

[54] **AUTOMATED CLINICAL
LABORATORY**

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Related U.S. Application Data

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[51] Int. Cl. B04b 9/12, B04b 9/14

[58] Field of Search 233/26, 4, 23, 24, 1 R, 7;
23/253, 259[56] **References Cited****UNITED STATES PATENTS**

3,081,158 3/1963 Winter.....23/253

3,532,469	10/1970	Vicario	23/259 X
3,151,073	9/1964	Anthon	233/4
3,379,370	4/1968	Anderson	233/26
3,475,130	10/1969	Baruch	23/259 X

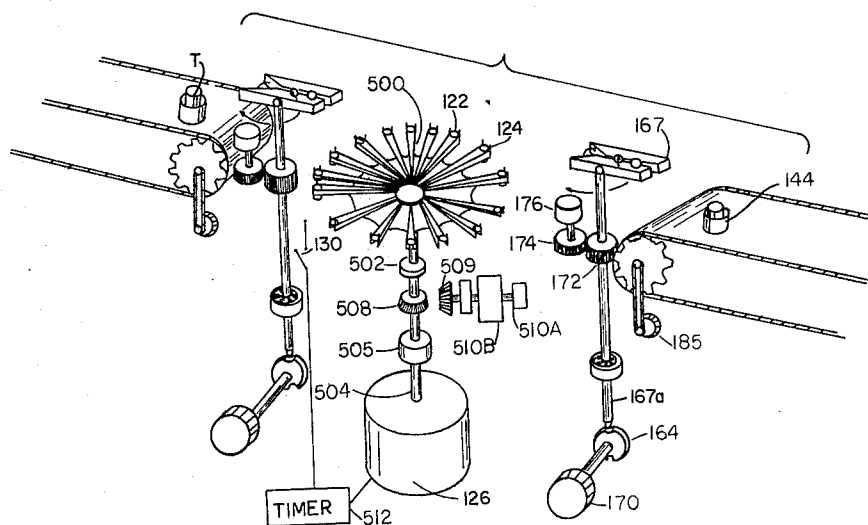
Primary Examiner—Jordan Franklin

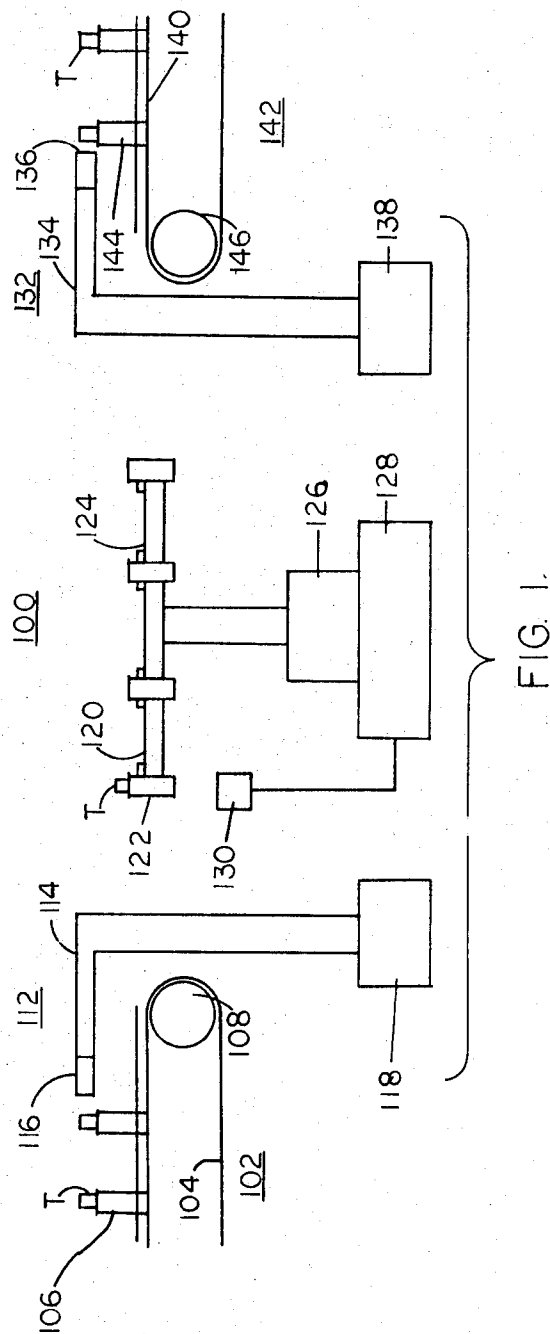
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[57] **ABSTRACT**

An automated centrifuge system having a conveyor for test tubes to be loaded thereon at a first transfer station, the test tubes are removed from the conveyor and placed into trunnion cups on a trunnion carrier. Program means are coupled to the trunnion carrier to first slowly rotate the trunnion carrier as the test tubes are loaded thereon, second, rapidly rotate the trunnion carrier to centrifuge specimens therein and third, slowly rotate the test tubes so that the test tube can be unloaded. The test tubes are then removed from the trunnion carrier and, second conveyor carries the test tubes away from the trunnion carrier.

2 Claims, 10 Drawing Figures



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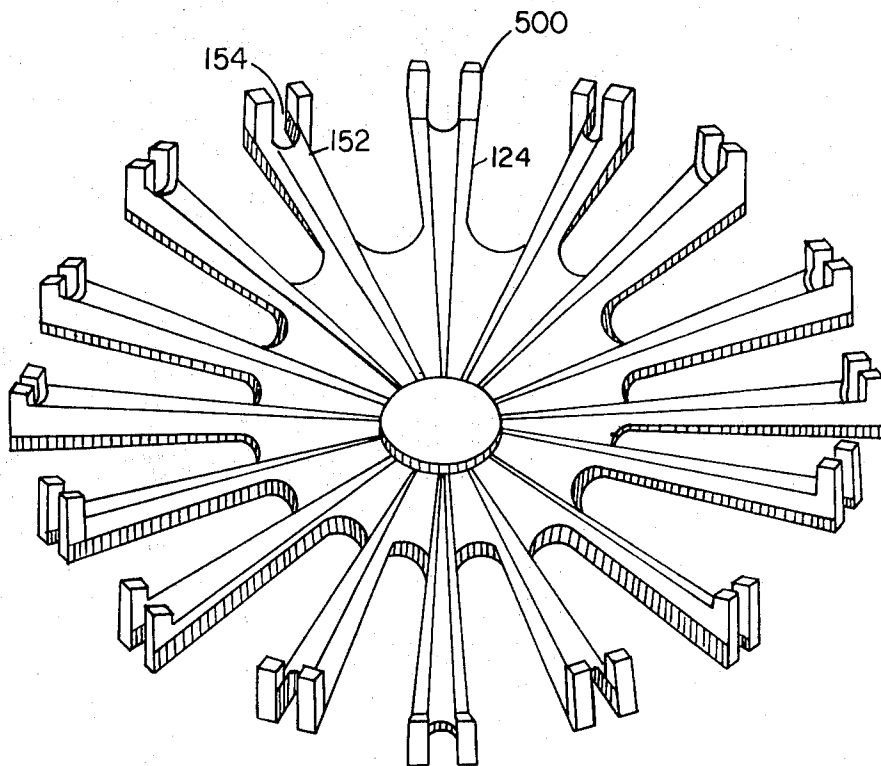


FIG. 2.

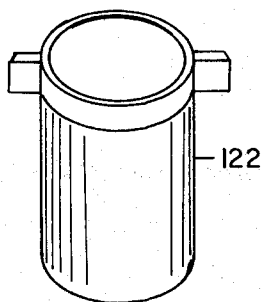


FIG. 3.

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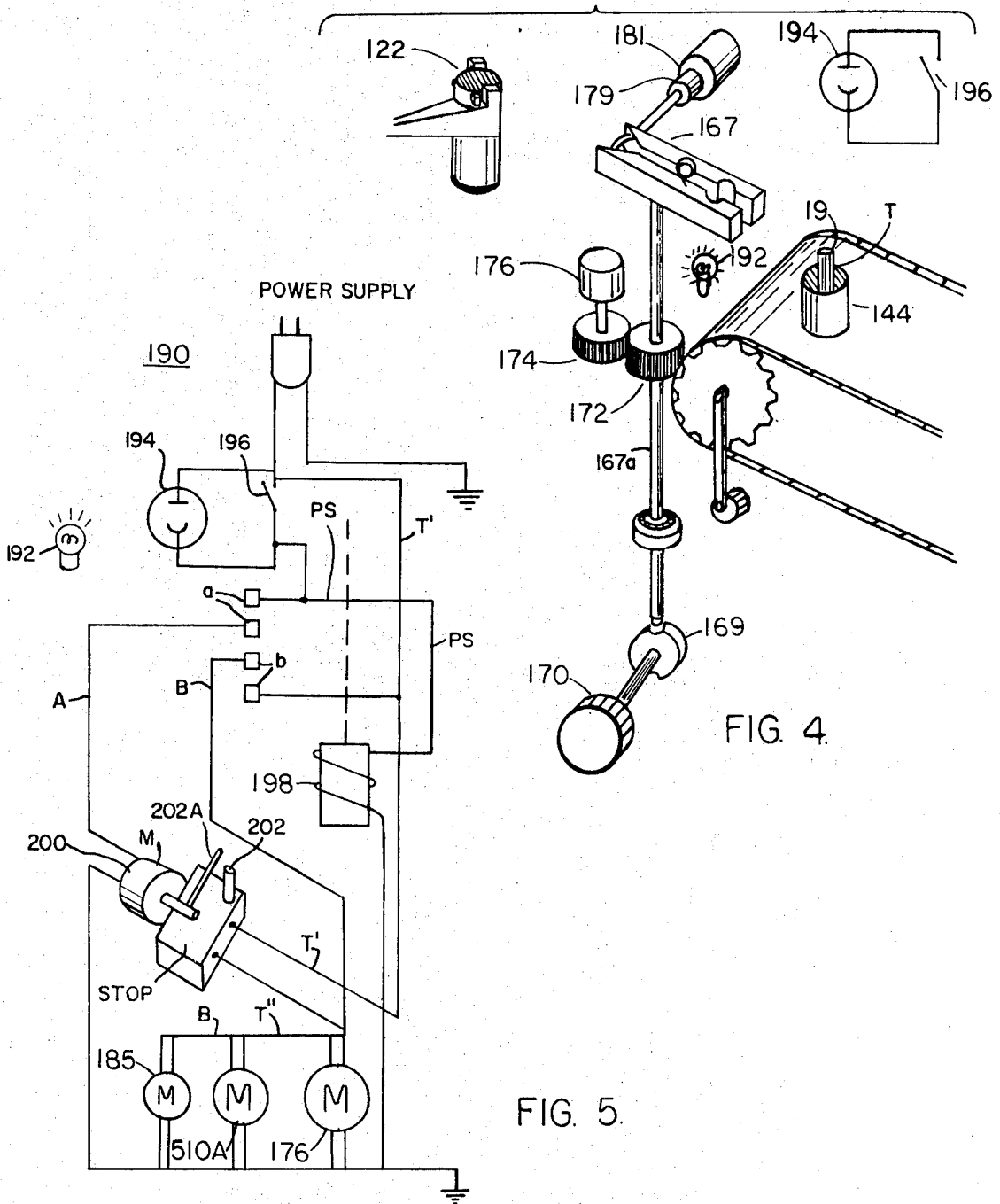


FIG. 4.

FIG. 5.

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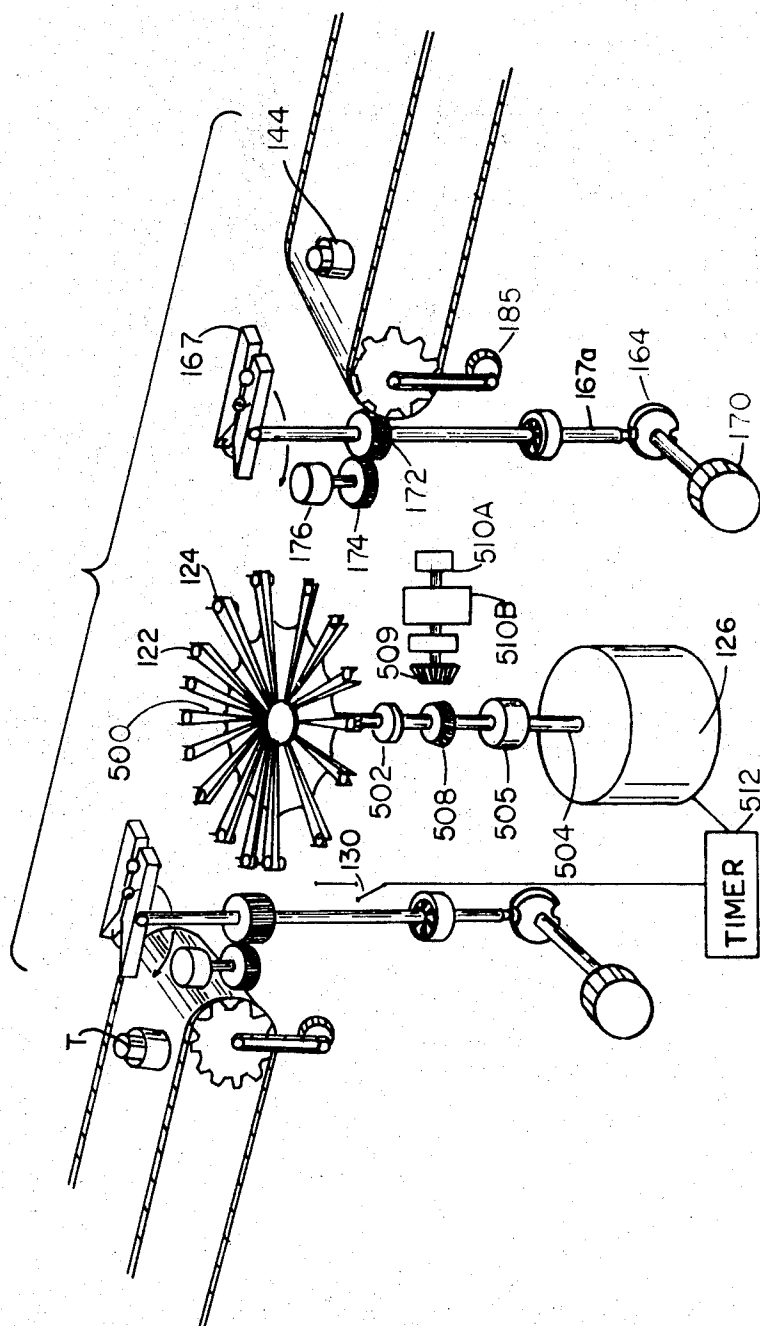
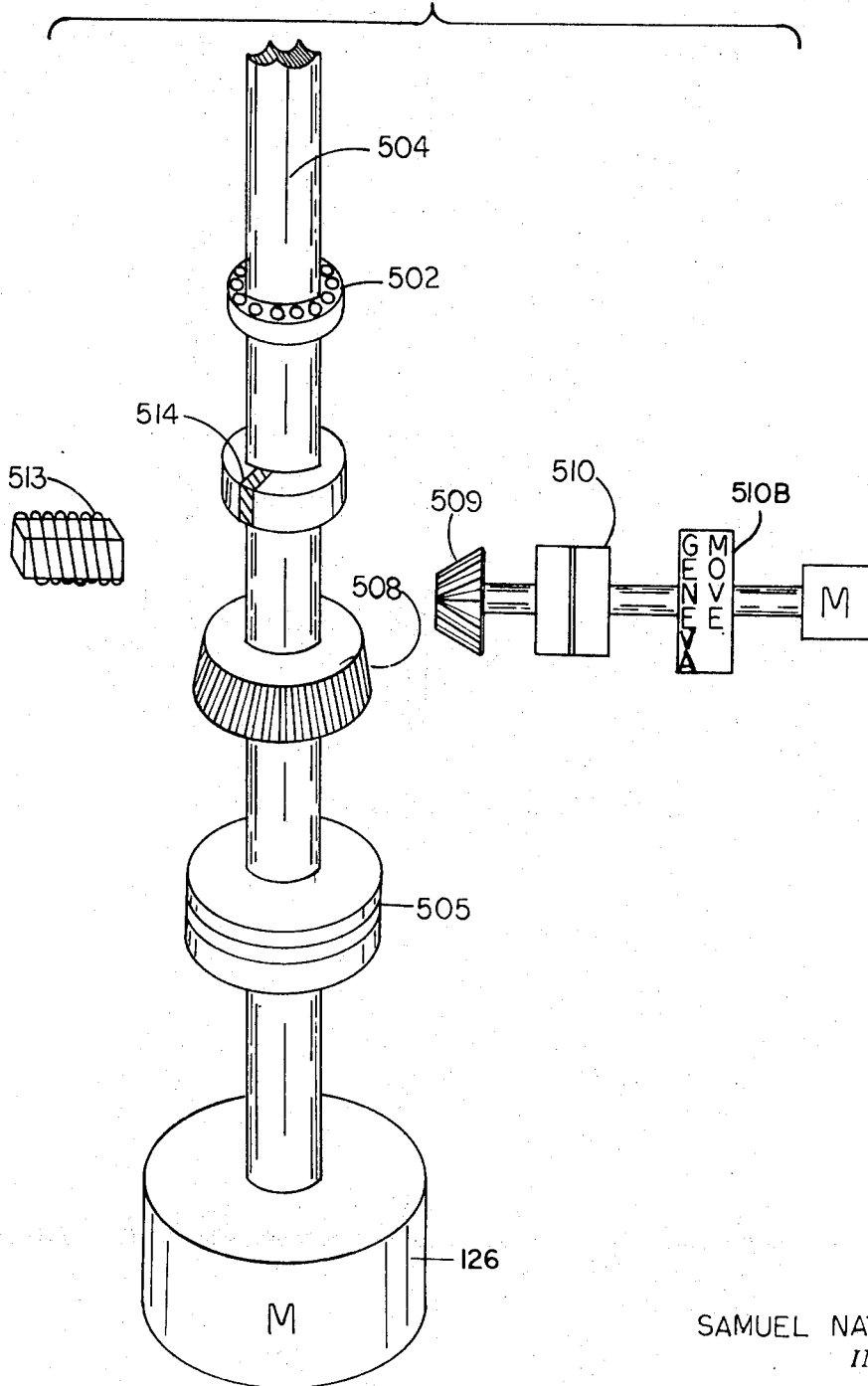


FIG. 6.

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FIG. 7



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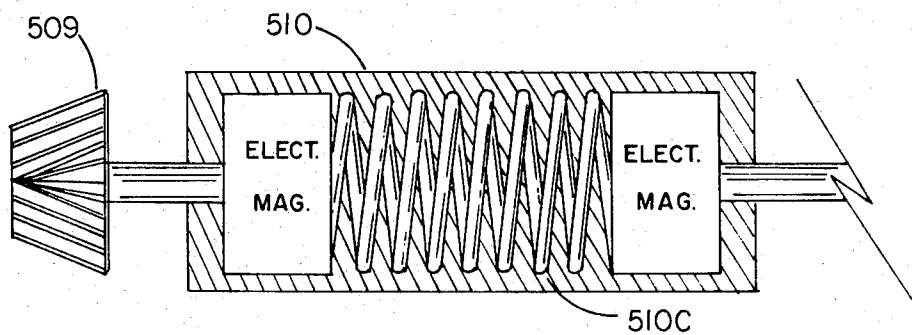


FIG. 8.

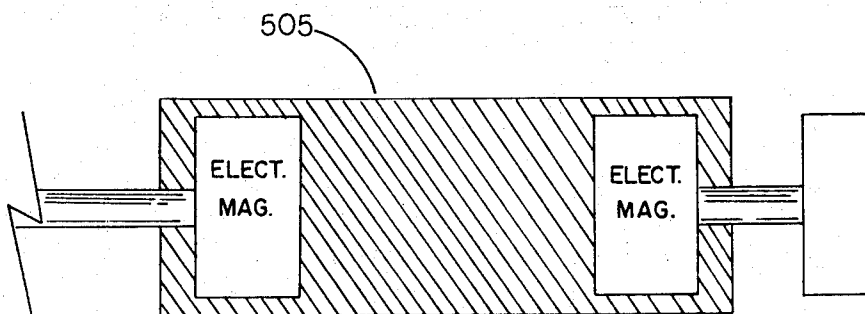
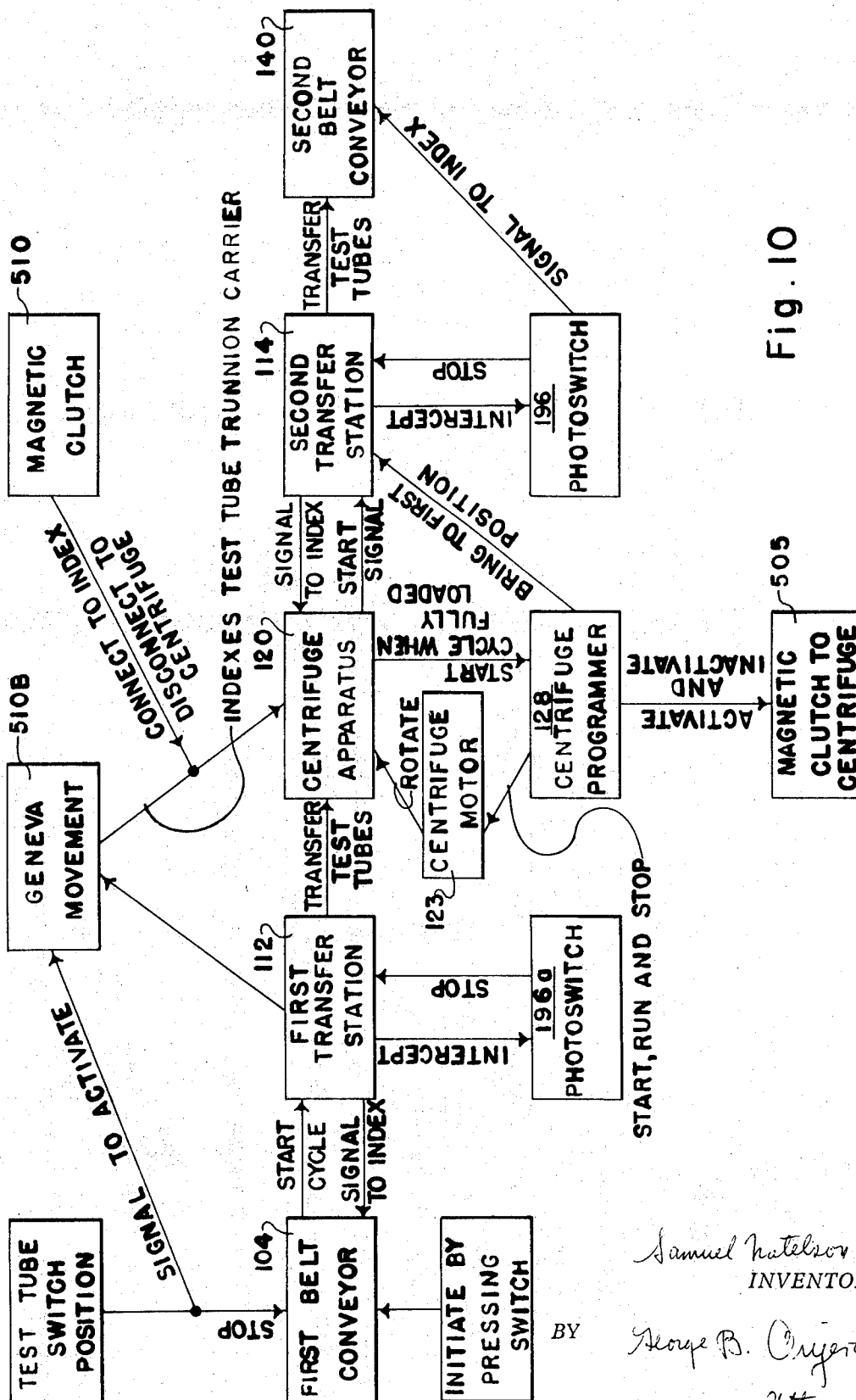


FIG. 9.

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AUTOMATED CLINICAL LABORATORY

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of U.S. Pat. application Ser. No. 845,992, filed July 30, 1969.

The present invention relates to an automated clinical laboratory and more particularly to an automated clinical laboratory system wherein samples can be rapidly and effectively processed, notwithstanding the fact that the workload of samples processed varies considerably over working periods.

Numerous attempts have been made to design a laboratory where blood or urine, or some other biological fluid can be processed automatically. No complete system has been developed. For example, for many chemical determinations a sample of serum needs to be prepared from the blood. The blood is then centrifuged and the serum sampled. The process of placing large numbers of tubes in a centrifuge waiting for the centrifuge to accelerate, operating at high speeds and then coming to rest, usually takes approximately 20-30 minutes. To this must be added the time required to load the centrifuge and unload it. However, one step cannot be carried out. That step is the automatic centrifuging of the sample in a continuous manner. The problem is to centrifuge the sample and have it move out of the centrifugal field. In the previous application of which this is a continuation-in-part, a system was shown for performing this process. This system is flexible and can handle from one to a multiplicity of specimens sequentially.

Where a large number of specimens come down simultaneously, as the bloods which arrive in the morning in a laboratory, it is advantageous to present these specimens in bulk, as in a rack, and have them centrifuged and returned to the rack. This would relieve the operator from the tedium of loading a centrifuge in sequence, adjusting the centrifuge, and then unloading the specimens in the same sequence. Were such a system available, the technician could concern himself with other duties while the tubes are being processed. This application presents such a system which is practical for the purpose. In addition, the automatic centrifuge proposed may also be used as an integral part of a completely automated system of analysis. In this case the centrifuge is loaded and unloaded automatically and the bloods proceed down a beltline for further processing as described in the previous application of which this is a continuation-in-part.

Generally speaking, the present invention contemplates an automated centrifuge system having a conveyor for test tubes to be loaded thereon; a first transfer station to remove the test tubes from the conveyor and place them into trunnion cups on a trunnion carrier; a trunnion carrier including trunnion cups, to receive the test tubes; program means coupled to the trunnion carrier to first slowly rotate the trunnion carrier as the test tubes are loaded, second rapidly rotate the trunnion carrier to centrifuge specimens therein and third slowly rotate the test tubes so that the test tube can be unloaded; a second transfer station to remove the test tubes from the trunnion carrier; and, second conveyor means to convey the test tubes away from the trunnion carrier.

The invention as well as the objects and advantages thereof will become more apparent from the following detailed description when taken together with the accompanying drawing, in which:

FIG. 1 is a block diagram of the arrangement contemplated herein;

FIG. 2 shows a top perspective view of a trunnion carrier useful in the present invention;

FIG. 3 illustrates a trunnion cup used with the trunnion carrier shown in FIG. 2;

FIG. 4 is a perspective explanation of a transfer station of an apparatus contemplated herein;

FIG. 5 is a schematic and block electrical circuit diagram used in connection with the terminal station shown in FIG. 4;

FIG. 6 shows a longitudinal perspective explanation of the inventive concept;

FIG. 7 is a perspective view providing details of the apparatus shown in FIG. 6;

FIG. 8 is a schematic explanation of one of the components useful with the apparatus shown in FIGS. 6 and 7;

FIG. 9 is a schematic explanation of another of the components useful with the apparatus shown in FIGS. 6 and 7.

FIG. 10 is a schematic explanation of the system including all of the mechanical parts related to each other and to the electrical components.

DETAILED DESCRIPTION

Broad Outline of the System

As hereinbefore pointed out, it is necessary to provide for an automatic and continuous centrifuging operation which will provide each separate sample with the required work period without stopping between operations and furthermore provide a sequential system so that one or many samples may be rapidly and sequentially loaded at one end of the apparatus and unloaded at the other.

A schematic and block diagram of the system is illustrated in FIG. 1 which shows an apparatus 100 having a sequential input side 102 shown as a belt conveyor 104 with a holder 106 and with test tubes T on the belt. The belt is turned by a sprocket arrangement 108. The input side 102 will carry a test tube T from a loading station to a first transfer station 112 which includes an arm 114 and engaging means 116. The engaging means 116 will grasp the test tube T and remove the test tube. The arm 114 is responsive to turning means 118 which will cause the arm 114 to swing 180° over a centrifuge apparatus 120 and deposit the test tube T in a trunnion cup 122. Centrifuge apparatus 120 includes a rotor 124 having the trunnion cups 122 disposed along the outer periphery thereof. The rotor is turned by a motor 126 the actions of which are in turn controlled by a programmer 128 the function and description of which will be provided herein.

The test tubes T are sequentially loaded into the trunnion cups as the rotor 124 slowly turns past the first transfer station 112, until they completely fill the rotor outer periphery. As the last test tube trunnion cup is loaded, this will trip the switch 130 and the motor 126 will turn at a rapid rate for a predetermined time period. After this, the rotor 124 will stop and again start turning slowly while a second transfer station 132 opposite the first transfer station 112 takes up the test tubes T sequentially. Second transfer station 132 is similar to first transfer station 112 and likewise has an arm 134 with engaging means 136 to grasp the test tube T from trunnion cups 122. The arm 134 is turned by turning means 138, and will take the test tube T and deposit it on belt conveyor 140 which is similar to belt conveyor 104. Belt conveyor 140 is on the output side 142 and likewise may include a holder 144 to hold the test tubes T, and likewise is run by a sprocket arrangement 146. The test tubes T are then carried to an unloading station where they are unloaded.

From the foregoing explanation it is apparent that the sample, e.g., blood, is placed in a test tube T which is loaded at a loading station on a conveyor belt 104 which will convey the test tube T to a first transfer station 112. The first transfer station 112 includes an arm 114 and engaging means 116 which will grasp the test tube and place it onto a centrifuge apparatus 120 having a rotor 124 with trunnion cups 122. The test tubes will be loaded into the trunnion cups until the rotor is completely filled and at this time the last test tube will enable a switch 130 which will cause the wheel to spin rapidly for a predetermined time period. The rotor will then stop and the test tubes will then be unloaded at a second transfer station 132 similar to the first transfer station. The test tubes are placed on a second conveyor belt 140 and carried to an unloading station.

A portion of the centrifuge apparatus shown schematically as a wheel in the block and schematic explanation given in FIG. 1 is illustrated in greater detail in FIG. 2, and comprises a circular trunnion carrier 500 with extending spokes 152 having outer recesses 154 to receive a trunnion cup 122 shown in FIG. 3.

The transfer device for transferring the test tubes between the trunnion cups and the belt conveyor, is shown in FIG. 4. The test tubes are carried along the belt conveyor in holders 144 permanently attached to the conveyor belt.

A device with elements similar to those shown in FIG. 4 has been described in the Samuel Natelson U.S. Pat. No. 3,331,665. Only one transfer device is shown in FIG. 4. However, two similar devices are used, one at each transfer station as shown in FIG. 1, one for loading and one for unloading test tubes between the centrifuge apparatus and the conveyor belts.

A clamp 167 which resembles in appearance that of a spring clothes pin is mounted on a rod 167a which has a gear 172 thereon and rotates in a circle. A cam 169 operates by a cam motor 170 rotates to lift and lower the clamp rod and gear 172. This gear 172 is engaged by a driver gear 174. Gear 172 is 1½ inch in thickness so that the rod can be lifted without disengaging from gear 174. Gear 174 is operated by a turn motor 176. The clamp is 3 inches in length from jaw to axis so that it moves in a 6-inch circle. When clamp 167, in the elevated position, is positioned over the test tube, turn motor 176 stops. A solenoid 179 with an armature 181 is activated and the clamp 167, now opened, is lowered over the neck 19 of the test tube T. The solenoid is deactivated and the container is clamped. The cam now raises the rod so that the container clears the holder 144. Turn motor 176 is reactivated and the clamp continues its rotation. The test tube T moves to a position over the trunnion cup 122. The cam lowers the test tube into the trunnion cup. The solenoid is activated releasing the test tube and the cam raises the clamp. Turn motor 176 is reactivated and the cycle is repeated. During the clamp travel, a motor 185 is activated and belt moves to position a second test tube for loading. At the same time, indexing motor 510A (See FIG. 6) rotates the trunnion carrier and indexes to the next position by means of the Geneva movement 510B.

The positioning of the clamp above the centrifuge holder and belt holder is controlled by the timer arrangement 190 shown in FIG. 5. Referring to FIG. 5, movement of the clamp of FIG. 4 between light 192 and a photocell 194 closes a photoswitch 196.

Shown in FIG. 5 are the following circuits:

Circuit A across contact points a which runs timer motor 200.

Circuit B across contact points b which runs motors 176, 510A and 185.

Circuit T' across a switch pin 202 responsive to the output shaft of the timer motor as will be herein explained. Circuit T' also makes motors 176, 185 and 510A run.

Circuit PS enabled by closing photoswitch 196. This circuit will close relay 198. Let us first take the situation where the photoswitch 196 is open. Current goes across contact points b which are closed along circuit B and turns motors 176, 185, 510A. Contact points a are not in contact. Next, photoswitch 196 is closed. Current goes through the photoswitch circuit. Relay 198 opens contact points b. The motors 176, 185, 510A stop. Current now goes through contact points a which are in contact. Current flows to timer motor 200. The motor shaft starts to rotate. At the end of the motor shaft is a flag 202A which will hit a normally open switch pin 202 at the end of its run.

Switch pin 202 is now closed by the flag 202A and current passes across the switch pin in circuit T', so that current is again fed to motors 176, 185, 510A. Thus, during the travel time of flag 202A, motor 176 does not run. This is set at 8 seconds for the instrument shown. Turn motor 176, trunnion carrier indexing motor 510A, as well as the belt drive indexing motor 185, are in parallel and when the flag 202A is traveling, all these motors are stopped. Thus, clamp 167 lifts test tube T out of trunnion cup 122 by the action of cam 169 and motor 170. It swings to a position over holder 144 by the action of motor 176, and again by the action of motor 170 and cam 169, lowers the test tube into holder 144.

The action of motor 176 is controlled by photocell 194. When clamp 167 passes between light 192 and photocell 194, the photocell switch 196 closes. This stops motor 176 until restarted by flag 202 hitting switch pin 202A.

When turn motor 176 is activated the trunnion carrier indexing motor 510A also is activated, as well as the indexing motor 185, of the belt drive. In this way, while the clamp is rotating both the trunnion carrier and belt drive carrying the test tubes are indexed to the next position. Motor 185, like 510A operates through a Geneva movement to move one position at a time.

After the test tubes are loaded in all positions the Geneva drive is disengaged from the main shaft of the trunnion carrier and motor 126 centrifuges the test tubes at high speeds for a preset time and then stops. At this point, the test tubes are unloaded in a manner similar to that described for loading, to a second belt drive and from there to a test tube rack. Unloading directly to a second test tube rack is also practical.

The apparatus contemplated herein is shown in FIG. 6 with detailed views of components being shown in FIGS. 7, 8 and 9. The trunnion carrier 500 carries the trunnion cups 122 which swivel in the hook of the trunnion carrier so that the test tube T will be in a horizontal position when centrifuging. The main centrifuge motor 126 is attached to the main shaft 504 of the centrifuge through a magnetic clutch 505. The main shaft is supported by roller bearing 502. When the magnetic clutch and the main centrifuge motor are activated, the trunnion carrier will rotate, centrifuging the samples carried in the test tubes. This clutch is illustrated in FIG. 9 and comprises two shafts with electromagnets which come together when activated. The loading and unloading systems have been described.

The trunnion carrier is indexed by the bevel gears 508 and 509 which connect the main shaft to a Geneva movement through a spring loaded magnetic clutch 510 shown in FIG. 8. When the main motor magnetic clutch is deactivated, the main shaft is disconnected from the main motor. At that time the magnetic clutch attached to the Geneva movement is deactivated, a spring 510C thrusting beveled gear 509 forward makes contact with synchronous bevel gear 508. The test tube T is picked up by the loading clamp which rotates and deposits the test tube in trunnion cup 122. The Geneva movement indexes one position and the next test tube coming from the loading belt drive is now placed in the next trunnion cup. This continues until all the trunnion cups have been filled with test tubes. Movement of the last test tube into the position of the first test tube trips a switch 130, which stops the motion of the loading assembly. This same switch activates the magnetic clutch of the Geneva movement disconnecting the bevelled gears. The switch 130 starts a timing motor of the type shown in FIG. 4 so that 8 seconds elapse. Contact is then made to deactivate the magnetic clutch 505 so that contact is made between main motor and the main shaft. At the same time, main motor 126 starts the rotation of the test tubes, so that the test tubes are centrifuged for a preset time, usually of the order of 5-20 minutes. When the centrifuge time has elapsed, the timer 512, controlling the centrifuging time, cuts the power to centrifuge main motor 126, and permits the centrifuge to decelerate against the electrical braking action of main motor 126. After 5 minutes the clutch 505 is activated and the trunnion carrier continues to rotate at reduced speed.

Braking electromagnet 513 is now activated. This acts on an Alnico magnet 514 embedded in a cylinder attached to the main shaft. The carrier comes to rest with the Alnico magnet facing the braking magnet. The Alnico magnet is so placed that when the trunnion carrier stops, the first test tube is in position to be picked up by an unloading assembly.

The magnetic clutch 505 attached to Geneva movement, 510B, is now inactivated releasing a spring and the unloading assembly and the Geneva movement is activated. The test tubes are now removed in the same sequence in which they were loaded. The unloaded test tubes are disposed along a belt or transposed to a test tube rack which moves stepwise from one

end to the other and returns shifting one row as it comes to the end. This continues until all the test tubes have been unloaded.

At this point a second set of test tubes is loaded to fill the centrifuge and repeat the cycle.

Loading may also proceed from a test tube rack, as pointed out above. In this case, as each tube is removed for loading, the rack moves over one space. At the end of the row a shift laterally, to the next row, takes place and the test tubes are removed from this second row. This proceeds until the trunnion carrier has been completely loaded. Such motions of test tube racks are often used in collecting fractions from a chromatography column and are known to the art.

As an alternative, the main motor 126, may be used to move the test tubes on the trunnion carrier during loading. In this case, a photocell and light assembly is used to position the trunnion cups sequentially in place. However, it is preferable to use the Geneva movement, since with the Geneva movement the trunnion carrier may be moved sequentially with a 50 inch pound shaded pole motor which carries less current in activation and deactivation.

The trunnion carrier shown is of the "swinging bucket" type. An angle head trunnion carrier may be substituted. A convenient number of tubes carried is 30, although smaller or larger trunnion carriers are available commercially. Using 30 trunnion cups, the total time elapsed is usually 5 minutes for loading, 10 minutes for centrifuging, 5 minutes to slow down and 2 minutes to come to rest. Thus every 22 minutes a set of 30 test tubes is centrifuged.

The overall operation of the instrument is summarized schematically in FIG. 10. The operator presses a bypass switch in order to activate the first belt conveyor 104. This causes the belt drive motor to turn until a test tube comes to a test tube switch position. This switch stops the motion of the first conveyor and causes the test tube to remain in this position. Arrival of the test tube at the test tube switch position signals the Geneva Movement and indexer 510A and 510B, to turn the rotor of the centrifuge apparatus 120, to the first position to accept the first test tube. Arrival of the trunnion carrier of the centrifuge apparatus to the first position trips a switch and starts the first transfer station 112.

The transfer mechanism shown in FIG. 4 will go through a cycle and stop if a short bypass signal is given. The transfer mechanism picks up the test tube, transfers it to the first position in the centrifuge apparatus and continues to run until the pick up arm is halfway between the feeder and the centrifuge. There it intercepts a first photoswitch 196a (similar to that shown in FIG. 4), which causes it to stop and index the first conveyor and centrifuge apparatus to each of their next positions. When the second test tube arrives at the photoswitch position the cycle is repeated. This continues until the trunnion carrier of the centrifuge apparatus is fully loaded.

At this point a projection at the final positions of the centrifuge rotor trips a switch which stops all mechanisms, disconnects indexers and starts the centrifuge programmer 128. This programmer 128 comprises a timer motor 126 attached to a shaft on which is disposed a series of cams. Each cam trips a switch at one point in its rotation. Thus, by adjusting the cams, a series of events can be programmed. One of the cams is the cycle cam. After a 360° rotation it trips a switch which stops a timer motor itself ending the cycle. The program is reactivated by providing a momentary bypass to cause this cam to move a short distance, thus releasing the stop switch. On rotation of 360° it will stop again.

The timer motor 126 of the centrifuge programmer 128 runs for a preset time (e.g., 15 minutes) and then disconnects the current from the centrifuge motor drive. The centrifuge now decelerates. The timer motor continues to run and at a preset time, (e.g., 3 minutes after centrifuging has stopped), activates the magnetic brake which causes the centrifuge rotor to stop in an unload position. The centrifuge programmer disconnects clutch 505 and connects clutch 510 and thus the

Geneva Movement. It then trips a switch which starts the second conveyor 142, to index in order to bring a receiving cup into position. The timing mechanism then trips a switch which stops its own rotation as hereinbefore explained. Arrival of the first receiving cup of the second conveyor at its first receiving position delivers a bypass to second transfer mechanism at second transfer station 132, so that it may begin its cycle.

In a manner similar to that at the first conveyor loading station, the transfer mechanism goes through its cycle picking up a test tube from the centrifuge trunnion carrier and transferring it to the second conveyor, 142. Each time it completes a cycle it stops halfway in its rotation between the centrifuge rotor and the unloader. There it intercepts the photoswitch, 196 shown in FIG. 4, which stops its motion and causes the second belt conveyor 140 and centrifuge programmer to index to the next position. When the centrifuge has been emptied of test tubes, a projection in the final position of the centrifuge trips a switch which stops all activities.

This instrument is similarly used in centrifuging the blood received in the chemistry laboratory in the morning, where a large number of tubes with blood are presented simultaneously. It is also useful in a completely automated system of analysis. In this case the test tubes containing the specimens are transferred to the centrifuge, centrifuged and unloaded on a belt drive. Subsequently, these test tubes can be sampled for further processing.

What is claimed is:

1. An automated centrifuge system comprising in combination:
 - a. first conveyor means disposed to horizontally convey test tubes to a first transfer station;
 - b. a first transfer station including transfer means thereat to grasp test tubes, remove them from the conveyor means and place them on another work unit;
 - c. a circular trunnion carrier, adjacent said first transfer station disposed for rotation in the horizontal plane including motor means to rotate said trunnion carrier;
 - d. trunnion cups mounted on the outer end of said circular trunnion carrier to receive said test tubes from said first transfer means;
 - e. a programmer including first rotating means coupled to said trunnion carrier which will index the trunnion carrier so as to allow loading of the test tubes thereon, and then again index the trunnion carrier so that the test tubes may be removed therefrom; second rotating means coupled to said trunnion carrier to rapidly turn the trunnion carrier to centrifuge the contents of the test tubes and, timer means coupled to said second rotating means controlling the centrifuge time;
 - f. a second transfer station adjacent said trunnion carrier angularly away from said first transfer station including transfer means thereat to grasp test tubes and transfer them from the trunnion cups to second conveyor means; and, second conveyor means disposed to carry said test tubes away from said trunnion carrier.
2. A system as claimed in claim 1 in which said second rotating means includes a main shaft connected to said trunnion carrier and a main motor connected to said main shaft for rapidly turning said trunnion carrier and a main motor clutch disposed in said main shaft for engaging and disengaging said main motor to said trunnion carrier, and in which said first rotating means includes a driven means on said main shaft intermediate said main motor clutch and said trunnion carrier and a Geneva drive arrangement for driving said driven means including a motor and clutch disposed for coupling to said driven means for slowly turning said main shaft, and trip switch means connected to said main motor, said Geneva drive arrangement turning said trunnion carrier until a test tube trips said trip switch at which time the Geneva clutch disengages and the main motor clutch engages the main motor with the trunnion carrier for a predetermined time period.

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