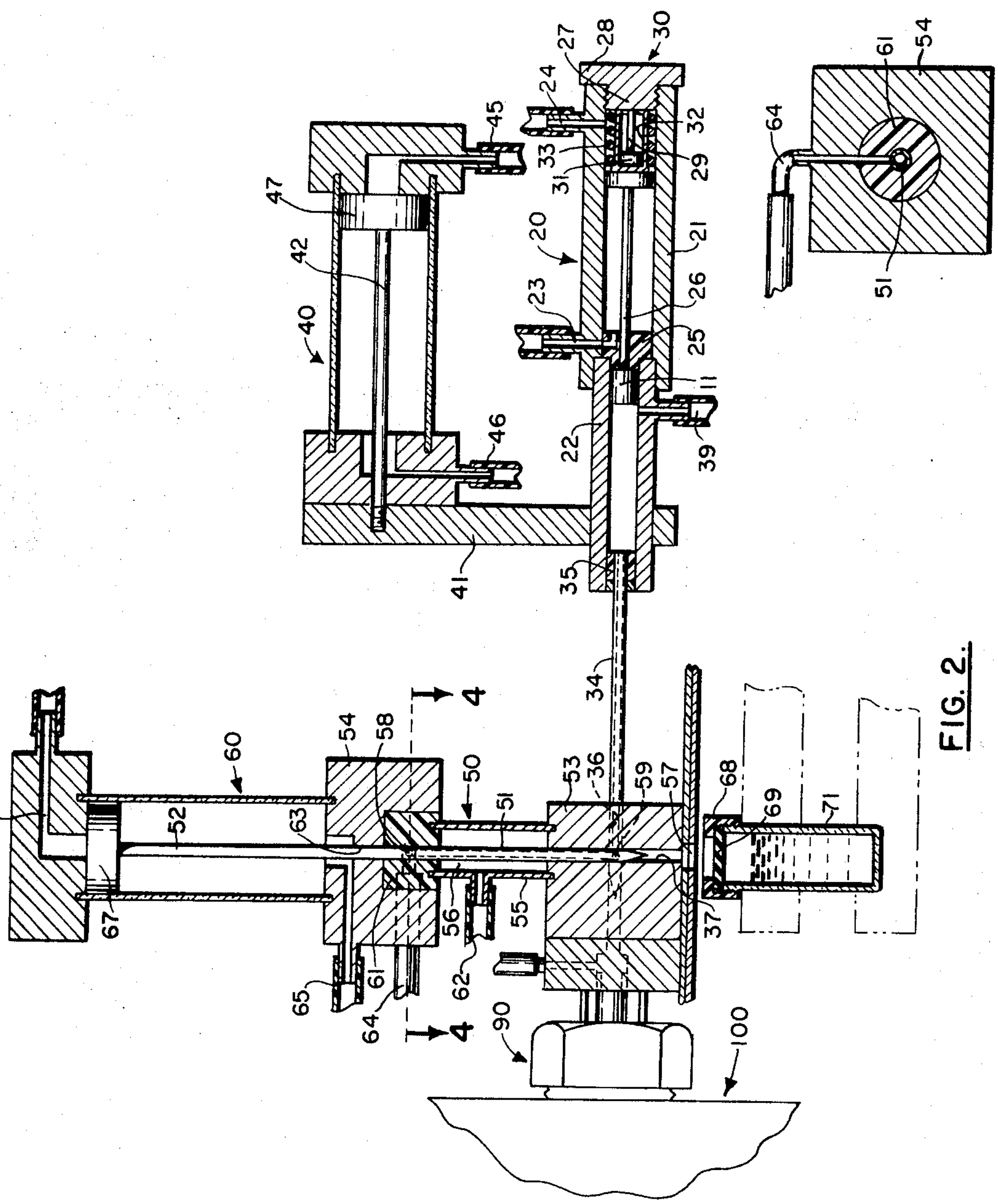


FIG. 4.

FIG. 2.

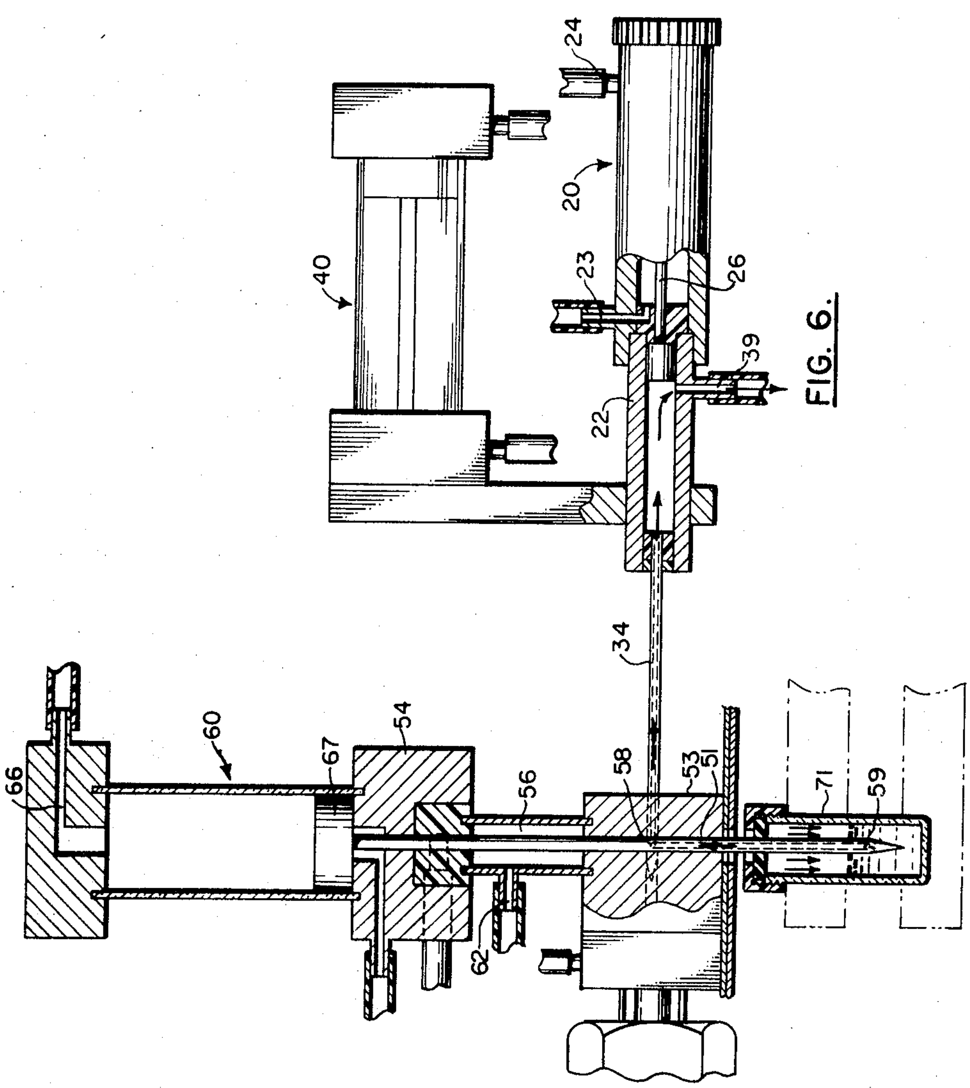

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FIG. 6.

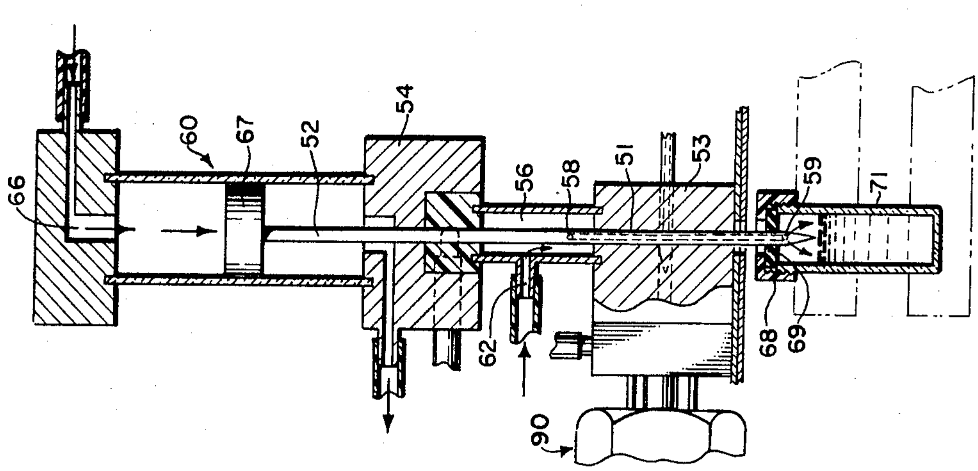
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FIG. 5.

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6 Sheets-Sheet 4

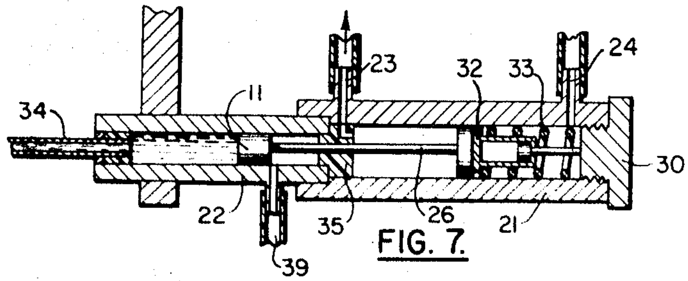

FIG. 7.

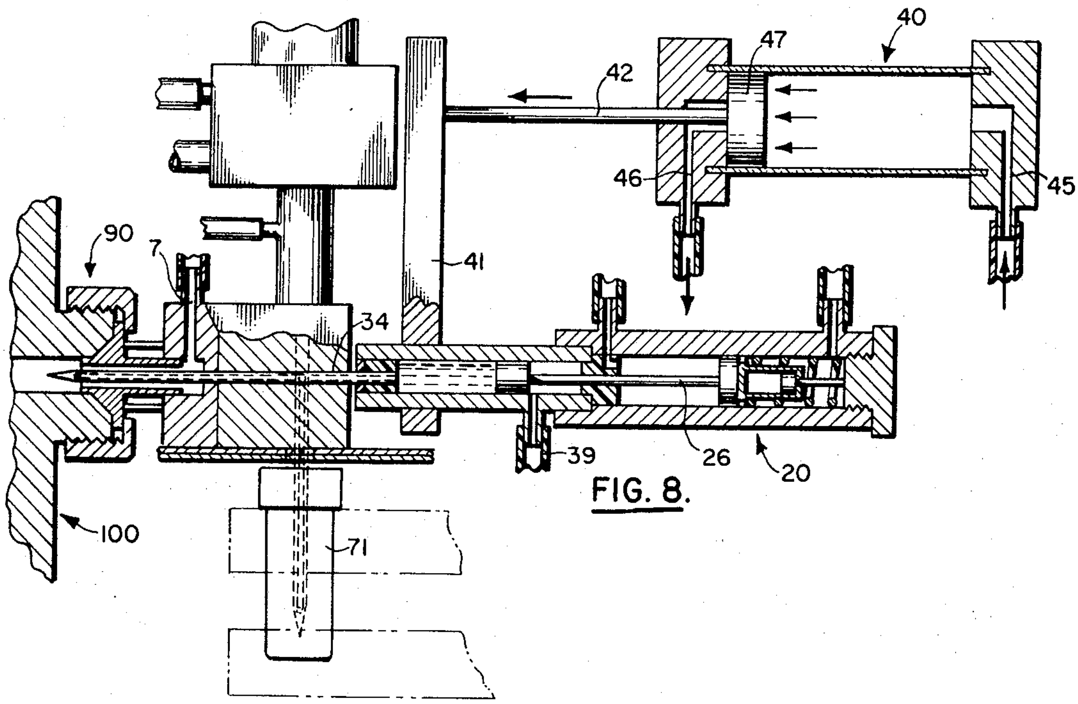

FIG. 8.

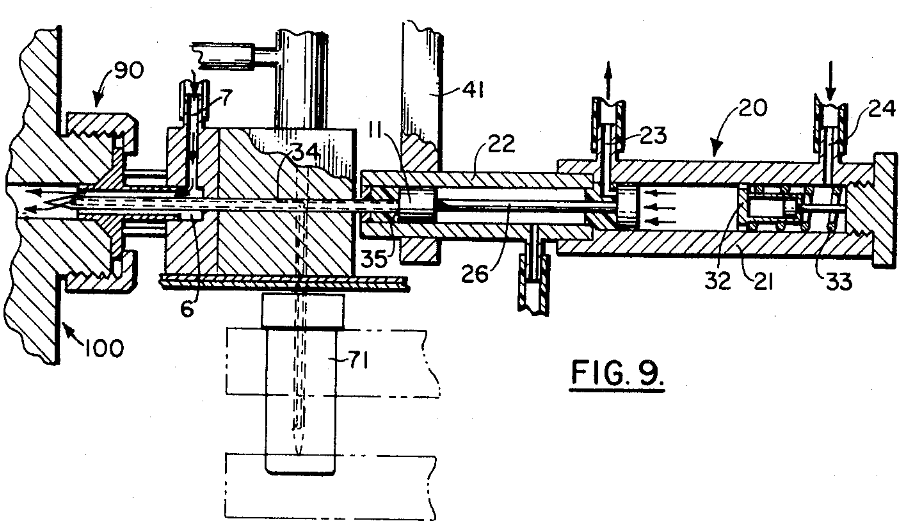

FIG. 9.

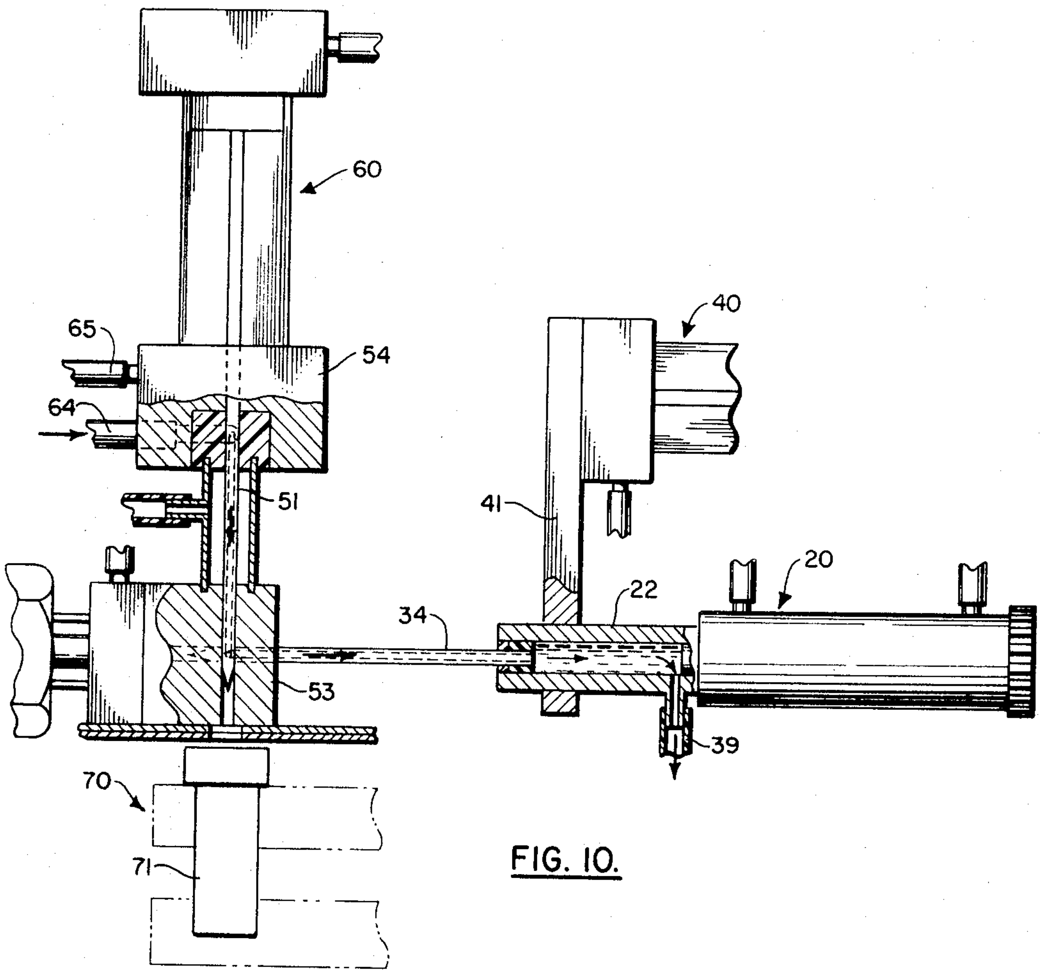
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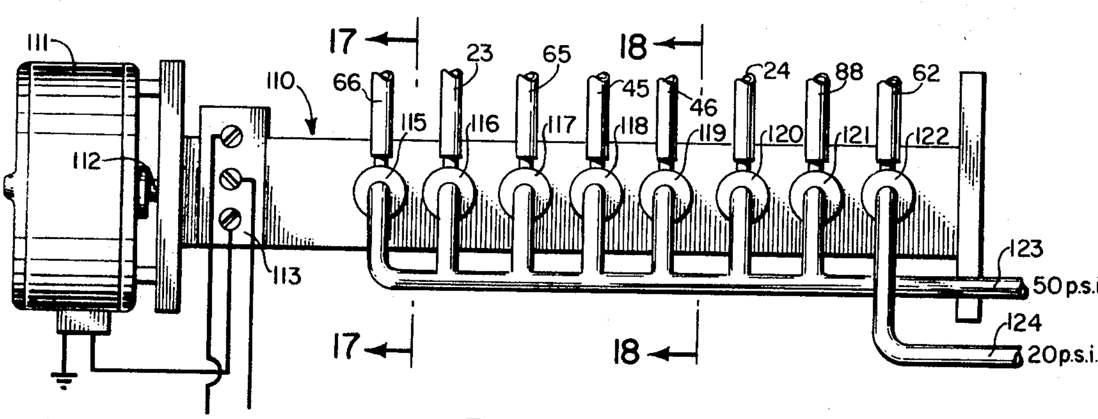
FIG. 10.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20 p.s.i.
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FIG. 16.

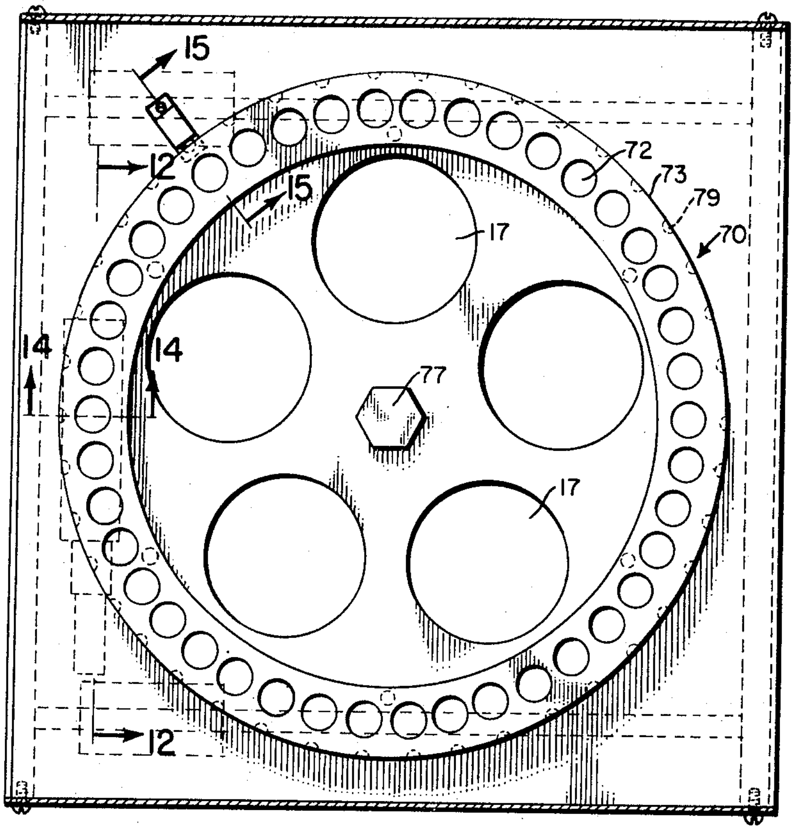

FIG. 11.

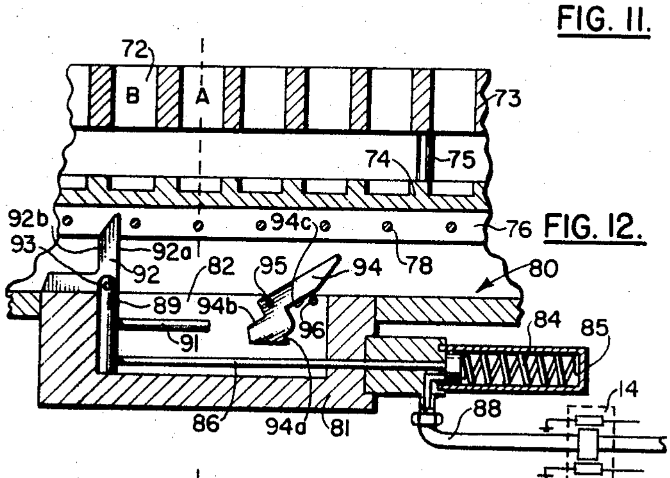

FIG. 12.

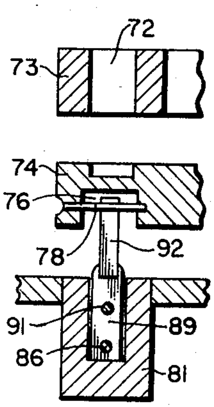

FIG. 14.

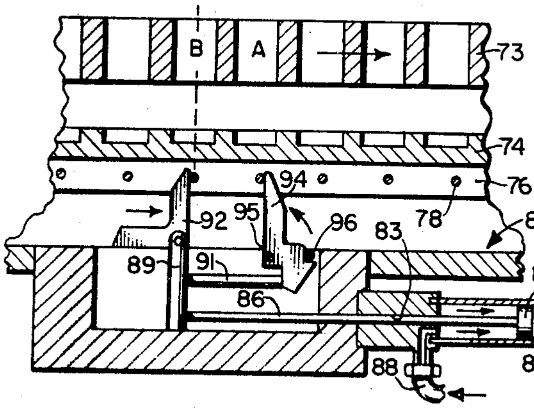

FIG. 13.

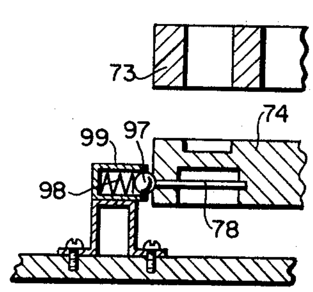

FIG. 15.

AUTOMATIC FLUID INJECTOR

The present invention relates generally to the art of injecting accurately measured quantities of fluids. More particularly, it relates to apparatus for continuous automatic measurement, and injection of very small, accurately measured quantities of liquid specimens into various media, e.g., modern analytical instruments.

It is often necessary, particularly in connection with modern analytical instruments, to accurately measure and then inject the precisely measured, often infinitesimally small quantities of fluid. For handling specimens of fluid on the order of only a few cubic micrometers total volume, or fractional parts thereof, high precision micro syringes have been developed. These devices, several types of which have been described in the art, are generally comprised of a barrel constituted of a thick walled glass tube scribed with indicia marks representative of the volume of the bore. A thin hollow needle or cannula is mounted on an end of the barrel, and a thin wire plunger, slidable within the bores of both the barrel and needle, is provided for withdrawal of accurately measured quantities of fluid and displacement thereof through the dispensing end of the needle.

Typically, micro syringes of such character are used by operators, chemists or other persons to inject liquid specimens on the order of only about 0.01 to about 5 microliters, or fractional parts thereof into modern analytical instruments, e.g., mass spectrographs, gas chromatographs (G.C.) or the like. A G.C., e.g., is provided with an entry port covered with a rubber membrane which is pierced by the dispensing end of the needle, whereupon a measured quantity of the contents of the bore of the syringe is injected into the instrument.

While certain types of these devices have proven quite successful in such usages, there are nonetheless certain disadvantages. The devices, e.g., are extremely sensitive and fragile, and difficult to clean. This is especially so in view of the very small diameter and length of the bore and, if proper precautions are not taken, the necessary reproducibility suffers. A major difficulty, however, is that considerable time in manpower is lost in performing the necessary maintenance functions, and constant attention and careful concentration are required in drawing, measuring and injecting the fluid specimens. Some inaccuracy is unavoidable and for these and other reasons automatic samplers, or instruments designed to overcome these and other shortcomings of micro syringes, have been recently introduced, e.g., such as described in U.S. Pat. Nos. 3,529,475, 3,550,453, and 3,577,279.

These automatic instruments, too, have not been without their deficiencies. One difficulty in use of such instruments is that the plunger of the syringe portion of the instrument must be successively pumped to fill the syringe. Moreover, the syringe is not supported. Over a period of time this causes the plunger to become distorted or bent, thus increasing maintenance problems, and inaccuracies of measurement are introduced because the pumping action can create bubbles. Moreover, as in the case of the conventional microsyringe, the metal plunger wears away against the glass barrel, causing loss of an effective seal, and a correspondent reduction in reproducibility (or precision) due to nonconsistent leakage or blow-back of the sample through the annular space between the plunger and the syringe bore during injection. The pumping action often does not properly clean the syringe and there is greater risk of sample contamination from previously measured specimens. In the operation of such instruments, the syringe itself is tilted prior to introduction into an inlet, this lessening overall reliability due, inter alia, to the difficulties of alignment between the dispensing end of the needle of the syringe and the sample inlet systems.

It is accordingly a primary object of the present invention to obviate the foregoing and other disadvantages associated with microsyringes, and to provide a new and novel automatic fluid injector readily adaptable to automatically perform the basic cyclic functions of filling, injecting and cleaning.

A more particular object is to provide apparatus capable of continuously cyclically withdrawing in seriatim precisely measured infinitesimally small quantities of gas or liquid specimens from prefilled vials or containers, injecting the specimens in seriatim in reproducible quantities, and cleaning prior to subsequent withdrawal and injection of a subsequent specimen.

A further object is to provide apparatus of simple and relatively inexpensive construction, particularly apparatus which can be readily operated and serviced, which apparatus readily lends itself to rapid mass production techniques.

These objects and others are achieved in accordance with the present invention which embodies improvements in automatic fluid injector systems. A preferred type of automatic fluid injector is comprised generally of (a) a movable syringe, or sample injector unit, (b) an injector feed unit, (c) a carrousel feed tray, or other type of feed tray for carrying or transporting individual fluid-containing vials, and preferably (d) automation or control means for repetitively and automatically carrying out the functions of cleaning, purging and filling the syringe with predetermined quantities of fluid specimens, in timed sequence. The several units of the automatic feed injector are generally contained within a housing, or housings. The sub-assemblies constituting (a) the movable syringe and (b) injector feed unit are preferably contained, with means for displacing and reciprocating the movable syringe along a straight predetermined path, in a single housing below which is mounted (c) the carrousel, or feed tray.

These and other features of the preferred automatic fluid injector, and its principle of operation, will be more fully understood by reference to the following detailed description of a specific embodiment, and to the attached drawings to which reference is made in the description. Letter subscripts are used to designate a portion of a given component, and number subscripts are used to show one of a plurality of similar parts or components.

In the drawings:

FIG. 1 depicts a side elevation view in partial section of a preferred automatic fluid injector wherein is included a housing which contains (a) a movable syringe, and (b) an injector feed unit, below which housing is mounted (c) a carrousel feed tray;

FIG. 1A is a section taken along line 1A-1A of FIG. 1, depicting specific features of the carrousel feed tray;

FIG. 2 depicts a cross-sectional side elevation view of the combination of (a) the movable syringe, and (b) the injector feed unit, and the manner of the alignment of the former upon the inlet to an analytical instrument;

FIG. 3 is a cross-section taken along line 3—3 of FIG. 1;

FIG. 4 is a cross-section taken along lines 4—4 of FIG. 2;

FIGS. 5 through 10 depict a series of fragmentary views, in section, describing the sequence of filling, injecting, cleaning and purging of the syringe during an operating sequence;

FIG. 11 is a section taken along line 11—11 of FIG. 1, showing a plan of the carrousel feed tray;

FIG. 12 is a section taken along line 12—12 of FIG. 11, showing the means by virtue of which the carrousel is activated and moved to rotate the vials in seriatim for delivery of the fluid contents thereof to the inlet to an analytical instrument;

FIGS. 12 and 13 taken together depict in more precise manner the mechanism, and illustrate the functioning of the mechanism in moving the carrousel;

FIG. 14 is a cross section taken through line 14—14 of FIG. 11, further depicting the mechanism described with reference to FIGS. 12 and 13;

FIG. 15 is a cross section through line 15—15 of FIG. 11, depicting another mechanism for stopping and positioning the carrousel; and

FIGS. 16—18 describe the automation features by virtue of which the operating sequence is carried out.

Referring to FIG. 1, there is shown generally an upper L shaped housing 10, constituted of top, bottom, side and back walls. It is also provided with a hinged front cover (not shown). The cover is L-shaped to match the front face of the housing, and is generally pivotally attached to a side wall of the housing 10 via a pair of hinges (not shown). It is also generally provided with a transparent panel made of clear plastic or glass. The heart of the automatic fluid injector system is constituted of the movable syringe 20, or sample injector unit, and the injector feed unit 50, both of which are contained within an upper compartment or housing 10. It will be observed that, in a typical usage, the housing 10 is mounted adjacent the inlet system 90 to an analytical instrument 100, that a block 53 constructed of a resilient plastic material, e.g., Teflon, is located at the front end of the housing 10 and that a horizontal opening 36 therethrough within which the needle 34 of the syringe 20 is reciprocably movable is aligned upon the sample inlet system 90 of the analytical instrument 100. The entire syringe 20, as a unit, is reciprocably mounted on the forward end of a double acting piston 40 such that the dispensing end of the needle 34 of the syringe 20 in a portion of an operating cycle can be thrust through the horizontal opening 36 of the Teflon block 53 to enter the inlet system 90, e.g., to pierce the septum of the sample inlet to the analytical instrument 100, the fluid specimen injected via a side opening 9 of the needle and the said needle 34 withdrawn. The injector feed unit 50, it will be observed, is provided with a hollow needle or probe 51 mounted on the forward end of a piston 52 of a double acting piston unit 60. Its prime function is to supply a predetermined quantity of a fluid specimen to the syringe 20 for dispensing into, e.g., the analytical instrument 100. The probe 51, it will be noted, is reciprocably movable through a vertically oriented opening 37 within the block 53, and can be extended through the said block 53 and through the opening 57 within the bottom of housing 10. The said vertical opening 37 is adjoined via a channel 38 to the horizontal opening 36 within which the needle 34 can be reciprocated. The injector feed unit 50 carries out its chief function by picking up a fluid specimen from a vial 71 introduced into the path of the probe 51 by action of the carrousel 70 located below the housing 10, within a lower compartment or secondary housing 01, and loads the said specimen into the syringe 20.

In all embodiments of this invention, a carrousel 70 or other type of mechanism, is provided for conveying fluid-containing vials 71 in seriatim to a location beneath the housing 10 for pick-up by the probe 51. The vials 71 are of open screw top type, sealed with an elastomer septum to prevent leakage or contamination and to permit pressurization. As the vials 71 are moved into position beneath the opening 57 in the lower part of housing 10, the probe 51 can be moved downwardly through the vertical opening 37 of block 53, and projected through the opening 57 at the bottom of housing 10 to pass through the open caps 68 and penetrate the septum of the vials 71 for uptake of the fluid. Various mechanisms, known to the art, can be used for conveyance of the vials 71 to the proper pick-up position by the probe 51, though a preferred type of mechanism is described herein.

It will be observed that the syringe 20 is constituted of a pair of contiguous tubular members comprising a relatively large diameter rearward section 21 and a smaller diameter forward section 22. The rearward section of the syringe constitutes a double acting cylinder-piston unit 21 with an air inlet 23 leading into the forward end of the chamber and an air inlet 24 leading into the rear end of the chamber. Each air inlet 23,24 is, for convenience, generally provided with a flexible hose connection. The forward end of the chamber is provided with a tubular shaped seal or packing 25 through which the forward portion of the shaft of the piston 26 is extended, this isolating the smaller diameter forward section 22 from the rearward position. The forward end of the piston 26, which always remains and travels within the forward section 22, is covered or capped with a resilient material, preferably Teflon, constituting a sealing head 11. A buffer assembly 30 is located at the rearward end of the chamber 21 and within the path of travel of the piston 26 of cylinder piston unit 20. The function of the buffer assembly 30 is to permit piston 26 to traverse essentially the full length of the chamber of double acting cylinder piston unit 21 as shown, e.g., by reference to FIG. 2, wherein the piston 26 has travelled to its extreme rearward position such that the sealing head 11 of plunger 26 does not block side opening 39 within the forward 22. It can also limit the rearward position of plunger 26 as shown, e.g., by reference to FIG. 8, wherein the said side opening 39 is closed by piston head 11 of plunger 26 which has been thrust forward by expansion of buffer assembly 30. The buffer sub-assembly 30 includes an adjustable plug comprising an enlarged portion 28, an externally threaded projecting shank 27, a rigid shaft 29 extending outwardly from the shank 27, and the terminal end of the shaft 29 is generally enlarged to form a head 31. A slidable tubular section 32 is fitted over the head 31. A helical coil or spring 33 is fitted concentrically upon the tubular section 32 and seated between the inside face of the enlarged terminal end of the tubular section 32, or stop, and the forward face of the shank 27. In the position shown by reference to FIG. 2, the helical spring 33 is compressed by the action of the head of piston 26 thrust against the forward face of tubular section 32, whereas in position shown by reference to FIG. 8 the tension on the helical spring 33 has been released. The piston 26 and buffer assembly 30 are retained in place within the cylinder-piston unit 21 by the externally threaded adjustable plug 27, or the buffer assembly 30, which is fitted into the tapped end wall of tubular member 21. Access for repair or for substituting various buffer sizes as may be desired is afforded via the opening 8 of housing 10.

The smaller diameter tubular forward section 22 of the syringe 20 is generally constructed of transparent plastic or glass, and scribed with indicia representative of the internal volume. The volume of the chamber formed within the tubular wall 22 is exaggerated in the drawings for clarity and, of course, can be varied in size depending upon the volume of specimen to be accurately measured and delivered, e.g., as where the specimen is a liquid or gas. One method of varying the volume of chamber 22 is by adjustment of the length of stroke of the plunger, as by change in the dimensions of the buffer assembly 30. A cannula or needle 34 is fixed within the forward wall or upon the forward end of the tubular section 22 by various means well known to the art. For example, it can be snugly fitted into the forward end of the barrel or smaller diameter tubular forward section 22 through an opening made in the forward wall, and an air-tight seal provided by means of a tubular packing or seal 35. The needle 34, provided with a side opening 9, is extendable through horizontal opening 36 of the block 53, and is communicable, in proper position, with the vertical opening 37 via the communicating channel 38. A port or side opening 39 vents the tubular forward section 22 of syringe 20 with the exterior.

The syringe 20 is, in its entirety, affixed via mounting bracket 41 on the forward end of piston 42 of the double acting cylinder-piston unit 40, which is secured via the mounting brackets 43,44 upon the back wall of housing 10. The syringe 20 is reciprocably movable along a fixed horizontal path via reciprocation of plunger 42. Forward movement of the piston 42 by injection of air into the rearward end of the cylinder-piston unit 40 via inlet 45 to impinge upon piston head 47 of piston 42 causes the entire syringe 20 to be thrust forward, this causing passage of the needle 34 through the opening 36 of block 53 and insertion of the dispensing end of the needle 34 through a septum or other type of inlet as for sample injection in a modern analytical instrument. Rearward movement of the piston 42 by injection of air into the forward end of the unit via inlet 46 again impinges upon piston head 47 to move the syringe 20 in the opposite direction, and causes withdrawal of the needle 34 from the sample inlet 90.

The principal portion of the injector feed unit 50 is constituted of a double-acting cylinder piston unit 60, and a hollow needle or probe 51 is mounted on the forward end of the piston 52 and reciprocable therewith. The orientation of the injector feed unit 50 is preferably vertical as contrasted with the syringe 20 which is horizontally aligned. The upper end of the cylinder-piston unit 60 is secured to the back wall of the housing 10 via mounting brackets (not shown) and the lower end thereof is held in place by the upper block 54, which is also affixed via mounting means (not shown) to the back wall of the housing. Tubular member 55 provides a separate chamber between blocks 53,54 and the probe 51 is extensible downwardly through a vertical opening 63 through the upper block 54, the opening 56 through the tubular member 55, through the vertical opening 37 of the block 53, and out of an opening 57 in the bottom of the housing 10. The hollow probe 51 itself, it will be observed, is provided with a pair of side openings 58,59 which are communicated one with the other via an axial opening through the probe 51.

The upper end of the tubular member 55 is snugly fitted into the packing 61 and the lower end within the resilient material of which the block 53 is constructed to provide a chamber 56 which is open only to the pressure gas inlet 62. The opening 63 is sealed off from the chamber 56 by the walls of probe 51. The port 64, and pressure gas inlet 62, can be opened to the probe 51 upon passage of the side opening 58 of probe 51 alongside the port 64 or through the chamber 56, respectively.

The double acting cylinder-piston unit 60, like double acting cylinder-piston units 20,40, is operated by virtually any source of pressurized fluid, e.g., hydraulic fluid or pneumatic pressure. The piston 52 of cylinder-piston unit 60 is moved upwardly via pressurized fluid injected via gas inlet 65, and downwardly by injection of pressurized fluid injected via gas inlet 66. When the piston 52 is thrust to its extreme downward position, by fluid pressure acting against piston head 67, the lower terminal end of the probe 51 is projected through the opening 57 in the bottom of housing 10, and the wall of the lower housing, through a centrally located opening through a cap 68, and septum 69 of a vial 71 for pick-up of a fluid specimen.

An operating cycle is best described by reference to FIGS. 5 through 10 which depict a series of views describing the filling, injecting, cleaning and purging of the syringe 20. The timed sequence can be repeated ad infinitum, as follows:

a. Referring first to FIG. 5, the piston 52 is pushed downwardly from an upward starting position by pressurized air which enters into the chamber of the cylinder-piston unit 60 via the port 66 to impinge on piston head 67. The probe 51 is side vented in two locations, and the side vent openings 58,59 are communicated one with the other by an axial opening through the probe. The septum 69 of the air-tight vial 71, located between the threaded cap 68 and the upper shoulder of the glass vial 71, is penetrated by the sharp, or pointed, end of probe 51. As the upper side vent opening 58 passes into the chamber 56 formed within tubular member 55, to which a gas is admitted via the pressure gas inlet 62, gas enters into side vent opening 58 and flows downwardly through the hollow probe 51 to exit via the lower side vent opening 59 and into the vial 71, pressurizing the latter.

b. Prior to the time that piston 52 has reached its most downward position, the chamber 56 and pressure gas inlet 62 are no longer open to the upper side vent opening 58 of the probe 51. Referring to FIG. 6, the upper side vent opening 58 of the probe 51, however, at the maximum downward position of piston 52 becomes open to the horizontal opening 36 of block 53, via channel 38, to communicate with opening 9 within needle 34. The needle 34 is purged, liquid flowing out of the needle 34 via the outlet 58, and through channel 38 into the needle. The liquid passes through chamber 22 of the syringe 20 and exits via the side opening 39. In this particular function of the apparatus, as in (a) above and as described by reference to FIG. 2, the piston 26 of syringe 20 is in its fully retracted position, the piston 26 having been driven rearward placing the spring 33 of the buffer assembly 30 under compression by air injected into the cylinder via air inlet 23. Air inlet 24 is in vented position.

c. Referring to FIG. 7, the spring 33 of the buffer assembly 30 is fully extended by release of air from the left side of cylinder-piston unit 21 via air inlet 23, this having been timed to occur after sufficient liquid has passed through the needle 34 and the chamber 21 to thoroughly flush and clean both. As this occurs, the end of the plunger 11 is moved, by thrust from the forward face of tubular member 32 against piston 26 by action of the released spring 33, sufficiently far forward to cut off and trap a measured quantity of fluid within the chamber and the needle of the syringe. At this point in the operation both inlets 23,24 are vented to the atmosphere.

d. The entire syringe 20, as shown by reference to FIG. 8, is moved forward by air injected into cylinder-piston unit 40 via gas inlet 45, the gas impinging upon the piston head 47, causing the piston 42 to be thrust outwardly and thus cause the needle 34 to be inserted into the inlet 90 of the analytical instrument, e.g., a gas chromatograph.

e. Referring to FIG. 9, air to inlet 24 drives piston 26 to its extreme forward position, the head 11 thereof transversing the length of the chamber 22 to inject the liquid specimen into the inlet 90.

A carrier gas is passed through carrier gas inlet 7, through the annulus between the external wall of the needle 34 and the internal wall of tubular member 6, to assure complete transfer of the specimen into the sample inlet 90.

4. Air is introduced into gas inlet 23 of cylinder-piston unit 20, gas inlet 24 is vented to the atmosphere, and the piston 26 is driven rearward to move plunger tip 11 rearward, opening vent 39.

g. The probe 51 is moved back toward its upward position by injection of air into gas inlet 65 of the cylinder-piston unit 60 which moves the piston 52 upwardly.

As the probe 51 moves upwardly to its former position, as described by reference to FIG. 2, and the upper side vent opening 58 of the probe 51 is exposed to the pressure gas chamber 56, the liquid within the probe 51 is blown back into the vial 71 (the pressure having been previously released during the filling of the syringe).

h. Reference is made to FIG. 10, which illustrates the portion of the cycle for cleaning and purging the needle and syringe. Thus, as the probe 51 reaches its upward position, the lower side vent 59 of the probe 51 is aligned with the needle opening 9 and the upper side vent 58 of the probe 51 is aligned upon port 64 whereupon both the probe and needle are ready to be flushed with solvent or gas, or both; generally a solvent followed by gas.

i. After the syringe is flushed and cleaned, air is next introduced into gas inlet 46 of cylinder-piston unit 40 and gas inlet 45 is vented to the atmosphere. This action causes piston 42 to be driven rearward to withdraw needle 34 from the G.C. inlet 90. At this point in time, the plunger of the syringe is in the position shown in FIG. 2. The spring 33 of the buffer assembly 30 is compressed to its limit..

The cycle is then repeated ad infinitum.

The carrousel feed tray 70 and its associated mechanism are described by reference to FIGS. 1, 1A and 11 through 15. Referring generally to these figures the feed tray 70 can be designed to transport virtually any number of vials 71, but generally it is designed to carry up to about 42 vials 71 which can be loaded into the apertures 72 (FIG. 11) of the feed tray. The size of an actual vial aperture 72 is generally exaggerated in FIGS. 1 and 1A, for purpose of clarity, but better perspective is shown in FIGS. 11–15 as to the more practical aperture sizes. A feature of the carrousel feed tray 70 is that it is journalled at its center upon a slidable mounting plate 76 so that the feed tray 70 can slide outwardly like a drawer to permit easy access for reloading or removal of the vials 71 (FIGS. 1 and 1A). The associated indexing mechanism 80 by virtue of which the carrousel feed tray 70 is positioned and rotated is best described by direct reference to FIGS. 12–15. The vials 71 are individually delivered in seriatim by the carrousel feed tray 70 to the location beneath the opening 57, this constituting a station, where they are positioned one by one in sequence, as demanded, for removal and pick-up of fluid contents therefrom by means of the probe 51.

The carrousel feed tray 70 is thus constructed in two separate circular sections 73,74, these sections being fastened together via a series of pins in parallel relationship, so that the two sections maintain a fixed position, one relative to the other. In addition, a circular series of round openings 17 can be cut through the circular sections 73,74 to lessen the total weight of the feed tray 70 though they serve no functional purpose. Preferably, the circular sections 73,74 are constructed of a light weight plastic or other material. By constructing the carrousel 70 in two separate sections 73,74, with cutaway portions 17, and by proper choice of construction materials, a rugged lightweight feed tray is provided.

The carrousel feed tray 70 is journalled from the center of the lower circular section 74 via a post or axis 77 mounted upon the slidable mounting plate 76 (FIGS. 1 and 1A). The upper and lower portions of the post or axis 77 is provided with sections of reduced diameter, as contrasted with its central portion, which extend, respectively, into centrally located openings within the circular section 74 of the feed tray and mounting plate 76. The central opening through the circular section 74 is provided with a metal collar 2, which serves as a bearing, and the circular section 74 is tightly secured to the axis 77 via threadable engagement with the bolt 2. The post or axis 77 is secured to the mounting plate 76 via a bolt 4, which is threadably engaged to the lower projecting portion thereof.

The mounting plate 76 rests upon and is secured to two bearings 5_1, 5_2 which slide upon two rods 6_1,6_2, the terminal ends of which are secured upon the front and end walls of the housing 01. Thus, the mounting plate, and hence the feed tray 70, can be moving outwardly and inwardly by virtue of the fact that it is freely movable with the bearings 5_1,5_2 which are free to traverse the length of the rods 6_1,6_2.

The lower peripheral edge, or circumference, of the circular section 74 of the feed tray is provided with a circumferential groove across the surrounding shoulders of which is located a series of uniformly spaced pins 78, separated one from another by a distance equal to the distance between the apertures 72. The pins 78 are equal in number to the number of apertures 72, each is located below the center of an aperture 73, and each is aligned upon the center of the circular section 74 on which it is located. The pins **78**, for practical purposes, are in parallel alignment. The spaces between the pins **78**, and the pins **78** themselves, form means by virtue of which the indexing mechanism **80** can control and rotate the carrousel feed tray **70** to position the individual vials **71** and deliver them in seriatim to the station below the opening **57** for pick-up of fluid contents therefrom by probe **51**. The peripheral edge of the circular sections **73,74** of the feed tray is aligned with a series of parallel notches **79** equal in number to the number of apertures **72** provided for the vials **71**, which also aid, as will be explained, in indexing the vials **71** in seriatim beneath the opening **57**.

Referring specifically to FIGS. **12–14**, it will be observed that the indexing mechanism **80** includes a block **81**, provided with an upwardly faced slot **82**, and a forward opening **83** which leads into an associated single-acting cylinder piston unit associated and in combination therewith. A helical spring **84** is located in the forward end of the housing **85** of the cylinder piston unit, and seated between the forward wall of the housing **85** and the head **87** of the piston **86**. A gas inlet **88** leads into the chamber within housing **85**, so that gas can be supplied thereto on demand to pulse the piston **86**, and cause the spring **85** to become compressed, by thrust of the gas against piston head **87** to move the piston **86** forward. An upright member or stud **89**, provided with a projecting pin **91**, is located on the opposite terminal end of the piston **86**. The stud **89** is oriented perpendicularly to the piston **86** and rides within the confines of the slot **82**. The upper end of the stud **89** is bifurcated or slotted and a generally reversed L-shaped member **92** is pivotally mounted therein by means of the pin **93**. It will be observed, on the one hand, that the forward, or shorter, side of member **92** projects vertically or perpendicularly upwardly with respect to the upper surface of the block **81**, the forward face 92_A is bevelled. The longer side of the member **92**, when the shorter side of the said member is so-positioned, is parallel with respect to the upper surface, and abuts the surface of the block **81**. Thus, the shorter side of the member **92** can be tilted forward, but never backward beyond a position perpendicular with the upper surface of block **81**. A second member **94**, or stop, is pivotally mounted via a pin **95** within the forward end of the slot **82** of block **81**. The lower portion of this member **94**, it will be observed, is provided with a forward toe 94_A and heel 94_B, the former portion of which member impinges upon pin **96** to limit the clockwise rotation of the member **94** so that the stop cannot pass or rotate beyond the vertical position. On the other hand, the motion of the said member **94** in the opposite direction is limited because the back face 94_C of the member, provided with a bevelled edge, impinges upon the pin **96**. The stop **94**, it will be observed, is activated and raised to its vertical position by impingement of the terminal end of pin **91** against the toe 94_B of the member **94**.

In operation, the carrousel feed tray **70** is rotated to transport the vials **71** in seriatim into position below the opening **57** as follows: air is fed into the chamber of housing **85** to impinge upon head **87** of the piston **86** and drive it forward to compress the spring **84**. As the piston **86** moves forward, the forward face 92_A of member **92** pushes against a pin **78**, directly centered below a vial aperture B (FIG. **12**) of the carrousel feed tray **70** and initiates a fractional rotation which will move aperture B to the position formerly occupied by aperture A (FIG. **13**). As the piston **86** continues forward, the pin **91** impinges upon the toe 94_B of stop member **94** and causes it to rotate upwardly until, upon reaching its vertical position, its upper end impinges against a pin **78** of the carrousel feed tray **73**, formerly centered below via aperture A, and interrupts its rotational movement. As this occurs, the ball bearing **97**, under tension of the spring **98**, contained within a housing **99**, drops into a peripheral slot **71**, retains and prevents any further motion of the carrousel feed tray **73** (FIG. **15**). Upon completion of this movement the gas inlet **88** is vented to atmosphere and movement of the piston **86** in the opposite direction is begun as the compression on the spring **85** is unleashed. As this occurs, the stop **94** drops downwardly to its original position, the rear face 92_B of the short portion of L-shaped member **92** rides over a pin **78**, and thereafter the weight of the long side of L-shaped member **92** again tips downwardly to rest on the upper surface of block **81** and causes the shorter side of the member **92** to rise vertically upwardly into a position for again initiating another push of the carrousel feed tray **70**.

A preferred type of control mechanism or programmer **110** by virtue of which the above-described apparatus is actuated in timed sequence to carry out its functions is described briefly by reference to FIGS. **16–18**. The programmer **110** includes generally an electric motor **111** and a shaft **112** on which is mounted a series of cam discs, each associated with a valve **115–122**. The valves **115–122** are each located, respectively at a manifold air outlet, and each is opened and closed in timed sequence by rotating cam discs to inject (or vent) air to the cylinder piston units **20, 40, 60, 85** and to injector pressure gas inlet **62**. Certain of the valves **115–118, 120, 122** are in normally closed position, until cammed open, and other valves **119,121** are in normally open position until cammed closed. In accordance with a specific embodiment of operating the presently described apparatus, valves **115–121** are associated with a first manifold **123** connected, e.g., to an air supply which maintains a pressure of 50 psig. Valve **122** is associated with a manifold line **124** which provides a pressure of **20** psig.

Reference to FIGS. **17** and **18**, which depict sections taken along line **17—17** and line **18—18**, respectively, of FIG. **16**, illustrate the construction and function of the two different types of valves. FIG. **17**, on the one hand, thus describes a valve, e.g., valve **115**, which is in a normally closed position. FIG. **18**, on the other hand, describes a valve, e.g., valve **119**, which is in a normally open position. Valve **115**, it will be observed, is comprised of a hollow body 115_1, the lower portion of which is externally threaded and threadably engaged to the housing surrounding the cam shaft **112**. The hollow body 115_1 provides a chamber to which is connected a manifold line 123_1. The chamber is normally closed to the flow of air, the flow of air through line **66** from the chamber being prevented by the head of plunger 115_2 which is spring biased so that the head is tightly seated within the opening 115_3. On rotation of shaft 112_1, however, cam 115_4 contacts the lower end of plunger 115_2 compressing spring 115_5 between the shoulders forming the opening 115_3 to the chamber and the enlarged portion 115_6. The enlarged portion 115_6 blocks opening 115_7 and the air entering the chamber and passing therethrough enters into line **66.** When the head of the plunger 115_2 has again seated, on passage of the cam 115_4 away from the lower projecting end of plunger 115_2, opening 115_7 is no longer blocked and the air in line **66** is vented via opening 115_7.

Valve **119** is generally similar in function and operation to valve **115** except that it is in a normally open position, i.e., the plunger 119_2 is spring biased in a position wherein air normally passes from manifold line 123_5 into the chamber formed within the hollow body 119_1 of the valve to exit via line **46.** When the head of plunger 119_2 is unseated from opening 119_3 via action of the cam 119_4 the terminal lower end of plunger 119_2, the head of the plunger 119_2 seats within opening 119_8 and shuts off the flow of air from line 123_5. In this position of the plunger 119_2, air is vented from line **46** by passage through an opening 119_9 in the enlarged plunger section 119_6 and through line 119_7.

In an operating cycle the motor **111** is automatically turned on by action of a conventional microswitch **113,** and remains on until cut off at the end of the cycle. On being switched on, the motor shaft **112** is rotated, the cams actuating the vales **115-122** in timed sequence. Flow of air through line **66** to cylinder piston unit **60** is initiated, and line **65** thereof is vented by the triggering action of the cams on valves **115,117.** The downward descent of the probe **51** is initiated and, as this occurs, a switch (not shown) is actuated, closing valve **14** which is actuated by a solenoid. This assures that no air can flow to and trigger valve **121** (which is in series with valve **14**) and thus cause chance movement of the carrousel feed tray **70** which could easily damage the probe **51** near termination of its downward movement. Air is then triggered to injection pressure gas inlet **62** via action of valve **122,** so that air is supplied to the probe **51** of the injector feed assembly on its downward descent. Line **23** of cylinder piston unit **20** is vented to permit plunger **26** of the syringe to move in front of outlet **39** of the syringe chamber to trap a sample of fluid specimen delivered by probe **51** to the chamber of the syringe. At this point in time, line **24** of the syringe is in vent position.

The dispensing end of the needle **34** of the syringe is then inserted in the septum inlet **90** by forward movement of the syringe occasioned by release of air into line **45** of the cylinder piston unit **40,** this action having been triggered by the action of valve **118.** Piston **26** of the syringe is next moved forward, and the sample is injected, by air released into line **24** via action of valve **120.**

The reverse portion of the cycle is then initiated. Air is injected via line **46** of the cylinder piston unit **40** to withdraw the needle **34.** Line **45** is vented, and the piston **42** is moved to its extreme rearward position. The injection of air into line **46** is initiated by the triggering action of a cam which opens valve **119.** Valve **117** is triggered and opened, air being passed into line **65** of cylinder piston unit **60** to initiate upward movement of the probe **51.** Upward movement of probe **51** again actuates a contact switch (not shown), solenoid valve **14** is actuated, and the valve opened. Valve **115** is then closed for venting line **66.** Valve **116** is triggered by a cam and the valve opened to permit air to flow into line **23** of cylinder piston unit **20.** Valve **120** is vented, and piston **26** is moved rearward to retract piston head **11,** and vent line **39.**

Valve **121** is next triggered, vale **14** having already been opened, this opening the valve to release air to line **88** of cylinder piston unit **85,** this actuating the carrousel feed tray **80** to move a new vial into position for initiation of a new cycle. The motor **111** is cut off by action of microswitch **113,** and the apparatus is now ready for a new cycle which is set to begin within a predetermined time sequence.

It is apparent that various substitutions, modifications and changes, such as in location, or in the absolute or relative dimensions of the parts, materials used and the like, can be made without departing the spirit and scope of the invention as will be apparent to those skilled in the art.

For example, the number and size of the openings of the carrousel feed tray can be quite varied, as can the type of vial carried. The vial itself, however, must be sealed but can be of convenional serum-bottle construction e.g., as one provided with an elastomer seal held in place by a crimped metal ring or screw cap. Various types of feed tray can be used to carry one or a plurality of vials, though a carrousel feed tray of the type described is highly preferred.

The relative positioning and relationship of the syringe and feed assembly are generally as described except that, of course, the angle at which the probe and needle of the syringe pass each other in performing their respective function is variable and, of course, the site of the feed injector and syringe can be reversed, e.g., the syringe could be mounted vertically and the feed injector mounted horizontally. The various inlet ports can be horizontal or vertical. The shape of the housing can be varied and, e.g., the feed injector and syringe assemblies can be attached or secured to the housing in any convenient manner e.g., as by separate attachment via a bracket to a wall or cover of the injector feed and syringe assembly housing or carrousel housing.

The barrel of the syringe or injection device can be made of substantially any material, metal alloys, steel, iron or the like. The plunger can be composed of stainless steel, tungsten, chrome, platinum alloy, or the like. Seals and packing can be made of generally conventional gasket material, including rubber, neoprene, nylon, and the like but preferably is a self-lubricating type of packing. Polytetrafluoroethylene, such as Teflon (Dupont Trademark for polytetrafluoroethylene), is a highly preferred material and has been found to provide excellent results.

It is apparent that various substitution, modifications and changes can be made in, e.g., as in the location, the precise construction materials, or in the absolute size, shape and relative dimensions of the parts, without departing the spirit and scope of the invention. It is also feasible, e.g., to change the size and shape, or location, as well as the number of the recesses, slots or grooves of the various component parts.

The various functions of the operating cycle can be carried out by hand, or by various means of automation. The latter obviously being preferred. The sequence of operations described for the syringe and injector assembly in performing their required function can be adapted to various types of automation, though that described is highly preferred. It will be understood that the nature of the various steps described is cyclic in nature, following a logical sequence, and that the written description is intended to cover a cycle of operation, a descriptive step of which can pick up at virtually any point in time to facilitate explanation.

Having described the invention, what is claimed is:

1. In an apparatus for repetitively accurately measuring and injecting preselected quantities of fluid specimens into a media such as an inlet to an analytical instrument, the combination comprising

a housing, which can be mounted adjacent an inlet leading into the analytical instrument,

a block mounted within the housing, said block including a pair of communicated openings therethrough, a first opening of the pair extending through the block and housing and being located at such an angle with respect to the second that it can be aligned upon the inlet leading into the analytical instrument,

a needle syringe mounted upon the forward end of a piston of a cylinder-piston unit affixed upon the housing, the needle of which is aligned upon the said second opening through the block within and through which the needle can be reciprocated by movement of the piston, said syringe including forward and rearward tubular portions separated one from the other by sealing means, the forward tubular portion of said syringe containing an exit port and providing a chamber for containing a predetermined quantity of fluid for injection via an opening within the dispensing end of the needle which is mounted on the front end of the said forward tubular portion, the rearward tubular portion of said syringe containing a plunger, the front end of which can be reciprocated within the chamber in the forward portion of the syringe, to provide in a first position a channel for the flow of fluid from the dispensing end of the needle through the said chamber to the exit port located therein, and in a second position to provide for the closure of the exit port to trap and contain a predetermined quantity of a fluid specimen for injection, and in a third position injection of the fluid specimen through the dispensing end of the needle.

an injector feed unit including a hollow probe provided with communicating upper and lower openings mounted on the forward end of a piston of a cylinder-piston unit affixed upon the housing, said probe being aligned upon the said first opening through the block within and through which the probe can be reciprocated by movement of the piston, and extended through the said first opening, and

means for transporting a fluid specimen contained in a vial, with a resilient, puncturable closure, below the said first opening and into the path of the hollow probe for penetration of said closure for pickup of the fluid specimen via the lower opening of the probe and conveyance of same via the upper side opening of the probe into the opening of the needle and into the chamber of the syringe.

2. The apparatus of claim 1 wherein an end of a tubular member, provided with a pressure gas inlet, is fitted into the said block substantially concentric with said first opening therethrough and the opposite end of the said tubular member is fitted into a second block, provided with a seal, and the said probe is snugly fitted within the said seal and movable through an opening through the said second block and seal, through the tubular member and through the first opening of said block referred to in the preceding claim.

3. The apparatus of claim 2 wherein an additional side port is communicated through the seal with the opening through the said second block.

4. The apparatus of claim 1 wherein the syringe is horizontally movable and the needle thereof is reciprocable within the second opening of said block which can be horizontally aligned upon the inlet of an analytical instrument, the first opening through the said block within which the probe is reciprocably mounted is at right angles, but in a different plane, from the said second opening of said block, and the said first and second openings are connected one to another by a short channel.

5. The apparatus of claim 1 wherein the reciprocable plunger in the rearward tubular portion of the said syringe includes a buffer assembly comprising a plunger head and stop, between which a helical spring is seated, the distance between the plunger head and stop being lessened when the spring is compressed, and wherein which rearward tubular portion pressure inlet means are provided to the forward and rearward sides of the plunger head so that when pressure is applied to the forward side of the plunger head, and while at the same time the rearward pressure inlet is vented, the spring can be compressed so that the plunger is all the way to the rear for passage of fluid through the chamber of the syringe, and wherein the pressure inlet to the forward side of the plunger head can be vented to release the tension on the spring and thereby close off the exit port within the chamber and trap a predetermined amount of the fluid specimen introduced, and the pressure inlet to the rearward side of the plunger head can be activated to activate the plunger and expel the fluid contents of the chamber.

6. The apparatus of claim 5 wherein the end wall of the rearward tubular portion of the syringe is topped and provided with an adjustable plug.

7. The apparatus of claim 1 wherein the syringe is mounted on the forward end of a piston of a fluid actuatable double acting cylinder-piston unit.

8. The apparatus of claim 1 wherein the piston on which the probe is mounted is that of a fluid actuatable double acting cylinder-piston unit.

9. The apparatus of claim 1 wherein block is constructed essentially of Teflon.

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