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[54] **FIREFLY PUMP-METERING SYSTEM**
6 Claims, 1 Drawing Fig.

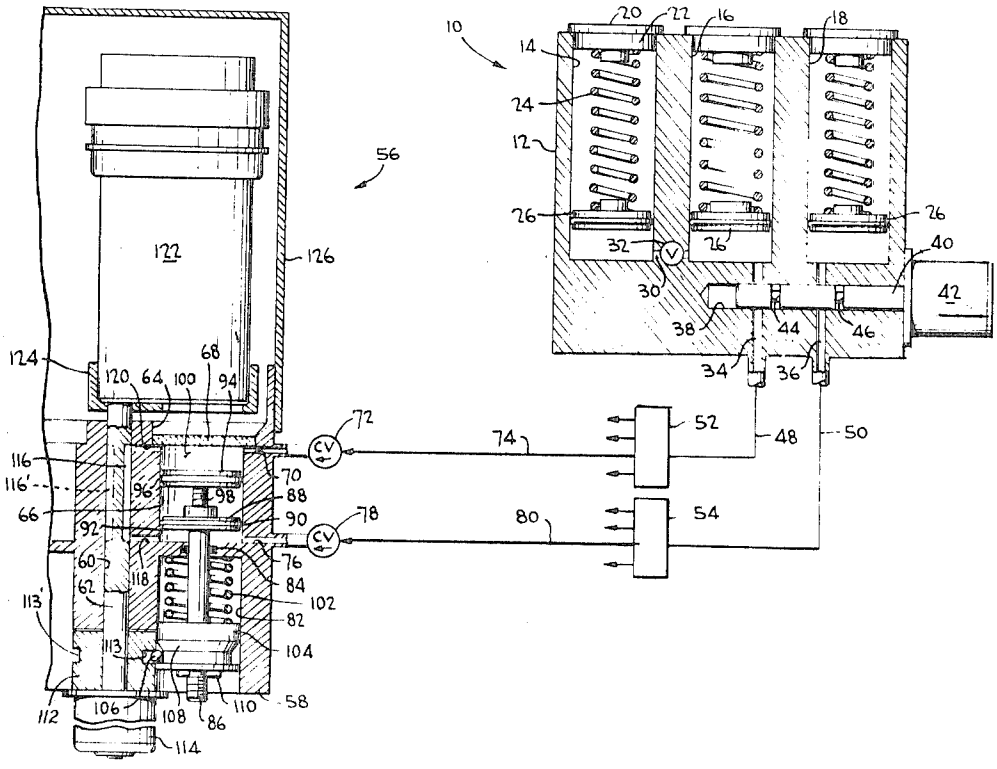
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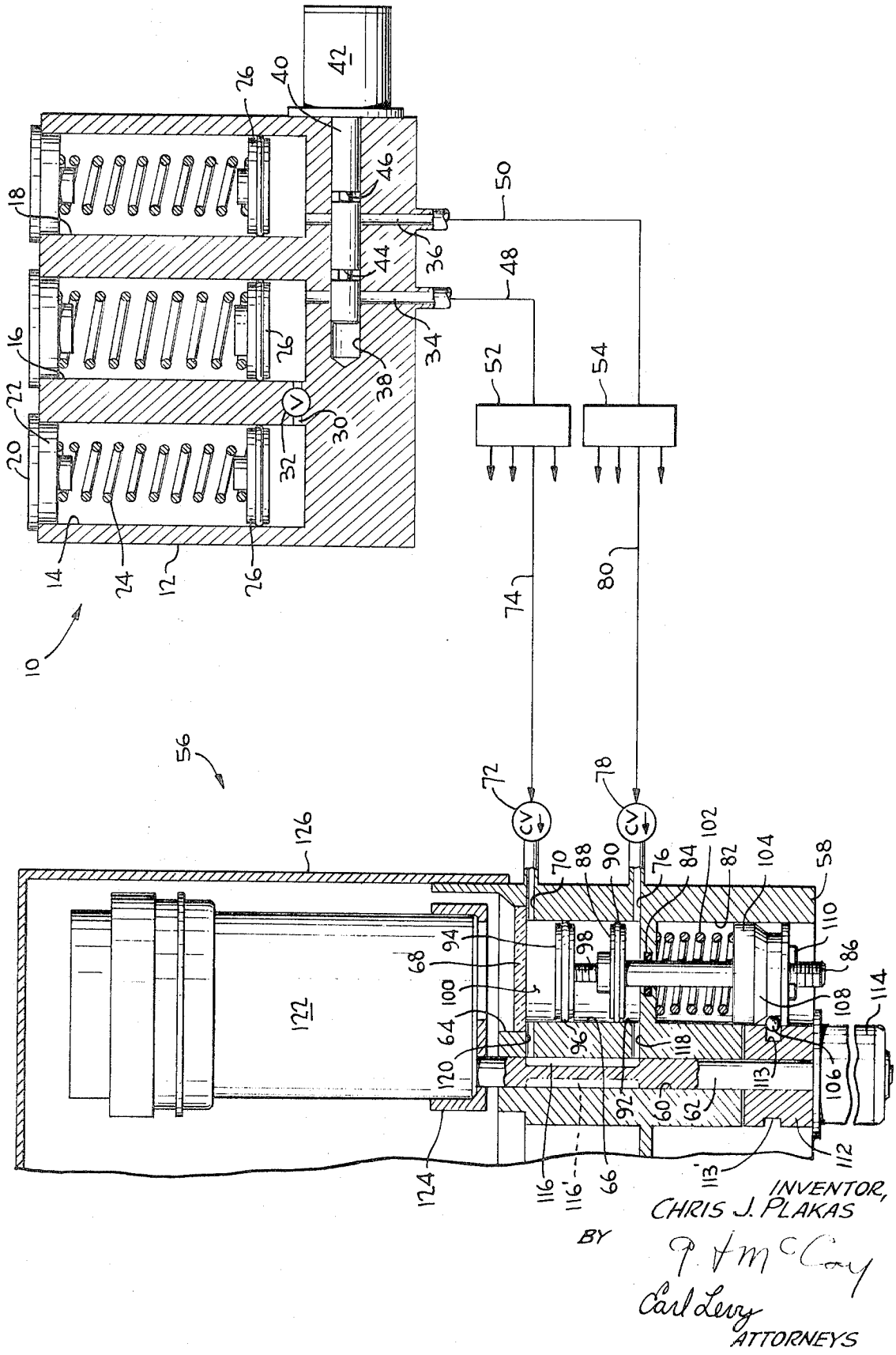
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ABSTRACT: A pumping and metering dual piston system for simultaneously injecting controlled amounts of sample and reactants into a reaction chamber and an enzyme into an adjacent injection chamber. A rotary shaft is actuated to communicate the injection chamber with the reaction chamber and to actuate a mechanism for forcing the enzyme from the injection chamber to the reaction chamber. Additionally, the shaft supports and operatively rotates detector apparatus from a magnetic and light radiation shielded position to a position for monitoring the reaction chamber constituents.





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FIREFLY PUMP-METERING SYSTEM

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 USC 2457).

The present invention relates to a pumping and metering system for laboratory sample analysis, and, more particularly, to an instrument for automatically mixing a sample with reactants and for injecting controlled amount of the same into a reaction chamber. Simultaneously, an enzyme or other reagent is metered into an adjacent injection chamber. A rotatable shaft is then actuated to operatively connect the reaction and injection chambers and to actuate a mechanism for forcing the reagent from the injection chamber into the reaction chamber. The shaft further is actuated to operatively position detector apparatus in registration with the reaction chamber for monitoring the constituents therein.

BACKGROUND OF THE PRIOR ART

A typical pumping and metering system of the prior art is described in U.S. Pat. No. 3,193,358 wherein a reciprocable piston divides a surrounding housing into two reacting chambers. An adjusting screw is utilized to limit piston travel enabling the dispensing of a measured portion of a mixed sample and reagent. A disadvantage of such construction resides in a requirement for separate sample and reagent mixing chambers and the absence of an automatic control for simultaneously mixing the sample and reagent and positioning detector apparatus for monitoring the mixed constituents.

BRIEF SUMMARY OF THE INVENTION

Apparatus according to the invention provides a storage unit for separately containing a sample, reactants and an enzyme or other reagent. A solenoid valve is activated to mix the sample and reactants and inject the same into a reaction chamber. Simultaneously the solenoid valve permits injection of the reagent into an injection chamber. Volume of the injection chamber is controlled by a reciprocating piston, the travel of which is purposely preadjusted. Volume of the reaction chamber is purposely metered by controlled travel of a second floating piston. As the injection and reaction chambers receive the reagent and sample, the two pistons will be caused to stop in abutting engagement with each other thereby metering controlled amounts of reagent and sample within the respective chambers. A rotatable shaft is then automatically actuated to operatively communicate the injection chamber with the reaction chamber. Further, actuation of the rotatable shaft releases a spring-loaded mechanism for slidably forcing the first piston to compress the reagent and force the same from the injection chamber into the reaction chamber. Additionally, rotation of the shaft rotatably positions a photomultiplier or other detector apparatus into registration with the reaction chamber in order to monitor the constituents therein.

OBJECTS OF THE INVENTION

An object of the present invention is to provide apparatus for pumping and metering controlled amounts of sample, reactants and reagents into adjacent controlled volume chambers, and for automatically mixing the sample and reagent within one of the chambers, and operatively positioning a detector apparatus for monitoring the constituents of said chamber.

Another object of the present invention is to provide apparatus for automatically pumping and metering controlled amounts of sample to a reaction chamber and controlled amounts of reactant to an injection chamber, and further for simultaneously automatically mixing the sample and the reactant and positioning detector apparatus which monitors the mixed constituents.

A further object of the invention is to provide a reactant injection chamber defined by a first controlled travel piston, a sample-receiving reaction chamber, the volume of which is determined by a floating second piston engageably stopped on said first piston, an automatic mechanism for reciprocating said first piston in order to transfer the reagent from the injection chamber to the reaction chamber.

Another object of the present invention is to provide a reaction chamber and injection chamber each defined by a reciprocating piston, one of the pistons metering a controlled amount of sample injected into the reaction chamber and the other piston both metering a controlled amount of reagent supplied to the injection chamber and pumping the reagent into the reaction chamber.

Other objects and many attendant advantages of the present invention will become obvious upon perusal of the following detailed description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a schematic in elevation and partially in section illustrating a preferred embodiment of the pumping and metering system according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With more particular reference to the drawing, there is generally illustrated in the FIGURE at 10 a storage and distribution unit comprising a housing 12 provided with three cylindrical vertically oriented storage cavities 14, 16 and 18. The storage cavity 14 is provided with a cover plate 20 having attached thereto an inverted depending retaining collar 22 having attached thereto one end of a compression coil spring 24 extending axially vertically within the storage cavity 14. The other end of the coil spring 24 is secured to a reciprocating piston 26 provided with a circumferentially surrounding ring seal 28. Similarly, the cavities 16 and 18 are provided with cover plates and structure similar to that described in conjunction with the cavity 14. However, such structure will not be described in detail for clarity. The bottom portions of cavities 14 and 16 are connected by a reduced diameter passageway 30 having a plug valve or other suitable valve 32 interposed therein. The bottoms of cavities 16 and 18 are provided with vertically oriented outlet passageways 34 and 36, respectively. The passageways 34 and 36 extend through and communicate with a laterally extending, enlarged diameter bore 38. Slidably reciprocable within the bore 38 is an elongated armature 40 of a solenoid 42 mounted on a lateral surface of the housing 12. The armature 40, shown in its retracted position, is provided with longitudinally spaced reduced diameter portions 44 and 46 which portions, will register in line with the passageways 34 and 36, respectively, when the armature 40 is in its extended position. Accordingly, in such extended position, the armature 40 acts as an automatically actuated double distribution valve. The passageways 34 and 36 are connected to distribution conduits 48 and 50, respectively. The conduit 48 operatively supplies a four-outlet distribution manifold indicated schematically at 52. Similarly, the conduit 50 supplies a distribution manifold 54 similar in construction to the manifold 52.

In the FIGURE, there is illustrated generally at 56 a fragmentary schematic of an injection unit 56 provided at its lowermost portion with an aluminum chamber block 58, only a portion of which is illustrated in the fragmentary view. The chamber block 58 is provided with a vertically extending bore 60 within which is received an elongated rotary shaft 62. The top portion of the chamber block 58 is provided with an enlarged diameter recess 64 laterally offset from the bore 60. The recess 64 opens into a generally reduced diameter bore 66 coaxial with the recess 64 extending vertically parallel to the rotary shaft 62. In practice, the rotary shaft 62 is disposed centrally of the chamber block 58 and four laterally offset bores 66 are provided. However, for clarity, only one of such bores will be described in detail hereinafter.

The recess 64 receives therein a transparent glass window 68 which forms a sealing cover plate for the bore 66. A laterally extending intake passageway 70 extends through the chamber block 58 into the bore 66 immediately adjacent to and under the bottom surface of the window 68. The passageway 70 is provided with a shutoff valve 72 to which is connected one outlet 74 from the distribution manifold 52. In similar fashion, an inlet passageway 76 is provided through the chamber block 58 adjacent the bottom wall of the bore 66. The passageway 76 communicates with a shutoff valve 78 to which is operatively connected one of the outlet conduits 80 of the distribution manifold 54.

Axially aligned with the bore 66 is an inverted recess 82 provided in the chamber block 58. A generally centrally located opening connects the recess 82 with the bottom portion of the bore 66 and has mounted therein a generally annular sealing ring 84 which surroundingly and slidably receives a reciprocating piston shaft 86. At one end of the piston shaft 86 is secured a generally cylindrical piston 88 disposed within the bottom portion of the bore 66. The piston 88 carries a circumferentially surrounding sealing ring 90 which sealably isolates the bottom portion of the bore 66 from its remainder thereof to define a reagent injection chamber 92. Accordingly, the injection chamber 92 is supplied through the conduit 76, the shutoff valve 78 and the outlet conduit 80 of the distribution manifold 54. In the remaining portion of the bore 66 is disposed a floating piston 94 carrying a surrounding annular sealing ring 96. The floating piston 94 carries a depending adjusting screw 98 having a flat head provided purposely to stop against the piston 88 in a manner to be hereinafter described in detail. Accordingly, the piston 94 sealably isolates the top portion of the bore 66 and defines thereby a sample reaction chamber 100 which is supplied by the conduit 70, the shutoff valve 72 and the outlet conduit 74 of the distribution manifold 52. It should be noted, that the remaining not shown bores 66 are provided with similar structure and are supplied in similar fashion by the remaining outlet conduits from the manifolds 52 and 54. A detailed description of the same is omitted for purposes of clarity.

With more particular reference yet to the FIGURE, the reciprocating piston shaft 86 is slidably extended through the inverted recess 82 and is provided with a surrounding concentric injection compression spring 102 retained initially in compression against the bottom wall of the recess 82 by an impinging injection spring retainer 104 slidably received in the recess 82 but initially restrained against movement by a ball latch 106 partially protruding into the recess 82 and engaged in a groove 108 provided circumferentially of the injection spring retainer 104. The reciprocating piston shaft 86 is slidably received centrally of the injection spring retainer 104. The end portion of the reciprocating piston shaft 86 is threadably provided thereover with a volume adjustment nut 110 initially in spaced relationship from the injection spring retainer 104. Initially, the ball latch 106 is retained in registration with the injection spring retainer 104 by a ball release mechanism illustrated schematically at 112. The ball release mechanism 112 is rigidly secured to and is adapted for rotation by the rotary shaft 62 to position a recess 113 as hereinafter described. A motor 114 is operatively connected to the rotary shaft 62. In its generally central portion the rotary shaft 62 is provided with a reduced diameter conduit groove 116 which extends generally parallel to the central axis of the shaft. The reagent injection chamber 92 is provided with an outlet passageway 118 and the sample reaction chamber 100 is provided with a similar reduced diameter passageway 120. Each of the passageways 118 and 120 communicate with the groove conduit 116 of the rotary shaft 62. It should be understood, however, that such communication occurs only upon rotation of the rotary shaft to be hereinafter described in detail. Accordingly, the initial position of the groove conduit and the recess is illustrated in phantom line at 116' and 113' so that initially no communication between the reagent injection chamber 92 and the sample reaction chamber 100 can occur. The remaining end of the rotary shaft 62 is operatively connected with a photomultiplier or other suitable detector mounted within a magnetic casing 122. For added support, the casing 122 may be carried by a mounting tray 124.

Casing 122 may be carried by a mounting tray 124 secured to the top portion of the chamber block 58. For further protection, the casing 122 may be contained within an inverted light shielding housing 126 also secured to the top portion of the chamber block 58 by any well-known fabrication techniques.

In operation, a quantity of sample to be tested is deposited within the cavity 16 of the storage and distribution unit 10. Additionally, a quantity of another substance, such as ATP extracts, is deposited within the cavity 14. Also, a reagent or a quantity of any enzyme may be deposited in the cavity 18. Each cavity is then covered with its appropriate cover plate 20. The depending spring 24 of each cover plate will be compressed due to the quantity of substance within each cavity. Accordingly, each piston 28 will exert pressure upon the quantity of substance within each storage cavity. Subsequently, the plug valve 32 is opened to permit communication between the cavities 14 and 16, for example, to mix the sample with the ATP extracts. Simultaneously, the solenoid 42 is actuated, thereby extending its armature 40 and aligning the reduced diameter portions 44 and 46 thereof with the outlet conduits 34 and 36. Ad a result of the solenoid actuation, the mixed substances within the sample cavity 16 and the enzyme substance within the cavity 18 will simultaneously be supplied under pressure provided by the pistons 26 of the storage cavities 16 and 18 to the distribution manifolds 52 and 54. Enzyme will be supplied under such pressure through the check valve 78 into the reagent injection chamber 92. Such pressure additionally reciprocates the piston 88 in order to accommodate the increasing volume of enzyme supplied to the injection chamber 92. The piston will continue to rise until the volume adjustment nut 110 impinges against the injection spring retainer 104. Accordingly, the volume of enzyme accepted by the injection chamber 92 is positively controlled by proper adjustment of the volume adjustment nut 110. Simultaneously, the mixed sample and ATP extracts from the manifold 52 are supplied through the check valve 72 into the sample reaction chamber 100. The floating piston 94 will reciprocate in response to the expanding volume of sample accepted into the reaction chamber 100 until the adjustment screw 98 stops against the piston 88. Accordingly, the volume of sample accepted into the reaction chamber 100 can be adjustably controlled by a proper setting of the adjustment screw 98.

At this point in the operation the valves 72 and 78 are closed thereby isolating the injection chamber 92 and the reaction chamber 100. The motor 114 is then actuated to operatively rotate the rotary shaft 62. By such operation, the groove conduit 116 is brought into registration with the passageways 118 and 120 of the injection chamber 92 and the reaction chamber chamber 100. Simultaneously, the ball release mechanism 112 is rotated to bring the recess 113 in registration with the ball latch 106, permitting the same to be withdrawn from the groove 108 of the injection spring retainer 104. Accordingly, the compressed coil spring 102 is permitted to expand, thereby reciprocating the piston 88 and purging the injection chamber 92 of the enzyme which is caused to flow through the passageway 118, the conduit 116, the passageway 120 and into the sample reaction chamber 100. Such reciprocation of the piston 88 permits a corresponding reciprocation of the piston 94, permitting expansion of the reaction chamber 100 to accommodate the increase in volume thereof due to the enzyme received therein. Additionally, rotation of the rotary shaft 62 rotates photomultiplier (not shown) initially from a position within the magnetic shield casing 122 to a position in registration with the glass window 68 covering the reaction chamber 100. Accordingly, the photomultiplier is operatively positioned upon rotation of the rotary shaft 62 to monitor the mixed constituents within the reaction chamber 100.

Accordingly, and in accordance with the objects of the present invention, the preferred embodiment of the invention is a dual piston sample analysis instrument which both meters the amount of the reactants and pumps the same into the reaction chamber. Additionally, the present invention utilizes an uncomplicated mechanism in the form of a rotary shaft for accomplishing within significant time relationships, three functions: namely, releasing a ball detent latch and enzyme injection spring, activating a conduit permitting enzyme to flow from an injection chamber into a reaction chamber where it is mixed with a sample to be analyzed, and supporting and positioning a photomultiplier tube from a protected position to a position whereby monitoring of the mixed constituents is accomplished. Other embodiments and modifications of the present invention are apparent and intended to be protected by the scope of the appended claims.

It is claimed:

1. A pumping and metering system comprising:
means for storing a sample to be analyzed;
means for storing a reagent separately from said sample;
a housing defining a reaction chamber in communication with said sample-storing means and an injection chamber in communication with said reagent storing means;
metering means for adjustably controlling the volume of said reaction chamber and said injection chamber, said metering means including a first piston slidable within said housing and mounted on an elongated shaft thereby defining said injection chamber and a second slidable piston mounted on said shaft within said housing thereby defining said reaction chamber;
adjustment means to control the volume of said reaction chamber including a nut threadably adjustable on said shaft and providing a stop in order to limit sliding travel of said second piston;
initially closed valve means providing communication between said reaction and said injection chambers;
pumping means for transferring reagent from said injection chamber to said reaction chamber; and,
automatically actuable means for actuating said valve means and said pumping means in a properly determined timed sequence.

2. The structure of claim 1, wherein said automatically actuable means comprises a rotatable shaft and said valve means comprises a groove conduit in said shaft.

3. The structure of claim 1, and further including a radiation shielded housing containing a pivotally mounted detector means, said automatic actuable means being so constructed and arranged to open said valve means, activate said pumping means and pivot said detector means into registration with said reaction chamber.

4. The structure of claim 1, wherein said pumping means includes a coil spring surrounding said shaft, a spring retainer slidably receiving said shaft and retaining said coil spring initially in compression, latching means initially precluding motion of said retainer means, said automatically actuable means adapted to release said latching means permitting expansion of said coil spring for transferring said reagent, said adjustment nut adapted for engagement on said spring retainer.

5. The structure of claim 1 and further including a first distribution manifold providing communication between said sample-storing means and said reaction chamber and a second distribution manifold providing communication between said reagent-storing means and said injection chamber.

6. The structure of claim 5 and further including an automatically actuable distribution valve operatively associated with said sample-storing means and said reagent-storing means for simultaneously supplying sample and reagent to said manifolds.