

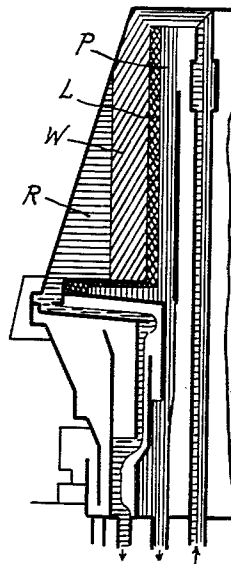
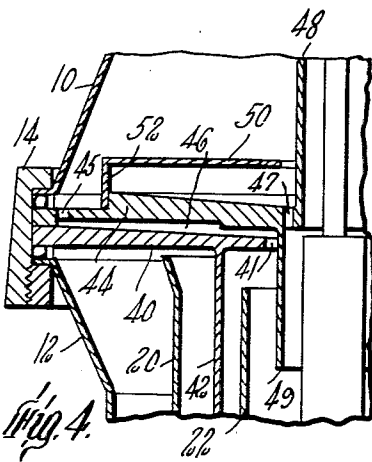
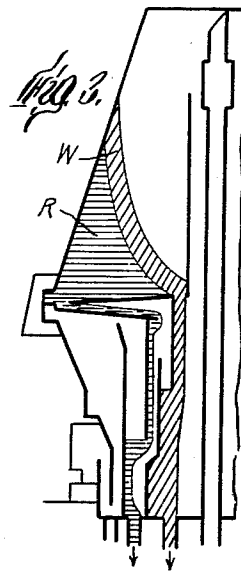
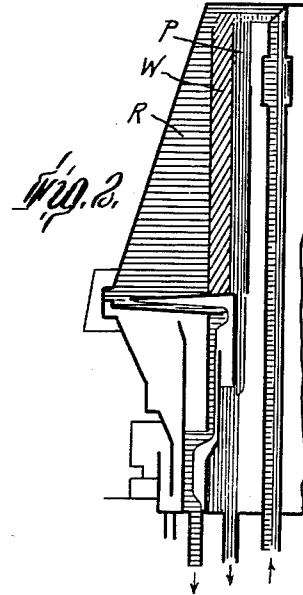
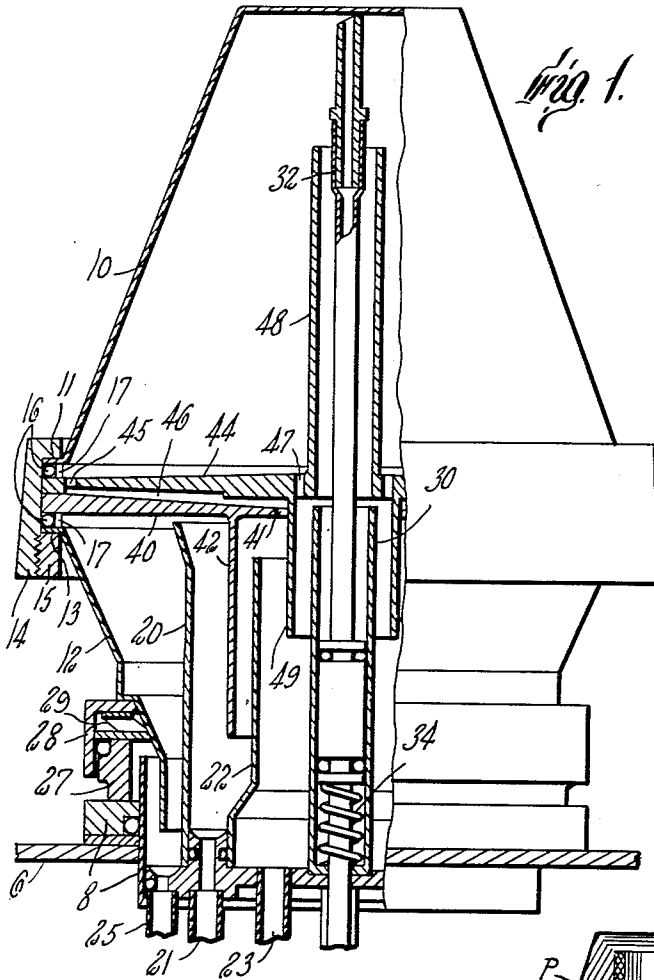
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C. E. APPLEGATE

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CENTRIFUGE

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CENTRIFUGE

Charles E. Applegate, Weston, Mass., assignor, by mesne assignments, to Protein Foundation Incorporated, a corporation of Massachusetts

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This invention relates to centrifugation and, more particularly, to centrifugal apparatus useful in the separation of the various components of animal blood, though it may equally well be used in the separation of components, having different specific gravities, of other liquids, fluids, suspensions, or the like.

In U.S. patent applications Serial Nos. 500,738 and now Patent No. 2,906,450; 500,746 and now Patent No. 2,906,452; 500,753 and now Patent No. 2,906,453; 500,787 and now abandoned; and 500,882 and now Patent No. 2,906,451, filed April 12, 1955, are described centrifugal apparatus and bowl structures therefor especially useful for carrying out various separations of the elements of whole blood, that is, red blood cells, white blood cells, platelets and plasma which differ in specific gravity.

The present invention is directed to improved centrifuge bowl structures especially adapted for use with the centrifugal apparatus described in said applications, such improved bowl structures providing continuous separation of two components of differing specific gravity, with collection in the centrifuge bowl of one or more additional components as desired.

It is a particular feature of the invention that, with two component separation, true continuous separation, not limited as to either component by bowl volume, is achieved. Thus, the quantity of liquid to be separated into two components is independent of bowl volume so that a uniformly small bowl may be used for any quantity of liquid to be separated.

It is another feature of the invention that a third component of specific gravity intermediate between the two components to be continuously separated is collected in the bowl during such continuous separation and may be periodically discharged therefrom.

It is still another feature of the invention that a component of specific gravity intermediate between said two components may be subjected to unusually high forces for better separation thereof from the lightest component to be separated, so that, for example, a fourth component of specific gravity intermediate between said third component and the lightest of said two components may be so separated and collected.

It is an important feature of the invention that any of the above mentioned separations may be carried out under sterile conditions as is especially important with fluids of animal origin, such as whole blood.

Various other objects and features of the invention will become apparent from the following description of preferred embodiments thereof, together with the accompanying drawings wherein

Fig. 1 is a cross-sectional view showing the centrifuge bowl structure of the present invention;

Fig. 2 is a diagrammatic cross-sectional view showing the operation of the bowl of Fig. 1 during continuous separation of two components and collection in said bowl of a third component;

Fig. 3 is a diagrammatic cross-sectional view showing

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the operation of the bowl of Fig. 1 during discharge of said third component;

Fig. 4 is a partial cross-sectional view showing a modification of the bowl of Fig. 1; and

Fig. 5 is a diagrammatic cross-sectional view showing the operation of the bowl of Fig. 2 during continuous separation of two components and collection in said bowl of a third and a fourth component.

The centrifuge bowl structures of the present invention are adapted to be used with the centrifugal apparatus as shown in said applications Serial Nos. 500,738; 500,746; 500,753; 500,787 and 500,882, and hence such apparatus will not be described herein in detail. Briefly, however, the apparatus supports and drives the centrifuge bowl and holds the external collecting receptacles, the bowl being rotatably mounted on a base which includes a table portion 6 and a cylindrical portion 8 removably mounted therein for directly supporting the lower portions of the bowl. The bowl is driven by a magnetic chuck (not shown) adapted to contact the bowl in the upper portion thereof.

The centrifuge bowl itself in general includes a top bowl 10 of generally conical shape having a top wall and an outwardly and downwardly sloping side wall, a bottom bowl 12 also of conical shape, and a compression arrangement including outer compressor ring 14 holding the two bowls together. The bowls and other elements which come in contact with blood are preferably of stainless steel with a silicone coating.

With a multiple piece centrifuge bowl as herein described, it is important that a fluid-tight seal be provided between the top and bottom centrifuge bowls and the intermediate ring. Thus, the top bowl has an outwardly extending annular flange 11 at its lower edge and the bottom bowl 12 has a similar flange 13 at its upper edge. The peripheral rim portion of the internal elements 40 and 44, as hereinafter described, is interposed between the flanges, and suitable sealing means comprising O rings 16 are interposed as required, between said rim portions and flanges 11, 13 respectively. Spacing rings 17 are also interposed between said rim portions and flanges 11, 13 radially inwardly of the O rings to limit the movement of flanges 11, 13 toward one another, said spacing rings being of a dimension somewhat less than that of the uncompressed O rings. Thus, a predetermined overall dimension of the assembled centrifuge can be provided, yet with adequate sealing. The opposed flanges 11, 13 are urged together by outer compression ring 14 and inner compression ring 15, the outer compression ring having an inwardly extending flange which fits over top bowl flange 11. The downwardly extending skirt of the compression ring itself is screw threaded on its inner surface to cooperate with the screw threaded outer surface of its cooperating locking ring 15, the upper surface of said latter ring contacting the bottom bowl flange as it is screwed into place to clamp flanges 11, 13 together.

Figs. 1 and 4 show the centrifuge bowl structure above described with various interior baffle arrangements according to the present invention, and Figs. 2, 3 and 5 show the operation of said bowl structures with the bowl running for the separation of the blood components. It will be noted that the outside of the bowl is the same in each case as with the bowl of said applications and only its interior structure has been changed in accordance with the present invention to provide continuous separation of two components with collection of additional components within the bowl if so desired.

As to the bowl structure shown in Fig. 1, the parts of the bowl are assembled on a cylindrical flanged base member 8, adapted to fit into an opening in table 6. The upper surface of the flange of said base 8 acts as a

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running surface for a sealing member 27 of low-friction material, said member being supported between said flange and bottom bowl 12 by a skirt 28 thereon. A waved spring washer 29 is provided interposed between said bowl and said flange which controls the pressure therebetween when clamping ring 15 is tight (and hence when the bowl is properly assembled). A suitable O ring seal is provided between member 27 and skirt 28.

The base 8 has mounted centrally thereof an upstanding stationary feed tube housing 30, said housing having slidably mounted therein a feed tube 32 with a compression spring 34 interposed between said feed tube and said base to normally urge said feed tube upwardly. The feed tube extends downwardly through base 8 to a suitable connector so that blood from a donor or other reservoir may be fed to the centrifuge. A pair of upstanding cylindrical members 20 and 22 are provided on the base, the outer of said members 20 being spaced between the inner and outer radial extent of the base and the inner of said members 22 being positioned between the outer member and housing 30. A plurality of openings are provided in said base in addition to said central opening for carrying away liquids discharged from the centrifuge to suitable glass or plastic containers, for example. Thus an outer opening having a downwardly extending tube 21 is provided in base 8 between its members 20 and 22 and an inner opening 23 is provided in base 8 between inner member 22 and feed tube housing 30, and an opening having a vent tube 25 is provided in said base outwardly of member 20 within lower bowl 12.

In Fig. 1 is shown a centrifuge bowl structure having internal centrifuge elements providing a baffle assembly especially adapted for the continuous separation of two liquid components without collection of either in the bowl, but with the collection in said bowl of a third component having a specific gravity between said two components, as will occur in the continuous separation of whole blood into red cells R and plasma P, with collection of white cells W therebetween. In this arrangement, the lower element 40 has an imperforate outer annular portion with its outer peripheral rim positioned between flanges 11, 13 and extending radially inwardly from the circumferential wall of the bowl to terminate at its inner edge 41 in a circular central opening. A cylindrical flange 42 extends downwardly from said inner edge, said cylindrical flange being spaced radially inwardly from the stationary cylindrical member or collecting ring 20 on base 8, so that liquid discharged therefrom will pass into outer tube 21.

An upper annular element 44 is mounted adjacent the lower said element 40 spaced therefrom inwardly of its outer contacting rim, said rim being positioned between flanges 11, 13 above the rim of lower element 40 and in contact therewith. The space 46 between the elements, thus extends radially outwardly from edge 41 but terminates short of the outer edge of said elements, communication between the outer end of space 46 and the interior of top bowl 10 being provided by an outer series of bores 45 therethrough adjacent the outer edge of said bowl. The inner edge of the upper annular element 44 extends substantially inwardly beyond the inner edge 41 of lower element 40 and is provided with a cylindrical flange 48 which extends upwardly therefrom and with a cylindrical flange 49 which extends downwardly therefrom. Said lower flange 49 is spaced radially outwardly of upper flange 48 and in a position within the inner stationary cylindrical member or collecting ring 22 on base 8 outside of housing 30. Communication through element 44 is provided by an inner series of bores 47. The above described structure in effect provides an internal baffle structure including a lower imperforate portion extending inwardly to terminate at circular edge 41 and an upper imperforate annular portion spaced thereabove extending outwardly to an outer edge formed by bores

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45 beyond the inner edge 41 and substantially inwardly therebeyond to bores 47, with a flange 49 extending downwardly from the inner edge of said upper annular portion formed by bores 47. Thus, liquid discharged from said flange 49 will pass into tube 23.

The normal operation of the structure of Fig. 1 to continuously separate red blood cells R and plasma P is diagrammatically shown in Fig. 2. Thus, with the centrifuge spinning, whole blood or other liquid having at least two components is fed upwardly through feed tube 32 and passes radially outwardly to the outer side wall of upper bowl 10. The heavier component, the red blood cells R, fills the compartment formed by said wall and the annular wall formed by element 40 and then begins to flow over inner edge 41 and outer flange 42 downwardly into tube 21. The lighter liquid collects above upper element 44 and then begins to flow downwardly through openings 47 over inner flange 49 into tube 23 so that both are continuously separated and collected outside of the bowl in suitable containers, and with true two component mixtures, this separation may be continued indefinitely. With whole blood, however, there exists an intermediate specific gravity portion which for simplicity may be denoted the white cells W, such white cells, during the continuous separation of the red blood cells and plasma, being collected in the bowl above element 44 between the layers of red blood cells and plasma. When its quantity builds up so that it begins to pass through openings 47 with the plasma P, instead of whole blood through central opening 32 is cut off and the speed of rotation of the bowl gradually slowed. This provides a condition as shown in Fig. 3 wherein the accumulated white cells W pass outwardly through outlet 23 and may be separately collected by suitable valve means as the speed continues to be gradually decreased. After a suitable portion of the accumulated white cells W have been so removed, the bowl is speeded up so that its normal operation, continuously to separate red cells and plasma, can be resumed, the boundary between the white cells and plasma then becoming nearly vertical again but spaced well outwardly of openings 47. Similarly, intermediate components of other three component liquids and the like may be periodically removed when they accumulate sufficiently to interfere with the continuous separation of the other two components.

The structure of Fig. 4 is in effect a structure modified from the structure of Fig. 1 above described to include an annular recess above the upper element 44 to separate an intermediate specific gravity liquid by application of high forces and to collect it in such recess. This situation occurs in the separation of platelets from plasma, such being intermediate in specific gravity between the white cells and the plasma. Thus, from a construction standpoint, an additional imperforate annular portion 50 is spaced above the upper element 44, with an imperforate cylindrical wall 52 extending therebetween downwardly from the outer edge thereof, the inner edge of said portion 50 preferably being positioned at least not substantially outwardly with respect to the inner edge 41 of lower annular portion 40.

The operation of the structure of Fig. 4 is shown in Fig. 5 and is generally similar to the operation described above with reference to Fig. 1 except that the plasma, the lightest component, before passing through openings 47, fills the recess formed by walls 50, 52 and 44. Since the end wall 52 of such recess is positioned substantially outwardly of openings 47, the high force there provided results in improved separation of the plasma P from higher specific gravity but difficult to separate material, mostly platelets L, so that a platelet-free plasma may be continuously separated, with platelets L being collected in the recess, and with the white cells W being collected above wall 50 much as before.

With either of the above described structures, upon

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stopping of rotation, all of the material remaining therein will drain by gravity so that, if desired, any accumulated intermediate specific gravity materials can be removed without disassembly, as can the remainder of the two materials undergoing continuous separation.

Thus, it is apparent that the invention has provided a novel apparatus for separating components from blood during the actual phlebotomy, which apparatus results in improved separation, closed-system sterility and ease of operation with continuous separation of two components, without collection of either in the bowl, and with the separation and collection of further components if desired. Various modifications of the apparatus, not herein disclosed, within the spirit of the invention and the scope of the appended claims will occur to those skilled in the art.

I claim:

1. A centrifuge comprising a closed top bowl having an outwardly and downwardly sloping side wall, an internal centrifuge element having a central baffle structure including a lower imperforate annular portion extending inwardly from the circumferential wall of said bowl and terminating at its inner edge in a circular central opening and an upper imperforate annular portion spaced thereabove extending outwardly beyond said inner edge of said lower portion and substantially inwardly therebeyond with its outer imperforate edge defined by an annular series of bores, said annular portions having inner cylindrical flanges extending downwardly from each of inner edges of said annular portions with the upper flange positioned inwardly from the lower flange, a stationary base positioned beneath said bowl and said element, stationary feed means extending upwardly from said base centrally through said element for feeding liquid into said centrifuge at a point adjacent the top wall of said bowl, and means disposed below said central opening for collecting liquids discharged from the inner edges of each of said upper and lower annular baffle portions to said centrifuge including an upstanding cylindrical member positioned radially outwardly from said inner flange and radially inwardly from said outer flange, said centrifuge being adapted for rotation whereby two liquids of differing specific gravity are continuously discharged from said centrifuge during spinning thereof said internal centrifuge element including an imperforate annular portion spaced above said upper annular portion and having a cylindrical wall extending therebetween outwardly from the inner edge thereof forming an annular recess for collecting a liquid having a specific gravity intermediate said two liquids.

2. A centrifuge as claimed in claim 1 wherein said annular portion spaced above said upper annular portion has its inner edge positioned at least not outwardly with respect to the inner edge of said upper annular portion.

3. A centrifuge comprising a bottom bowl having a central opening therein, a side wall, and an outwardly extending annular flange at the upper edge of said wall, a stationary base positioned beneath said central opening, sealing means interposed between said base and said bottom bowl, a top bowl having a top wall, an outwardly and downwardly flaring conical side wall and an outwardly extending annular flange at the lower edge of said wall, a central baffle assembly of generally circular shape comprising a lower flat circular plate with its outer imperforate annular edge positioned between said opposed flanges and having a central opening with an inner annular imperforate edge and an upper flat circular plate spaced a limited distance upwardly from said lower flat circular plate to form a passageway therebetween and having a central opening with an inner annular imperforate edge with the outer imperforate annular edge of said upper flat circular plate extending to a point adja-

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cent to but spaced inwardly from the inner surface of said top bowl and defined by an annular series of bores providing a passageway from the outer annular imperforate edge of said upper plate to the inner annular imperforate edge of said lower plate, the inner imperforate annular edge of said lower plate being positioned radially outwardly of the inner imperforate annular edge of said upper plate, and stationary feed means extending upwardly from said base centrally through the central openings of said plates for feeding liquid into said centrifuge at a point adjacent the top wall of said bowl, said centrifuge being adapted for rotation whereby two liquids of differing specific gravity are separately and continuously discharged respectively from the inner annular edge of the lower plate and the inner annular edge of the upper plate.

4. A centrifuge as claimed in claim 3 wherein said central baffle assembly further comprises an upwardly extending tubular skirt on said upper plate and an inwardly extending annular plate having its outer edge mounted on said upwardly extending skirt and a central opening, said upwardly extending tubular skirt and said inwardly extending annular plate providing an annular recess for collecting a liquid having a specific gravity intermediate said two liquids.

5. A centrifuge comprising a bottom bowl having a central opening therein, a side wall, and an outwardly extending annular flange at the upper edge of said wall, a stationary base positioned beneath said central opening, sealing means interposed between said base and said bottom bowl, a top bowl having a top wall, an outwardly and downwardly flaring conical side walls and outwardly extending annular flange at the lower edge of said wall, a central baffle assembly of generally circular shape comprising a lower flat circular plate with its outer imperforate annular edge positioned between said opposed flanges and having a central opening with an inner annular imperforate edge and a downwardly extending tubular skirt positioned outwardly of said inner annular edge of said lower plate and an upper flat circular plate spaced a limited distance upwardly from said lower flat circular plate to form a passageway therebetween said upper plate having a central opening with an inner annular imperforate edge and a tubular skirt positioned outwardly thereof with the outer imperforate annular edge of said upper flat circular plate extending to a point adjacent to but spaced inwardly from the inner surface of said top bowl and defined by an annular series of bores providing a passageway from the outer annular imperforate edge of said upper plate to the inner annular imperforate edge of said lower plate, the inner imperforate annular edge of said lower plate being positioned radially outwardly of the tubular skirt of said upper plate, stationary feed means extending upwardly from said base centrally through the central openings of said plates for feeding liquid into said centrifuge at a point adjacent the top wall of said bowl, and collecting means on said base including a collecting ring extending upwardly between said downwardly extending tubular skirts, said centrifuge being adapted for rotation whereby two liquids of differing specific gravity are separately and continuously discharged respectively from the inner annular edge of the lower plate and the inner annular edge of the upper plate.

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