A system for injecting sample fluids from a plurality of containers into a sample receiver. The containers are supported on removable racks having a plurality of permanent cam tracks on its lower surface which cooperate with switches to produce binary information identifying the sample rack and sample container location at the sample station.
SAMPLE CONTAINER SUPPORT WITH CODING MEANS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the analysis of sample fluids and more particularly relates to systems for controlling the introduction of sample fluids into an analyzer.

2. Prior Art

Systems for supplying fluid samples for analysis by equipment, such as chromatographic analyzers, have been proposed by the prior art. Some prior art systems have employed a syringe for introducing a predetermined quantity of sample fluid into the analyzer equipment. Sample fluids to be analyzed were disposed in separate closed sample containers and successive individual fluid samples were removed from their containers, supplied to the syringe, and injected into the equipment.

It is imperative in most sample analyses that the sample fluid being analyzed be as free as possible from any type of foreign substance. Accordingly, the injection syringe was required to be thoroughly purged of one sample fluid and/or any residual cleansing solvent before a succeeding sample was placed in the syringe. The syringes employed for sample fluid injection were quite delicate because of the extremely small quantities of sample fluid they handled, e.g. quantities of from 5–50 microliters, this made manual operation and purging of the syringes both tedious and time consuming. Furthermore, when large numbers of samples were being successively analyzed, a skilled operator was required to attend the equipment and perform the tedious and repetitive task of purging and filling the syringe.

In order to increase the speed and efficiency of the analysis of multiple fluid samples, mechanized syringe handling systems were proposed. The purpose of such systems was to reduce the amount of operator time required in connection with the analysis procedures and to reduce equipment failures, e.g. the syringe breakage and damage which inevitably resulted from frequent handling.

The mechanized systems generally consisted of a supporting tray for sample containers and an injection syringe manipulating mechanism which functioned to enable removal of sample fluid from individual containers, injection of the fluid into the analyzer and purging of the syringe. The sample container trays were usually actuated to index successive sample containers to a location from which fluid was transferred to the syringe.

While the prior art mechanized systems were effective in reducing the amount of operator time required to analyze fluid samples, several problems relating to syringe manipulation and purging remained unsolved and errors in sample identification due to handling by the operators were encountered.

The sample identification errors were most frequent in circumstances where fluid samples from a number of different laboratories or other sources were analyzed on a time sharing basis by a centralized analyzer. In such a situation the analyzer operator was sometimes required to load large numbers of sample containers containing unfamiliar substances into the container storage trays and, in one way or another, account for the analysis of the various individual samples. The sample container storage trays also frequently contained identical solvent containers used for purging the syringes. Mistakes as to the identity of individual samples tended to occur because of confusion in handling and placement of the sample containers in the apparatus.

In order to remedy this problem the use of sample labeling devices, such as punched cards, was proposed. These devices were frequently combined with card reading apparatus associated with the sample storage apparatus. The use of such sample identification devices required the preparation of identification cards, the provision of identification codes, etc. Furthermore, the card reading devices were sometimes complex and thus increased the size and complexity of the sample storage and syringe manipulating equipment. As a result the initial equipment costs were increased and servicing and maintenance of the equipment was complicated. Furthermore, the possibility of human errors in handling the identifying information was not eliminated.

SUMMARY OF THE INVENTION

The present invention provides a new and improved sample analysis method and system wherein fluid samples to be analyzed need not be loaded by the operator of the analysis system and confusion as to the identity of fluid sample analysis results is minimized; sample fluid injection equipment and associated sample flow conduits are purged by a controlled volume of purging fluid so that samples of fluid injected in the apparatus are nearly uniformly pure regardless of differences in sample fluid viscosity and/or volatility; the volume of sample fluid injected into the analyzer is accurately governed by adjustable dosage controls; damage to syringe-like elements of the system resulting from misalignment of sample containers or other fluid receivers and the syringe-like elements is avoided; and numerous different sample fluids can be analyzed automatically without requiring full time attendance of a skilled operator.

In a preferred and illustrated embodiment of the invention a sample analysis system is provided which comprises a sample analyzer, preferably a gas chromatograph, a sample injection module by which a sample of fluid to be analyzed is injected into the analyzer, a sample storage module which houses a number of discrete samples of fluid to be analyzed and which supplies sample fluid to the injection module, a sample analysis computer which may be programmed to partially govern operation of the system and to receive raw data from the analyzer concerning the analysis of the given sample of fluid, a recorder which is connected to the analyzer for producing graphic information concerning the analysis of given samples by the analyzer, and an electronic control module which governs operation of the components of the system.

The sample storage module receives a plurality of separate sample storage trays, or racks, in which a number of sample containers may be placed. The trays or racks are detachably connected to the storage module and as such can be loaded with samples remote from the analysis system. The trays or racks can be loaded with containers in laboratories and forwarded to the analysis system. The operator of the system thus does not have to load or unload trays and is not required to account for the identity and location of any given fluid sample.
The storage module and sample trays cooperate to automatically provide information concerning the identity of the sample being analyzed to the electronic control module so that the analysis data produced by the computer and/or recorder is automatically coded with the identity of the sample being analyzed. In the preferred and illustrated embodiment of the invention the sample trays carry a series of cam tracks which interact with a series of switches in the storage module. The switches are actuated to identify the rack and contain position of the sample being analyzed by binary numbers. These numbers are decoded and printed on the output data of the computer or recorder.

The new system is also capable of distinguishing between a sample container and a solvent container as well as determining when the samples in all of the containers have been analyzed.

The sample storage module is detachably connected to the injection module and sample fluid which is withdrawn from an individual container in the storage module is conducted into the injection module via a sample conduit. The injection module includes a syringe connected to the conduit which injects a predetermined dose of the fluid into the analyzer. Prior to the injection of a sample, the sample conduit and the injection syringe in the module are purged to remove residual fluid from a previous cycle of the system.

Another feature of the invention is the provision of a sample analysis system wherein a control module governs operation of sample storage and injection modules and is capable of interrelating these operations with a computer. The system is constructed and arranged so that the entire analysis of multiple samples can be controlled by a programmed computer while at the same time permitting system operation by an operator.

Other features and advantages of the invention will be apparent from the following detailed description of a preferred embodiment made with reference to the accompanying drawings which form a part of the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a sample storage container module forming part of the system of FIG. 1 with parts removed and portions broken away;
FIG. 2 is a cross sectional view seen approximately from the plane 2—2 in FIG. 1;
FIG. 3 is a cross sectional view seen approximately from the plane of the line 3—3 of FIG. 1;
FIG. 4 is an elevational view of one side of a sample storage tray;
FIG. 5 is an elevational view of the opposite side of the sample storage tray of FIG. 4;
FIG. 6 is an enlarged elevational view of the portion of the tray of FIG. 4 within the line 6;
FIG. 7 is a cross sectional view seen approximately from the plane indicated by the line 7—7 of FIG. 6;

THE STORAGE MODULE

The storage module 16 supports a plurality of separate containers 240 for fluid samples and purging solvents and defines an extraction station 250 at which a fluid sample or purging solvent is extracted from a respective container and is directed to the injection module 14. The individual containers 240 are supported by a plurality of the sample supporting tray members, or racks, indicated by the reference characters 252—255 (see FIG. 1). The trays, or racks, are individually removable from the storage module 16 with their associated sample containers. An actuator assembly 258, forming a part of the module 16, moves the container supporting trays in carrousel fashion so that individual containers are successively moved to the extraction station 250 from which the contents of the container at the extraction station can be removed and directed to the injection module.

Referring now to FIG. 2, the storage module 16 comprises a support frame 260 which is defined by a peripherally extending skirt 262 and a circular base plate 264 connected to the skirt. Side panels 266, 268 extend perpendicularly with respect to each other and generally tangentially with respect to the support base portion 264 and skirt 262 to define a projecting corner of the storage module. The extraction station 250 is located at the projecting corner of the module and the trays 252—255 are circularly arranged over the support base 264.

The sample supporting tray members 252—255 are, in most respects the same, and only the tray 253 is described in detail to the extent that the trays are identical. The tray 253 is shaped to approximate a frustum of a 90° circular segment having a circularly curved outer wall 270, radially extending side edges 272, 274 and a radially inner edge 276 which extends between the side edges. A segmental radially inner tray body 280 extends between the edges 272, 274, 276 and terminates in a circular wall portion 282. The edges of the tray member are defined by lips which project from a face of the body 280 and these lips, along with radially extending webs 284 rigidify the tray body portion 280. A pair of cylindrical bosses 285 extends from the body 280 beyond the webs 284. The bosses provide a detachable driving connection with the tray actuator assembly 258 as is described in greater detail presently.

A radially outer tray body portion 286 extends from the wall 282 and is recessed from the body 280. The outer tray body portion 286 terminates in the circumferential wall 270 and is rigidified by integral webs 292 which extend radially outwardly from the wall 282 flush with the inner tray body portion 280.

A circumferential series of sample container pockets 296 (preferably 15 pockets for accommodating 15 separate containers) is disposed circumferentially about the periphery of the outer tray body 286. The pockets 296 are defined by semicircular recesses 298 formed in the tray wall 270 and semicircular faces 300 formed on projecting lips 302 at the radially outer ends of the webs 292. The recesses 298 and faces 300 are positioned with respect to each other so that the container in each individual pocket is maintained accurately positioned in the pocket and constrained against tipping, even if the tray should be vertically oriented.

The container support actuator 258 comprises a turntable assembly 310 to which the individual trays 252—255 are detachably connected and a turntable drive mechanism 312 by which the assembly 310, and the attached trays, can be rotated with respect to the frame base 264. The assembly 310 comprises a support shaft 314 which extends through the frame base 264 and is supported for rotation about an axis 315 by a bearing unit 316 connected to the frame base. The projecting end of the support shaft 314 carries a circular tray support member 320 which is fixed to the shaft 314 for rotation about the axis 315 and which defines
four pairs of circumferentially spaced locating holes 321. A drum-like member 322 is disposed between the tray support 320 and the frame base 264 and is fixed to the shaft 314 for rotation with it.

A tray locking assembly 324 is disposed beyond the tray support 320 from the drum 322 and functions to permit the individual sample supporting trays to be connected to and locked in place on the tray support member.

The locking assembly comprises a cylindrical body 330 which is fixed to the end of the shaft 314 for rotation about the axis 315. Four shouldered holes 332 are formed in the body 330 at locations spaced 90° apart about the axis 315, with the holes extending generally parallel to the axis. A circular retainer plate 334 is connected to the body 330 to close the holes 332. Each of the holes 332 supports a shouldered detent pin 336 and a helical compression spring 338 which reacts between the detent pin 336 and the retainer plate 334 so that the projecting end of the detent pin is urged from the body 330 towards the tray support 320.

Trays are inserted and locked in place in the assembly 310 by cocking the tray slightly with respect to the support member 320 and inserting the inner edge 276 of the tray between the support member 320 and the body 330 of the locking assembly. The end of the detent pin 336 is rounded so that the detent pin is forced into its shouldered hole 332 against the force of the spring 338 as the tray is slid radially inwardly along the support member 320. When the locating bosses 285 are aligned with the pair of the locating holes 321 the tray is cocked downwardly so that the bosses 285 extend through the associated locating holes 321. At this juncture the webs 284 of the tray are engaged along the face of the support member 320 and the detent pin 336 is firmly engaged with the tray body portion 280 to maintain the tray member in contact with the support member 320. The bosses 285 cooperate with their respective locating holes to enable the transmission of drive from the rotatable support member 320 to the tray.

The drive mechanism 312 includes a reversible electric motor 340 having a gear reduction (not shown) connected to its rotor shaft. An output shaft of the gear reduction (not shown) extends through the frame base 264 and an output pulley 344 is connected to the projecting end of the gear reduction output shaft. A drive belt 346 is reeved about the pulley 344 and the drum 322 so that drive from the motor 340 is transmitted to the turntable assembly 310 and thence to the individual trays supported by the turntable assembly.

The containers 240 may be of any suitable construction but in the illustrated embodiment are glass vials which fit snugly into the pockets 296. The containers 240 have a capacity of several milliliters of fluid and each container is closed by a septum 241 which is carried by a removable cap 348.

An important feature of the invention resides in the ability of the storage module 16 to receive from one to four trays of a large number of support trays which may be loaded with sample containers at locations remote from the actual location of the system. As an example, the system can be a central analyzer system at which a primary analyzer system serves a number of separate laboratories. Sample trays can be loaded with sample and/or solvent containers in the laboratories and forwarded to the analyzer system, thus relieving the analyzer operator from the task of loading the sample trays and recording the identity of each sample and its position in the tray. Each of the trays is provided with indicia indicating the identity of the tray, by a decimal number as well as indicating, by decimal numbers, the identities of the individual pockets in the tray. When the trays are loaded at their individual laboratories, the personnel loading the trays need only record the tray or rack number and the substance in each container along with the associated pocket number. The operator of the analyzer need not be involved in this process. In the preferred embodiment, the module 16 can handle up to four of 16 separate sample trays at any given time.

The turntable assembly 310 moves the trays to position successive container locations at the extraction station 250. Fluid in a container at the extraction station is removed by a syringe-like dipper tube assembly 352 (which is described in detail below) and is directed to the injection module 14. The storage module 16 provides a container locating assembly which functions to precisely align the containers at the extraction station with the dipper tube assembly so that the dipper tube assembly is not damaged from being advanced into engagement with a misaligned container.

The storage module also houses a fluid container identifying system which functions to identify the container at the extraction station by tray and pocket number as well as by whether the container is a sample container or a solvent container. When a container has been appropriately located at the extraction station and identified, the dipper tube assembly 352 is operated to enter the container, extract fluid from it, and direct the fluid to the injection module 14.

The container locating assembly comprises a locating cam structure defined by the individual trays and a roller follower 360 which is biased into engagement with the cam structure. The roller 360 is supported by a lever 362 pivoted to the frame base 264 and is urged into engagement with the associated tray by a tension spring 264 connected to the lever. Each of the trays 252–255 defines a circumferentially extending generally sawtooth configuration cam track 366 formed on its outer periphery adjacent the frame base 264. The cam tracks each define a series of radially outer peaks 368 and intermediate radially inner troughs 370. The roller 360 is urged into engagement with the peaks and troughs as the trays are rotated by the actuator 258. Each cam trough 370 corresponds to a particular container pocket. When each container pocket is aligned with the dipper tube assembly 352 the roller 360 is disposed in the cam trough. The motor 340 is energized to rotate the turntable so that a particular container is advanced to the extraction station and is approximately aligned with the dipper tube assembly 352. While the motor drives the turntable, the roller 360 rides along the cam track 366. When the motor is deenergized at the approximate desired container position, the roller is moved into the corresponding trough of the cam track by the force of the spring 364. This movement of the roller causes rotation of the turntable and the trays by the spring force and results in the container being shifted into precise alignment with the dipper tube assembly. The roller is capable of rotating the motor and gear reduction when the motor is deenergized and thus eliminates the necessity of sophisticated, complicated motor controls which might otherwise be necessary to
precisely locate the container pockets at predetermined desired positions.

The container identification system comprises a container identifying arrangement which ascertains the kind of fluid, i.e., sample fluid or solvent, at the extraction station. When a sample fluid container is located at the extraction station the system 10 is enabled to perform a complete purging and/or analysis cycle utilizing the sample fluid. When a solvent container is located at the extraction station the system 10 is automatically conditioned to perform only a purge cycle to avoid the injection of the solvent into the analyzer.

In the preferred embodiment of the invention, the containers 240 each cooperate with SPD'T micro-switches 382, 384 when the containers are at the extraction station and the interaction between the containers and the switch depends on whether the containers are sample or solvent containers. Three different containers 240a, 240b, and 240c are illustrated in FIG. 2. The containers 240a and 240b are representative of containers for sample and solvent fluid, respectively. The container 240b carries a removable ring 380b disposed about its cap 248 and spaced from the projecting end of the cap. All of the fluid sample containers 240b are provided with a ring 380c of the character described, and in each case the ring is positioned remote from the projecting end of the container cap 348. The container 240a carries a removable ring 380b which is disposed about the cap 348 at its projecting end. All of the solvent containers 240b are provided with a similar ring 380b disposed at the projecting end of the container cap 348.

When a given container is positioned at the extraction station 250 the container cap 348 is engaged by the operating arms of the microswitches 382, 384 (see FIG. 3). When a sample fluid container 240b is at the extraction station, the ring 380a is engaged with the arm of the microswitch 382 so that the microswitch 382 is actuated by the cap 380a while the microswitch 384 is not actuated. On the other hand, when a solvent container 240a is at the extraction station, the cap ring 380b is engaged with the arm of the microswitch 384 so that the microswitch 384 is actuated while the switch 382 is not actuated.

When a container is not aligned with the extraction station or when an empty pocket passes the station, neither of the switches 382, 384 is actuated. Alternatively, the rings 380a may be dispensed with and a wash cycle pin 701 (FIG. 3) can be inserted in the holes 702 in the periphery of the racks 252-255 to indicate that the particular location contains a wash material instead of a sample. Pin 701 reacts with the lower microswitch 283 to indicate presence of wash container. In this embodiment, both an indication of a pin and a vial is necessary to initiate a wash cycle.

The container for the final sample to be analyzed in any given series of analyses is provided with both a ring 380a and a ring 380b. Hence when the final sample is located at the extraction station both switches 382 and 384 are engaged by the respective cap rings 380a, 380b and both switches are actuated.

The switches 382, 384 are electrically connected to logic and sequence controlling circuitry in the control module 22 so that operation of the system can be governed in part by information supplied to the control module from the switches 382, 384. If a sample container is sensed at the extracting station the system will perform a complete purging and analysis cycle. When the final container is sensed, i.e., the container carrying both cap rings 380a and 380b, a purge and/or analysis cycle is completed by the apparatus after which the system 10 is automatically shut down. When a solvent container is detected and it is not desired to purge the injection syringe with solvent the turntable continues to index until a sample container is sensed. When a solvent is desired to purge the injection, the control module 22 can be conditioned to operate the turntable until a solvent container is sensed at the extraction station after which the purging cycle is completed but not an analysis cycle. The tray and pocket identifying arrangement comprises a plurality of SPD'T micro-switches supported by the frame body 264 adjacent the extraction station along a line extending radially from the extraction station towards the turntable axis 315. Cam tracks are formed on each of the container trays. Each cam track faces a respective microswitch and operates the microswitch in such a way that identification of the sample tray and the particular pocket at the extraction station is provided to the control module 22. In the preferred embodiment, eight micro-switches 401-408 are mounted on the frame base (see FIG. 1) and eight cam tracks 411-418 are formed on each of the tray bodies 286 (see FIGS. 4, 6 and 7). The cam tracks define lobes 420 projecting from the tray bodies for engaging and actuating the respective microswitches. The lobes are constructed to provide for binary coded actuation of the switches. The tray 253 shown in FIGS. 4-7 happens to operate only the switches 401-404 and accordingly the cam tracks 415-418 have no switch operating lobes. Removable cam tracks 415-418 are used to identify up to 16 different racks.

The micro-switches are electrically connected to a binary decoder in the control module 22 and when the switches are actuated they produce signals which identify the particular pocket location at the extraction station as well as the identity of the tray, at which the pocket is located. The use of eight switches enables the illustrated system to be used with 16 separate trays each containing 15 sample pockets, i.e., the system is capable of handling 240 different identities. The control module binary decoder functions to identify the sample tray and pocket location of each sample being analyzed by decimal numbers and provides information to the computer and/or the recorder so that the data relating to the analysis is correlated to the actual sample fluid location and tray in the storage module 16. This information is preferably printed out by the computer and the recorder in terms of tray number and sample pocket location. The decimal identity of the container location can also be displayed on an operator's console if desired.

This feature avoids operator errors in identifying the sample analysis results since the computer printout and/or the recorder printout indicates the tray and sample pocket location of the sample analysis results and these results can be compared with the laboratory records indicating the samples which were placed in the trays prior to the analysis.

While a single embodiment of the present invention has been illustrated and described in considerable detail, the invention is not to be considered limited to the precise construction shown. Numerous adaptations, modifications and uses of the invention may occur to those skilled in the art to which the invention relates.
and it is the intention to cover all such adaptations, modifications and uses which fall within the scope or spirit of the appended claims.

We claim:

1. In a system for transferring a fluid from one of a plurality of containers to a fluid receiving device including a structure defining a station at which a fluid is removed from a container, a plurality of container supporting members each of which defines a plurality of fluid containers supporting locations, said container supporting members each having a lower face, actuation means for moving a selected container location of one of said container supporting members to said station, actuation means comprising a table member supported for rotation about an axis, said locations of said container supporting members being disposed circumferentially about said axis, connecting means detachably connecting said actuating means to respective ones of said container supporting members for enabling removal and replacement of respective container supporting members; and identification means comprising sensing means fixed with respect to said station and unique structure movable with each said container supporting members and cooperable with said sensing means to determine the identity of each said container, THE IMPROVEMENT COMPRISING said unique structure movable with said container supporting members being defined by a series of permanent cam tracks supported by the lower face of said container supporting members, said cam tracks within a segment defined by the axis and said container location having raised portions corresponding to a number assigned said container supporting member and said container supporting locations, said raised portions being radially aligned with said corresponding container supporting location and said cam tracks being parallel to each other and concentric with the axis of rotation of said table member and said sensing means comprising a plurality of cam operated switches arranged parallel to each other on a radius from said table member axis to said station cooperating with said cam tracks to produce binary information identifying the sample container supporting location at said station, and identifying said container supporting member, said container supporting member being individually removable cylindrical segmental racks.

2. In the system of claim 1 wherein said removable racks include a hole radially outwardly located with respect to each said fluid container supporting locations for receiving a marker pin which enables identification of those container locations having washing solvents.