Jan. 7, 1969 J. BLUM ETAL 3,420,437

CELL WASHING CENTRIFUGE

Filed Jan. 5, 1968 Sheet 1 of 3

Fig. 1.

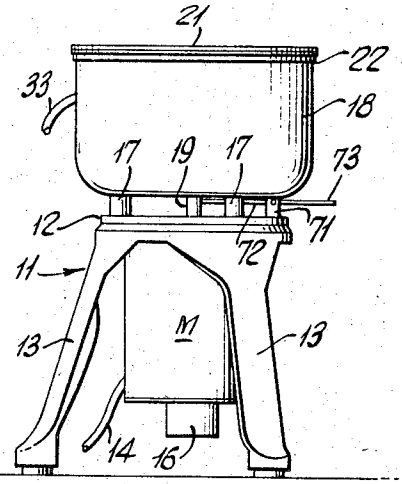


Fig. 2.

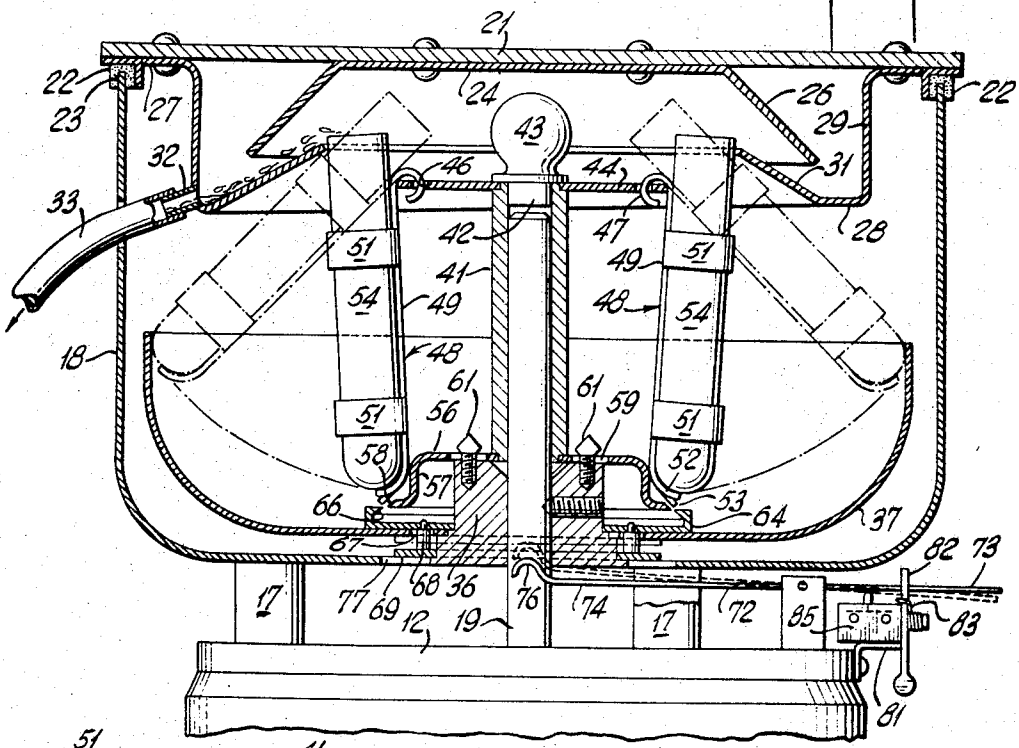


Fig. 3.

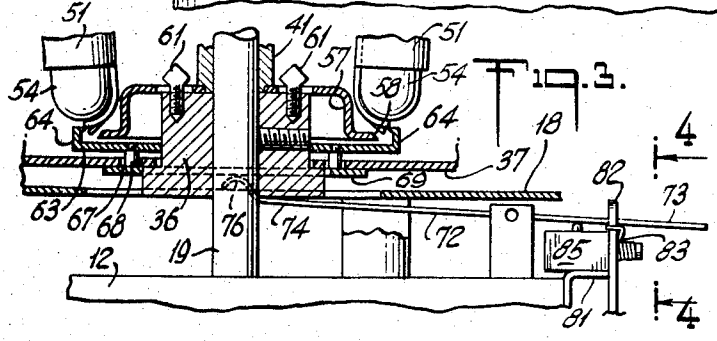
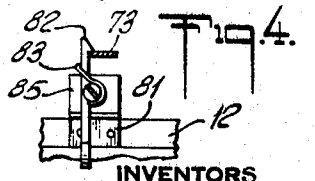


Fig. 4.



INVENTORS
JOSEF BLUM
CHARLES J. FILZ
BY
L. Jordan Kennedy
ATTORNEY

Jan. 7, 1969 J. BLUM ETAL 3,420,437

CELL WASHING CENTRIFUGE

Filed Jan. 5, 1968 Sheet 2 of 3

Fig. 5.

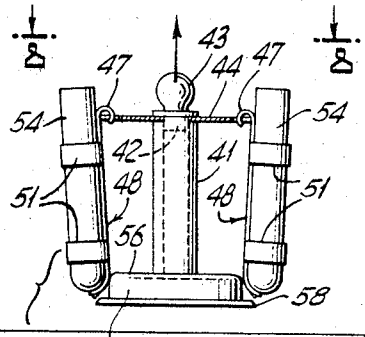
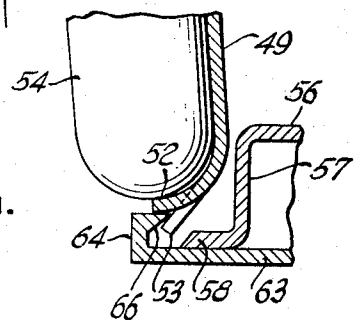
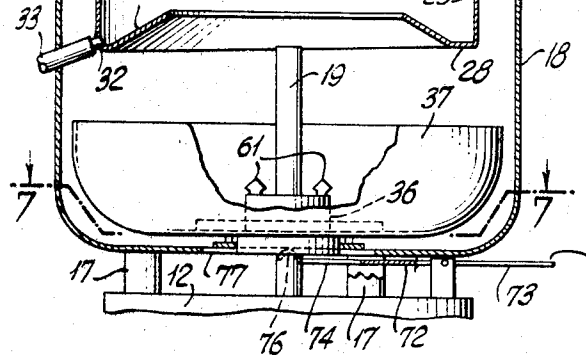


Fig. 6.





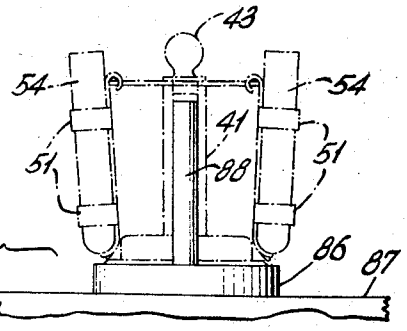


Fig. 7.

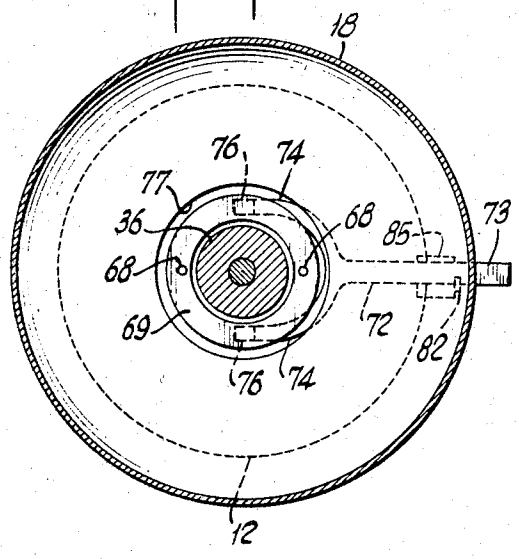
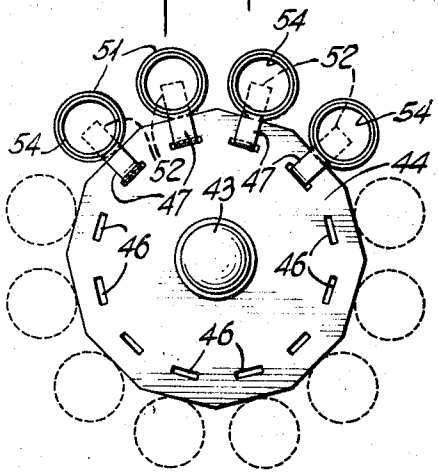


Fig. 8.



INVENTORS
JOSEF BLUM
CHARLES J. FILZ
BY
L. Jordan Kinnick
ATTORNEY

Jan. 7, 1969 J. BLUM ETAL 3,420,437

CELL WASHING CENTRIFUGE

Filed Jan. 5, 1968 Sheet 3 of 3

Fig. 9.

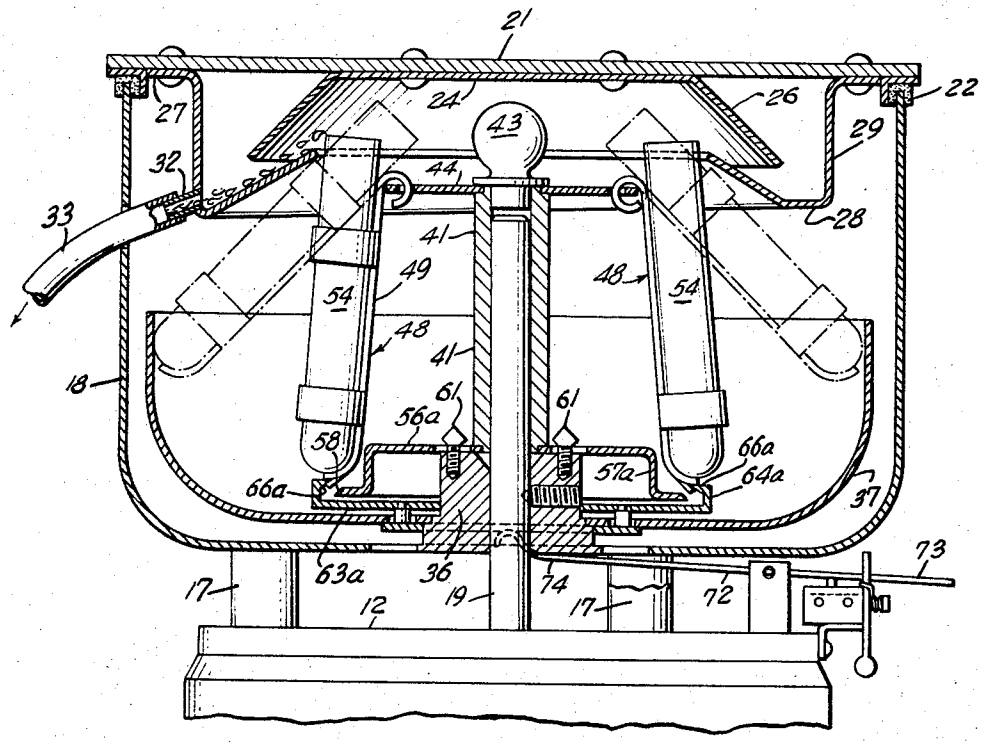


Fig. 10.

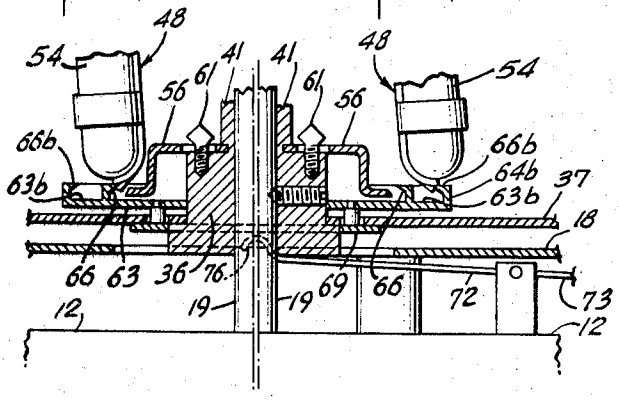
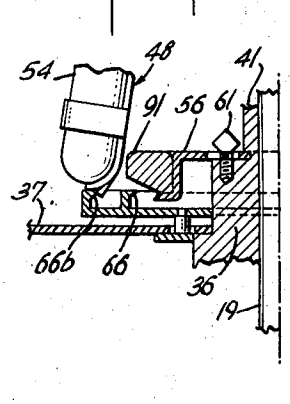


Fig. 11.

Fig. 12.



INVENTORS:
JOSEF BLUM
CHARLES J. FILZ

BY
J. Jordan Finnick
ATTORNEY.

United States Patent Office 3,420,437
Patented Jan. 7, 1969

3,420,437

CELL WASHING CENTRIFUGE

Josef Blum, Norwalk, Conn., and Charles J. Filz, Hamilton, Mont., assignors to Ivan Sorvall, Inc., Norwalk, Conn., a corporation of Connecticut

Continuation-in-part of application Ser. No. 616,393, Feb. 15, 1967. This application Jan. 5, 1968, Ser. No. 696,038
U.S. Cl. 233—26 19 Claims
Int. Cl. B04b 5/04

ABSTRACT OF THE DISCLOSURE

A multispeed centrifuge for treating biological materials in swinging test tubes where both centrifugation and subsequent decantation take place by centrifugal force.

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of a copending United States patent application, entitled Cell Washing Centrifuge, Ser. No. 616,393, filed Feb. 15, 1967, by the same inventors, Josef Blum and Charles J. Filp.

BACKGROUND OF THE INVENTION

(1) *Field of the invention*

The present invention relates to centrifuges and, more particularly, to a multispeed apparatus for centrifuging biological materials which are subjected, successively, to centrifuging and decanting operations.

(2) *Description of the prior art*

As far as applicants are aware, there is no single apparatus known to them that performs successive functions of centrifugation and decanting. In previous apparatus, as disclosed in U.S. Patent No. 2,739,750, biological materials have been subjected to centrifugation in swinging test tubes after which the test tubes had to be removed from the centrifuge for decantation and returned to the centrifuge for further processing with fresh washing liquids or the like. This not only was excessively time-consuming but also involved the handling of apparatus which might be deleterious to the contents of the test tubes. Applicants have solved these problems by providing for biological materials to remain in the test tubes between successive centrifugation and decanting steps without the necessity for disassembling the centrifuge and transporting test tubes containing the biological materials from one place to another. Applicants' apparatus provides for faster, more convenient, and more efficient washing of biological materials by means of the apparatus disclosed herein whereby all of the processing takes place within a single instrument until the work is done.

SUMMARY OF THE INVENTION

The present invention comprises a centrifuge apparatus having a plurality of swinging test tube holders which pivotally support respective test tubes in which biological materials are treated by centrifugation. The apparatus also comprises means for operating the centrifuge at different speeds; first, at high speed, for subjecting the biological materials to centrifugation in the outwardly pivoted test tubes and then, optionally, at a lower speed of rotation of the centrifuge during which the test tubes are held parallel or at a small negative or small positive angle relative to the vertical axis of the centrifuge rotor whereby supernatant washing liquid is decanted automatically from said test tubes. Further means are provided for suspending pivoting or swinging test tube holders on a removable carrier mounted on the rotating shaft of the

centrifuge whereby the test tubes may be initially filled at a location separate from the centrifuge and thereafter mounted on the centrifuge. After processing is completed, the carrier with the test tubes thereon is removed from the centrifuge and can be set upon a laboratory table or other suitable support element for subsequent analysis or testing of the centrifugal materials. Alternatively and optionally, the test tubes may be filled while they are located in the centrifuge apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation of the apparatus incorporating the present invention;

FIG. 2 is a greatly enlarged vertical central section view of the upper portion of FIG. 1, showing details of the centrifuging apparatus, some parts being shown in elevation and with the centrifuging locations of the test tubes being shown in dotted outline;

FIG. 3 is a fragmentary view of a portion of the apparatus shown in FIG. 2 wherein the test tubes are retained in a negative angle decantation position;

FIG. 4 is a fragmentary view taken on line 4—4 of FIG. 3;

FIG. 5 is an enlarged fragmentary view of the lower end of a test tube holder as engaged by the locking ring for the decanting operation;

FIG. 6 is an exploded view, in three sections, showing the manner in which the test tube carrier is removed from the centrifuge shaft, and the manner in which said carrier may be positioned on a laboratory table or stand, some parts being shown in section, some in elevation, and some in dotted outline;

FIG. 7 is a view taken approximately on line 7—7 of FIG. 6;

FIG. 8 is a view taken on line 8—8 of FIG. 6;

FIG. 9 is similar to FIG. 2 showing the test tubes retained in a decanting position at a small positive angle relative to the axis of the centrifuge rotor;

FIGS. 10 and 11 are similar to FIG. 3 and comprise a composite fragmentary view of a further modification of the invention showing a test tube retaining element capable of holding the tubes in either a small negative angle or small positive angle position; and

FIG. 12 is a fragmentary view of a portion of the apparatus showing an additional component for automatically locating the test tubes in a positive angle decanting position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While several embodiments of the present invention are illustrated in separate figures of the drawings and described herein, it will be understood that similar parts will be designated throughout all the figures of the drawings by similar reference numerals.

Referring now to the drawings in detail, the apparatus of the present invention is shown mounted on a base or stand, generally designated **11**, comprising a platform **12**, having three radially and downwardly disposed legs **13**, two of which are shown in FIG. 1. Connected to the underside of platform **12** is a flexibly mounted electric motor M which is connected by a suitable line cord **14** to a source of electric power, not shown. Connected to the motor M is a tachometer **16** which regulates the speed of motor M.

Mounted on the top of platform **12** and raised therefrom on a plurality of posts **17** is a bowl-shaped enclosure **18** of circular shape. Enclosure **18** has a central circular opening at the bottom thereof through which drive shaft **19** extends vertically, said drive shaft being connected to and rotated by motor M.

Mounted on the open top of enclosure **18** is a removable circular cover lid **21**, said cover lid having an annular resilient gasket **22** whose annular recess **23** coacts with the upper edge of eclosure **18** to form an air-tight and liquid-tight seal therewith. See FIG. 2. Connected by suitable means to the bottom surface of cover lid **21** is a circular plate **24** which has a downwardly and outwardly extending annular baffle or deflector flange **26** whose function will be described hereinafter. Also connected to the bottom surface of cover lid **21** by suitable means is the circular horizontal flange **27** of a circular collection trough **28** comprising a vertical annular portion **29** and an inwardly and upwardly extending circular lip **31**, the inner circular edge of said lip having a somewhat smaller diameter than the outer peripheral edge of baffle flange **26** whereby said lip and said baffle flange overlap each other radially. The bottom portion of collection trough **28** is inclined at a slight angle and at the lower portion thereof there is formed an outlet tube **32** that extends outwardly of said collection trough. Connected to the outer end of tube **32** is a drain tube **33** made of rubber or the like which extends through a suitable aperture in enclosure **18**.

In some embodiments, cover lid **21** may be connected to enclosure **18** by means of a suitable hinge, not shown, whereby said lid may remain secured to said enclosure while in the open position.

Drive shaft **19** extends upwardly into enclosure **18**, and to the lower portion of said shaft within said enclosure there is connected, by means of set screw **34**, a drive hub **36** which rotates in unison with said shaft. Connected by suitable means to drive hub **36** is a rotor bowl **37** which rotates with said hub within the chamber formed by the enclosure **18**.

Removably mounted on the upper portion of shaft **19** and fitting telescopically therewith is an elongated tubular or cylindrical hub **41**. Connected to the interior of the upper end of hub **41** is a stub **42**, the bottom of which is spaced apart from the top of shaft **19**. Stub **42** extends upwardly and terminates in a grip knob **43** which enables the manual removal and replacement of hub **41** and its associated parts relative to said shaft. Connected centrally to the upper end of hub **41** is a horizontal carrier plate **44** extending outwardly from said hub. Arrayed in a circle coaxial with shaft **19** near the outer portion of said carrier is a plurality of evenly spaced apart slots **46** which are each pivotally engaged by the curved hinge **47** of a skeleton tube carrier, generally designated **48**, integrally formed with said hinge. See FIG. 8. Each tube carrier **48** comprises an elongated spine **49** made of sheet metal or the like, said spine having at least one or more spaced apart circular tube bands or rings **51**. The bottom portion of each spine **49** terminates in an outwardly curved support flange **52**, a portion of said flange being split to form a hook or tine **53** which extends downwardly from said flange and, together with said flange portion, forms a forked element whose function will be described hereinafter.

Removably insertable through rings **51** of each of the skeleton tube carriers is a test tube **54** made of glass, aluminum, stainless steel, or other suitable material, the bottom of said test tube resting upon and being supported by flange **52**.

Connected to the bottom of hub **41** is a circular bottom plate **56** which has an integrally formed downwardly extending collar **57** which terminates in an outwardly extending flange **58**. Bottom plate **56** has a pair of diametrically spaced apart apertures **59** through which extend the upper ends of respective drive pins **61** mounted in hub **36**. The sides of drive pins **61** are tapered inwardly toward their bottom portions whereby said tapered sides bear against the side apertures **59** to urge bottom plate **56** downwardly during rotation of hub **36**. The inner portion of bottom plate **56** rests upon the top of drive hub **36**.

Although rotation of hub **41** and support plate **44** has been described as being provided by the action of drive pins **61** upon bottom plate **56**, it is understood, in some embodiments, that rotation of said hub and support plate may otherwise be provided by a friction fit between hub **41** and shaft **19**, with said hub being readily removable from said shaft notwithstanding said friction fit.

When the apparatus is normally at rest, skeleton tube carriers **48**, together with the test tubes **54** therein, are suspended at a slight negative angle toward their bottom portions relative to the axis of shaft **19** by virtue of the off-center location of hinges **47** relative to the respective axes of tubes **54**. Skeleton tube carriers **48** and their respective test tubes **54** are maintained at a substantially uniform negative angle relative to shaft **19** by virtue of the lower portions of spines **49** bearing against collar **57** of bottom plate **56**, said angle in some embodiments being in the order of 0° to 5°. The outer periphery of collar **57** is substantially coaxial with the axis of shaft **19**.

During the centrifugation step of the processing performed by the apparatus of the present invention, motor M is energized to cause rotation of drive shaft **19** whereby hub **41** and top plate carrier **44** is rotated, whereby test tubes **54** in skeleton tube carriers **48** are caused to swing outwardly on respective hinges **47** under the action of centrifugal force until the bottoms of said test tubes abut the upper inner end portion of the rotor bowl **37** to limit the outward motion of said tubes. During such centrifugation, the heavier mass of materials such as blood cells or the like in test tubes **54** are urged towards the bottom ends of said tubes by the centrifugal forces engendered therein.

After centrifugation takes place, it is then desired to decant the supernatant liquid in test tubes **54**. Accordingly, motor M is shut off and the centrifuge bowl **37** decelerates to a stop whereby said tubes pivotally descend to their original slightly negatively inclined position as shown in FIG. 2.

Decantation of the supernatant liquid from test tubes **54** takes place under rotation of the centrifuge rotor while the test tubes are maintained in a parallel or slightly negative angled position of 0° to 5° approximately or more relative to the central axis of the centrifuge depending upon the decantation conditions that are necessary or desired. This is accomplished by providing a vertically movable locking element which comprises a circular horizontal ring plate **63** having a central aperture which surrounds a portion of drive hub **36**. Horizontal plate **63** has a peripheral upwardly extending annular flange **64** which terminates in an inwardly extending annular angled locking ring **66**. See FIGS. 2, 3 and 5.

During the centrifuging action of the apparatus, plate **63** rests upon the bottom surface of bowl **37** with rim **66** being downwardly spaced apart from the path of the bottoms of tube holders **48**, as shown in FIG. 2.

The bottom of bowl **37** has a pair of diametrically spaced apart apertures **67** through which vertical actuator pins **68** freely extend, said pins being connected to horizontal plate **63**. The bottom ends of actuator pins **68** rest freely upon a circular actuator ring **69** which surrounds drive hub **36** and which is movable vertically relative thereto.

Mounted on platform **12** is a pivot post **71** to which is pivotally connected a lift fork, generally designated **72**, the outer portion of which comprises a manually operated handle **73** and the inner portion of which terminates in a pair of spaced apart tine elements **74** extending to opposite sides of shaft **19**. See FIGS. 2, 3, and 7. The ends of tine elements **74** are each formed in the shape of upwardly bowed knuckles **76**.

The bottom floor of enclosure **18** has an annualar opening **77** through which knuckles **76** are freely movable vertically. Knuckles **76** are normally in the retracted position, as shown in the solid line representation of FIG. 2. When

handle 73 is depressed to raise lift fork 72, knuckles 76 move upwardly through annular opening 77 to bear against and raise actuator ring 69 which, by way of pins 68, lifts ring plate 63 into a position where locking rim 66 is engageable by hook 53 or, optionally, by the outer end of support flange 52 of each tube holder 48.

When bowl 37 is again rotated, the normal outward pivoting action of tubes 54 is prevented by hook 53 or flange 52 engaging locking rim 66 so that said tubes are maintained in a vertical or slightly negative angle position relative to the axis of rotor shaft 19. While bowl 37 rotates with the retention of tubes 54 by locking rim 66 against the action of centrifugal force, supernatant liquids discharge from the tops of tubes 54 over onto circular lip 31 and thence into collection trough 28. Said supernatant liquids then flow in trough 38 toward outlet tube 32 through which they are discharged into drain tube 33 for collection or disposal, as may be desired or necessary. Baffle plate 26 prevents splashing of the discharging supernatant liquids which are thereby deflected into trough 28.

During decantation operation of the rotor, handle 73 may be continually depressed manually for the comparatively short time that is necessary for such decantation. In some embodiments, however, a bracket 81 mounted on platform 12 may be provided pivotally to support a lever latch 82 which is actuated by a spring 83 to hold handle 73 in the depressed position, as shown in FIG. 4. Handle 73 may be released by manually moving latch 82 out of engagement with handle 73. In other embodiments, solenoid or other electrical means may be provided to operate handle 73 for controlling the position of locking rim 66.

When rotor bowl 37 comes to rest after decantation, the bottom ends of tube holders 48 and tubes 54 move inwardly by pivoting under their own weights on the off-center hinges 47 until spines 49 bear against collar 57 of bottom plate 56, whereby hooks 53 have become disengaged from locking rim 66. Thereafter, with handle 73 released, locking rim 66, plate 63, and actuator ring 69 descend by gravity, thereby lowering locking rim 66 away from the arcuate path otherwise traversed by hook 53 when tubes 54 are subjected to centrifugation. The descent of actuator ring 69 also causes the descent of knuckles 76 when downward pressure is released from handle 73.

When tubes 54 are in the decanting position, the tops thereof are spaced apart from the inner edge of lip 31 of trough 28. Under centrifugal action in this circumstance, supernatant liquid in each tube 54 rises upwardly along the outer portion thereof and when said liquid reaches the top of the tube, the liquid traverses across the gap into trough 28 under centrifugal action without any leakage of liquid into rotor bowl 37.

After decantation has taken place, cover lid 21 may be lifted from enclosure 18 so that washing fluid or the like may be added to test tubes 54 for further treatment of the blood cells or other biological materials that are being processed therein. Thereafter, cover lid 21 is closed and successive centrifugation and decantation processing steps may be repeated.

After a sufficient number of cycles of centrifugation and decantation have taken place, cover lid 21 is opened and with locking rim 66 in the disengaged position, knob 43 is grasped and lifted vertically to remove hub 41 from shaft 19 whereby the assembly of top plate 44, bottom plate 66, test tube holders 48 and test tubes 54, is simultaneously removed as a separate, self-contained unit from the centrifuge, as shown in FIG. 6, with flange 58 serving as a base for location upon a table or platform. It may also be desirable to provide a separate stand for said assembly as shown in another portion of FIG. 6 in the form of a base 86 of suitable shape standing upon a table or bench 87, said base 86 having a vertical dummy shaft 88 which has the same dimensions as shaft 19. Hub 41 is placed upon dummy shaft 88 so that the assembly of the test tubes may be securely positioned in order to facilitate the handling of said test tubes by the laboratory experimenter or technician.

Although deflector 26 and trough 28 are shown in FIG. 2 as being connected to cover lid 21 whereby all of said elements are removable as an assembly from enclosure 18, it is contemplated that suitable modifications can be arranged whereby cover lid 21 and deflector 26 together are removable while trough 28 remains secured to enclosure 18 and is separately removable therefrom for cleaning. In both alternative structures, drain tube 33 may be disengageable from outlet tube 32. Deflector 26 and trough 38 may also be removably attached to cover lid 21 whereby said components may be disassembled for cleaning or replacement and then reassembled.

In some processing operations, it may be desirable to perform the decanting step with the test tubes retained at a small positive angle relative to the axis of the rotor. Accordingly, as shown in FIG. 9, the apparatus is modified by providing that plate 63*a* has a larger diameter than plate 63 in FIGS. 2, 3 and 5. Plate 63*a* has an integrally formed vertically extending flange 64*a* which terminates in an inwardly extending annular angled locking rim 66*a*, the diameter of locking rim 66*a* being somewhat larger than the diameter of locking ring 66 in FIGS. 2, 3 and 5.

Thus, when plate 63*a* is lifted into the hooking position and the rotor is spun, upon outward movement of tubes 54 hooks 53 are engaged and retained in position by locking rim 66*a* in a location where tubes 54 are secured at a small positive angle relative to the axis of the centrifuge rotor. In this position, when the rotor turns at the lower decantation speed, as described hereinbefore, the extent of decantation can be controlled. Furthermore, it is evident that, because of the small positive angle of tubes 54, which are restrained in that position, a certain controlled amount of residue can be detained in said tubes irrespective of the speed of rotation. By selecting the diameter of plate 63*a*, it is possible to determine the extent to which a particular desired quantity of material should remain in the tubes after decantation. The positive angle of retention of tubes 54 may vary between 0° to approximately 15° or more relative to the central axis of shaft 19, depending upon the decantation conditions that are necessary or desired.

In the composite illustration of FIGS. 10 and 11, an arrangement is provided whereby a single component may be operated to retain the test tubes in either the negative or positive angle decantation positions. Horizontal plate 63 is provided with an integrally formed outwardly extending ring 63*b* which has an integrally formed upwardly extending annular flange 64*b* which terminates in an inwardly extending annular angled locking rim 66*b*. Alternatively, hooks 53 may be engaged either by coaxial locking rims 66 or 66*b*, depending upon whether tubes 54 are to be retained in a negative angled (FIG. 10) or positive angled (FIG. 11) decantation position, respectively, at the choice of the operator of the apparatus. Other suitable equivalent means may be utilized to provide alternative and selective retention of tubes 54 in either the small negative or small positive angled position for decantation purposes.

In order to facilitate the use of the alternatively selectable device shown in FIGS. 10 and 11 for locating the tubes 54 in a positive angle position, a removable ring 91 may be slipped over the shoulder 57 of plate 56 whereby the lower portions of spines 49 will be prevented from moving too far inwardly so that hooks 53 will be engaged only by locking rim 66*b*.

Although it has been indicated herein that decantation may take place at a lower speed than that of centrifugation, it is to be understood that the particular speed of decantation may be predetermined by the particular angle at which tubes 54 are retained and the acceleration rate of the rotor on which said tubes are mounted. By controlling the negative or positive angle of the tubes relative

to the axis of shaft **19**, the acceleration rate of the rotor and the duration of rotation of the rotor, it is possible to decant the supernatant liquid from tubes **54** down to a precise volume. In some embodiments, a suitable variable speed control may be connected to motor M for determining the most advantageous speed of said motor in the circumstances of the particular structure of the apparatus and the gap across which the supernatant fluid is to traverse between the tops of tubes **54** and the inner edge of lip **31** of trough **28**. In other embodiments, automatic determination of a specific decantation speed different from the centrifuging speed may be accomplished by providing a microswitch **85** on bracket **81** which is actuated when handle **73** is depressed, said switch being connected to suitable electrical speed control circuitry well known in the art.

It is evident that when tubes **54** are retained at a slight negative angle as shown in FIGS. 3 and 5, the time of rotation of the centrifuge at the lower decantation speed must be limited by the operator to prevent complete evacuation of the contents of said tubes. Accordingly, a definite time limit must be prescribed for decantation at the negative angle either by visual inspection or by predetermined time periods as established by empirical experience so that the desired amount of residue will remain in the test tubes after decantation.

As to the conditions obtaining when decanting from test tubes **54** are retained at a positive angle relative to the rotor axis, the decantation angle will be determined, in addition to the factors of rotor speed and time of rotation, by the dimensions of tubes **54**. The retention of tubes **54** at a positive decantation angle will delimit the amount of supernatant liquid that can emerge from the upper and outer edge portion of the mouths of said tubes.

It is evident that the greater the positive angle of decantation retention, the lesser amount of fluid will be discharged by decantation from tubes **54**. With positive angle decantation, the inside diameter of lip **31** of trough **28** will be somewhat smaller and would be suitably retracted to provide a small enough gap for the decanting liquid to flow from tubes **54** into trough **28**.

The apparatus of the present invention is particularly useful where repeated washing and centrifuging operations are necessary as, for example, in the procedure for testing cells for the D^u factor by the indirect antiglobulin (Coombs) test wherein a saline suspension of red blood cells are successively centrifuged and washed at least three times. It is evident that with centrifuge apparatus that lacks the inherent means for decantation, considerable time and effort would have to be expended in removing supernatant liquid from a plurality of test tubes for several successive stages of the processing. The present apparatus, however, conserves considerable time and effort whereby the decantation takes place simultaneously from all of the test tubes without the necessity for handling each of them. Refilling of the test tubes with successive quantities of wash solutions in the apparatus described herein is quickly and easily accomplished for the next succeeding centrifuging operation.

The present invention contemplates within its scope the provision of means for removably mounting a plurality of test tubes relative to a centrifuge rotor whereby said test tubes are enabled to swing outwardly during a centrifuging step and are prevented from swinging completely outwardly during a decantation step. Also, simple test tube holders are provided comprising means that not only serve to support the bottoms of the removable test tubes, but also are engageable by a movable locking element associated with the rotor for retaining the holders and the test tubes therein in the decantation position during rotation of the rotor.

Although the present invention has been described with reference to particular embodiments and examples, it will be apparent to those skilled in the art that variations and modifications can be substituted therefor without departing from the principles and true spirit of the invention.

What is claimed is:

1. A centrifuge comprising a motor, a rotor connected to and driven by said motor, a plurality of test tube holders mounted pivotally in circular array on said rotor, said tube holders being movable pivotably outwardly under centrifugal force when said rotor rotates, and an element on said rotor movable into either of two positions, said element in one position being spaced apart and disengaged from said tube holders, said element in the other position engaging said tube holders and retaining them captive in a position where the axes of the tubes in said tube holders are maintained between a parallel array and a small angle relative to the axis of said rotor as the latter rotates for decantation purposes.

2. A centrifuge according to claim **1** and further comprising a circular trough mounted above said rotor, the inner edge of said trough being spaced apart from and surrounding coaxially the circular path defined by the tops of tubes in said tube holders when held captive whereby supernatant liquids in said tubes are caused to flow into said trough during rotation of said rotor.

3. A centrifuge according to claim **1** and further comprising means removably positioned on said rotor for pivotally supporting said test tube holders.

4. A centrifuge according to claim **1** wherein each of said tube holders comprises an elongated spine, pivot means on the top of said spine, means intermediate the ends of said spine within which a test tube is removably retained, and outwardly extending means on the bottom of said spine for supporting the bottom of said tube in all pivoted positions of said holder relative to said rotor.

5. A centrifuge comprising a base, a motor connected to said base, a drive shaft connected to said motor, a rotor mounted on said drive shaft, an elongated tubular hub removably mounted on said drive shaft and rotatable therewith, a support plate connected to the upper portion of said hub, a plurality of test tube holders mounted pivotally in a circular array on said support plate, the pivot mounting of each of said test tube holders being located off-center of the axis of test tubes to be held in said holders whereby said holders are normally suspended at a slight negative angle relative to the axis of said shaft when said shaft is at rest, an element on each of said test tube holders, a locking ring mounted on said rotor, said locking ring being normally positioned out of engagement with said elements, said locking ring being movable at will into a position to engage said elements and to retain said test tube holders in a position where the axes of the tubes therein are between a zero degree and a small angle relative to the axis of said shaft during rotation of said rotor.

6. A centrifuge according to claim **5** wherein said test tube holders comprise an elongated spine and a hinge formed at the upper end of said spine for said pivot mounting, the lower end portion of said spine being curved outwardly to serve as a support for a test tube, and at least one curved band on said spine into which a test tube may be removably inserted, the end of the curved portion of said spine forming the element engageable by said locking ring.

7. A centrifuge according to claim **5** and further comprising a generally circular bottom plate connected to the lower portion of said hub, said bottom plate serving as a base for positioning the assembly of said hub, support plate, and test tube holders in another location when said assembly is removed from said shaft.

8. A centrifuge according to claim **5** and further comprising a rotor bowl connected to said shaft, the inner walls of said bowl serving as a limiting abutment for test tubes located within said test tube holders when said locking ring is in a location of disengagement from said

tube holders and said test tube holders are swung outwardly under centrifugal force.

9. A centrifuge according to claim 5 and further comprising a test tube in each of said holders, an enclosure surrounding the assembly of said drive shaft, hub, tube holders and test tubes, a circular trough in the interior of said enclosure, the inner peripheral edge of said trough being spaced apart from and surrounding coaxially the circular path of the tops of the test tubes when the latter are retained in the locked position whereby fluids flow from said test tubes into said trough under centrifugal force as said test tubes rotate around said shaft in said locked position.

10. A centrifuge according to claim 9 and further comprising a circular baffle plate suspended on said enclosure and located above said trough, said baffle plate overlapping the inner portion of said trough and serving to ensure the deflection of said fluids from said test tubes into said trough.

11. A centrifuge according to claim 5 and further comprising a pivotally mounted lever on said base, said lever cooperating with said locking ring whereby the pivoting action of said lever moves said locking ring into engagement with said elements and the release of said lever permits said locking ring to move into a position of disengagement from said elements.

12. A centrifuge according to claim 5 and further comprising a drive hub connected to said shaft, a bottom plate connected to said tubular hub and removable therewith, at least one aperture in said bottom plate, a drive pin mounted in said drive hub and extending through said aperture to cause rotation of said bottom plate and said tubular hub with the rotation of said drive hub.

13. A centrifuge according to claim 5 and further comprising a rotor bowl connected to the lower portion of said shaft underneath and spaced apart from the lower portions of said test tube holders when the latter are at rest, a circular locking plate mounted around and movable vertically relative to said shaft and normally resting upon the inner bottom surface of said bowl, an upwardly extending annular ring on said locking plate, said ring being normally spaced apart from said elements, an actuator plate located below said bowl, a pair of spaced apart apertures in the bottom of said bowl, a pin extending freely through each of said apertures and connecting said locking plate to said actuator plate, the upward movement of said actuator plate causing the upward movement of said locking ring into position for engagement with said elements, and a lever pivotally mounted on said base for moving said actuator plate and said locking ring into said element engaging position, the release of said lever permitting said locking plate to descend to the floor of said bowl and said locking ring out of engagement with said elements.

14. A centrifuge according to claim 13 wherein said lever is formed in the shape of a two-tined fork with said tines located on opposite sides of said shaft, the end portions of said tines being movable under the pivoting action o said lever into lifting engagement with said actuator plate for lifting said locking ring.

15. A centrifuge comprising a motor, a rotor connected to and driven by said motor, a plurality of test tubes mounted pivotally in circular array on said rotor, said tubes moving pivotally outwardly during centrifuging operation of said rotor, and a locking element on said rotor normally retracted from said tubes during centrifuging operation of the rotor and movable at will into a position to retain the axes of said tubes at between a parallel array to a small angle relative to the axis of said rotor during decantation operation of said rotor.

16. A centrifuge according to claim 15 and further comprising a support structure removably mounted on said rotor, said test tubes being mounted on said support structure for removal and replacement in a group relative to said rotor.

17. A centrifuge comprising a motor, a rotor connected to and driven by said motor, a plurality of test tube holders mounted pivotally in circular array on said rotor, each of said tube holders having an elongated spine, means intermediate the ends of said spine within which a test tube is removably retained, outwardly extending means on the bottom of said spine for supporting the bottom of said tube in all pivoted positions of said holder relative to said rotor, and movable means associated with said rotor, said movable means in one position being spaced apart and disengaged from said supporting means, said movable means in another position engaging said supporting means to retain said tube holders captive in a position where the axes of tubes in said tube holders are maintained substantially between a parallel array and a small angle relative to the axis of said rotor as the latter rotates.

18. A centrifuge according to claim 17 wherein said movable means comprises a pair of coaxial annular locking elements, said supporting means being engageable alternatively and selectively with either one of said locking elements, the engagement between said supporting means and the first of said locking elements causing said tube holders to be retained at a small negative angle relative to the axis of said rotor, the engagement between said supporting means and the second of said locking elements causing said tube holders to be retained at a small positive angle relative to the axis of said rotor.

19. A centrifuge comprising a motor, a rotor connected to and driven by said motor, a plurality of test tube holders mounted pivotally in circular array on said rotor, said holders moving outwardly under centrifugal force when said rotor spins, means on said rotor movable selectively at will toward and away from said test tube holders, and first and second coaxially arrayed locking elements on said movable means, the engagement of said tube holders with the first of said locking elements causing said tube holders to be retained at a small negative angle relative to the axis of said rotor while the latter spins the engagement of the tube holders with the second of said locking elements causing said tube holders to be retained at a small positive angle relative to the axis of said rotor while the latter spins.

References Cited

UNITED STATES PATENTS

411,570	9/1889	Beimling	233—26
2,507,309	5/1950	Larsson	233—26
2,739,759	3/1956	Davidson et al.	233—26
2,834,541	5/1958	Szent-Gyorgyi et al.	233—26

FOREIGN PATENTS

527,712	10/1940	Great Britain.
737,761	9/1955	Great Britain.

WILLIAM I. PRICE, *Primary Examiner.*