Aug. 25, 1964 A. LATHAM, JR 3,145,713

METHOD AND APPARATUS FOR PROCESSING BLOOD

Filed Sept. 12, 1963 4 Sheets-Sheet 1

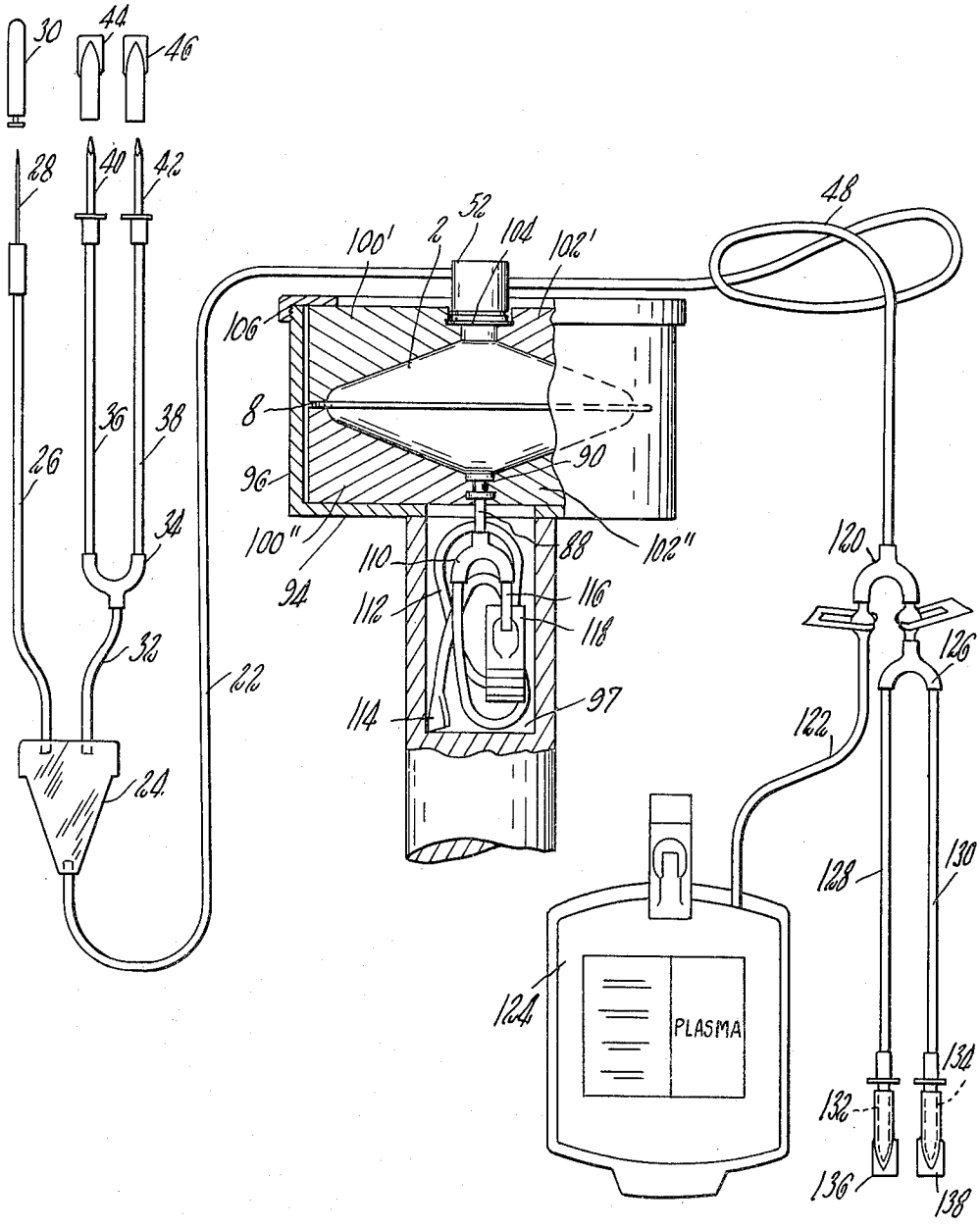


Fig. 1.

Aug. 25, 1964 A. LATHAM, JR 3,145,713

METHOD AND APPARATUS FOR PROCESSING BLOOD

Filed Sept. 12, 1963 4 Sheets-Sheet 2

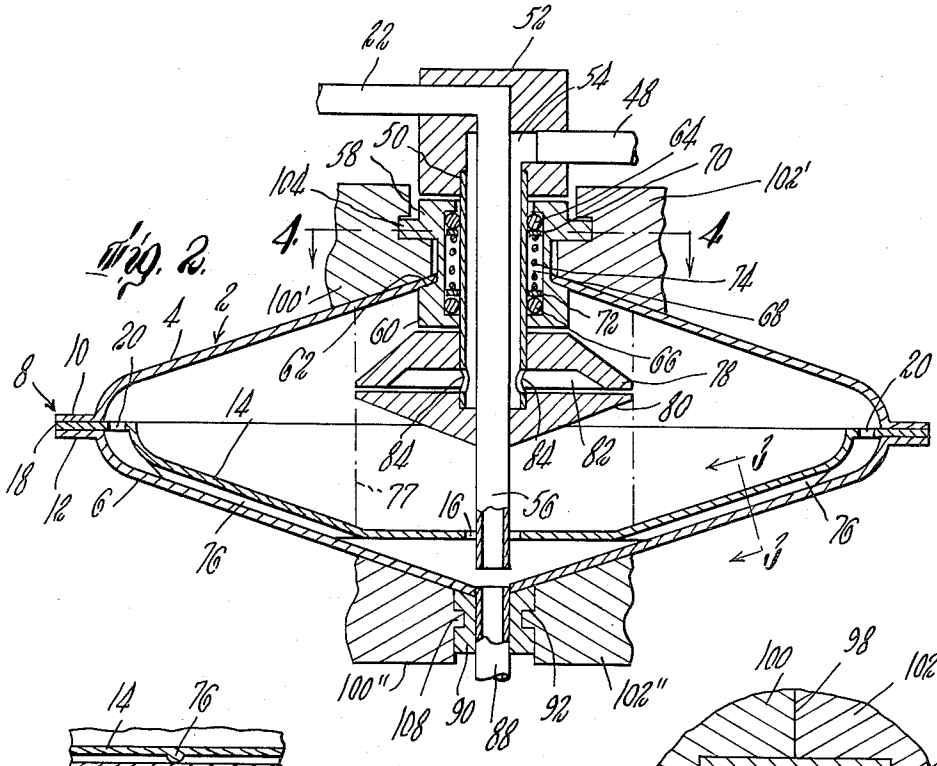


Fig. 2.

Fig. 3.

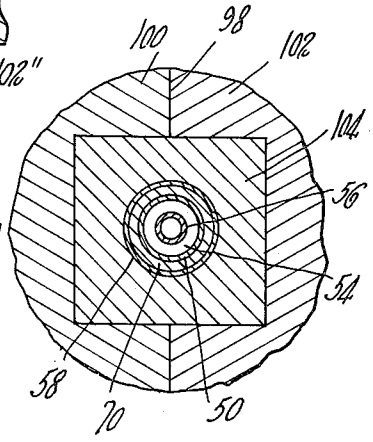


Fig. 4.

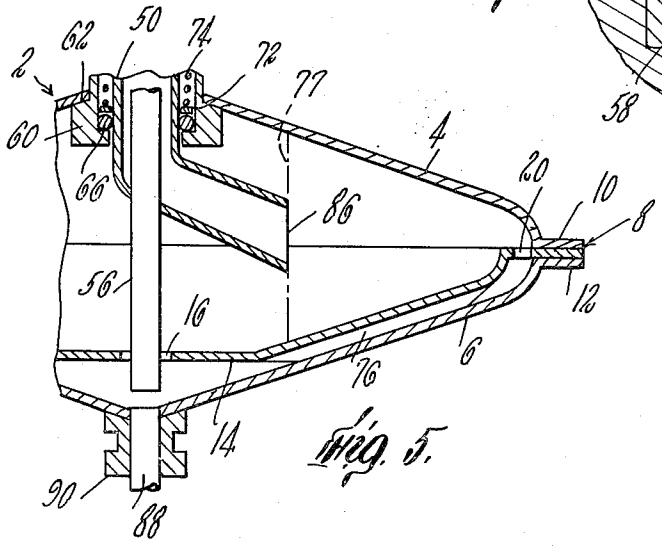


Fig. 5.

Aug. 25, 1964 A. LATHAM, JR 3,145,713

METHOD AND APPARATUS FOR PROCESSING BLOOD

Filed Sept. 12, 1963 4 Sheets-Sheet 3

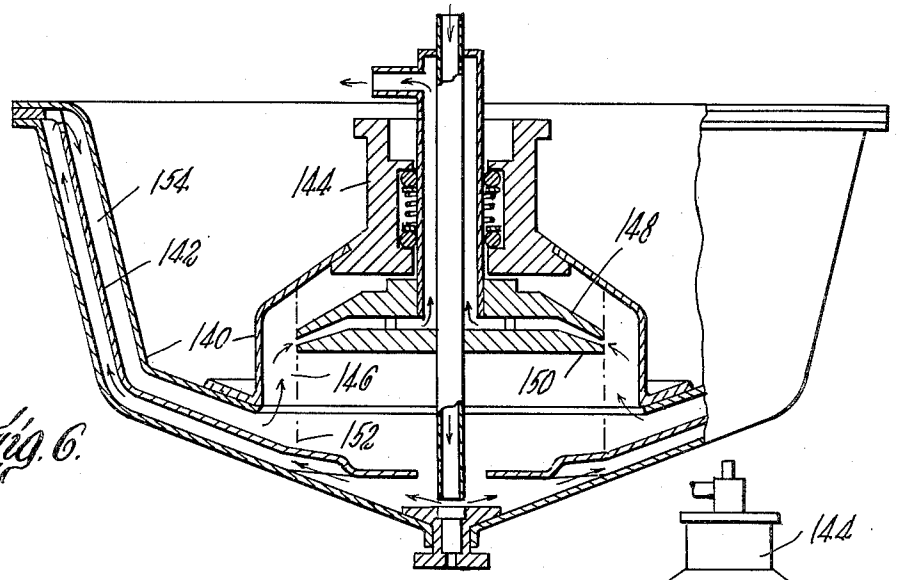


Fig. 6.

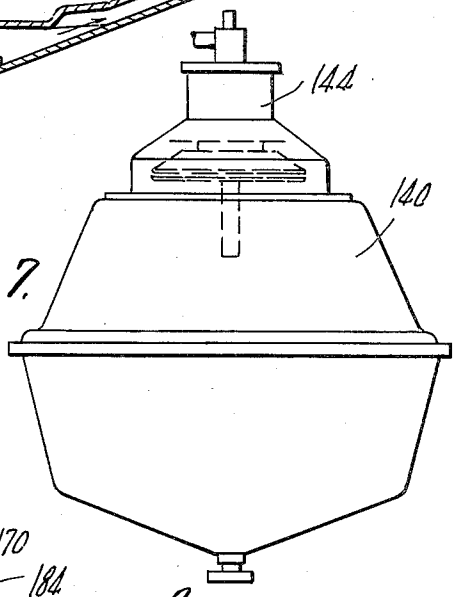
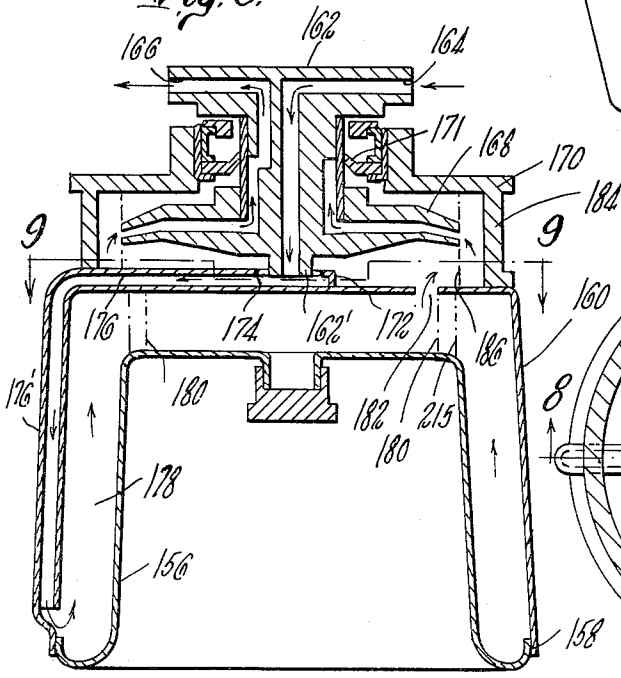


Fig. 7.

Fig. 8.



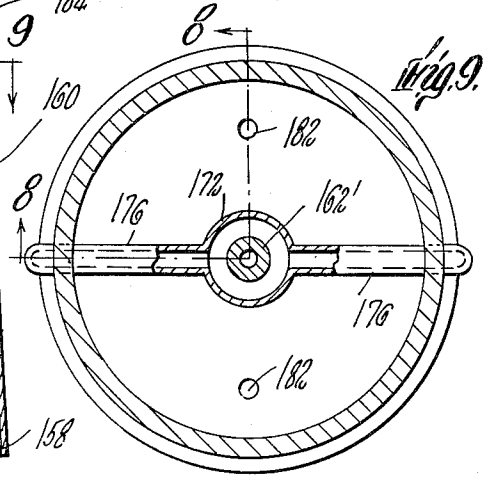


Fig. 9.

Aug. 25, 1964 A. LATHAM, JR 3,145,713

METHOD AND APPARATUS FOR PROCESSING BLOOD

Filed Sept. 12, 1963 4 Sheets-Sheet 4

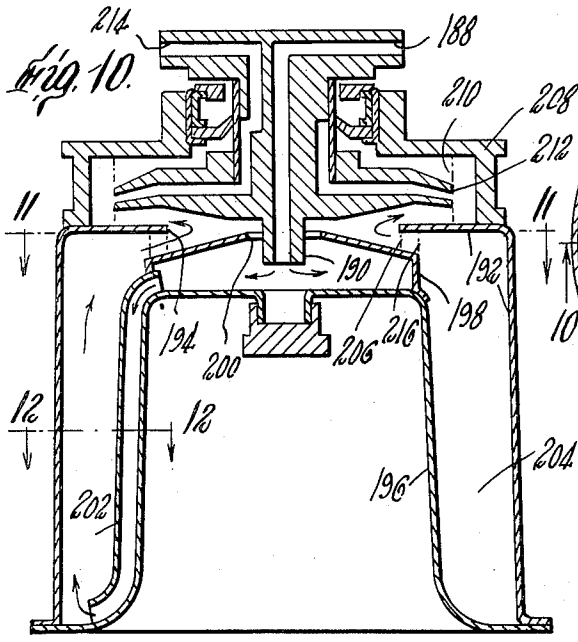


Fig. 10.

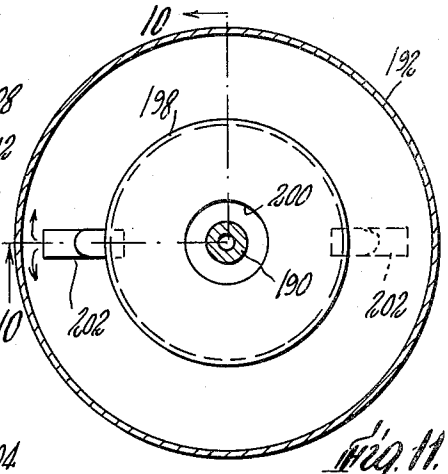


Fig. 11.

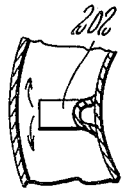


Fig. 12.

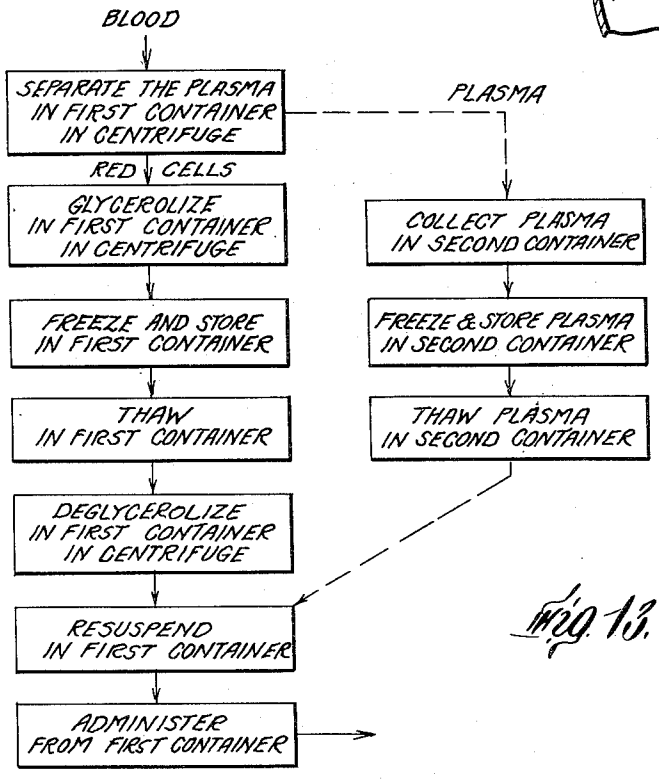


Fig. 13.

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Patented Aug. 25, 1964

3,145,713

METHOD AND APPARATUS FOR PROCESSING BLOOD

Allen Latham, Jr., Boston, Mass., assignor, by mesne assignments, to Protein Foundation, Incorporated, Cambridge, Mass., a corporation of Massachusetts

Filed Sept. 12, 1963, Ser. No. 308,559
11 Claims. (Cl. 128—214)

This invention relates to the collection, processing and storing of blood and its components and more particularly to a disposable kit and to a simple, economical and reliable process for this purpose.

The present application is a continuation-in-part of my prior applications Serial Nos. 79,286 and 79,625, both filed December 30, 1960 and both now abandoned.

The collection and storage of human blood, or its components, to be used for transfusion and other purposes in which it must retain its physiologic effectiveness as fully as possible, presents many difficulties. First of all, all collection, processing and storage operations must be carried out under sterile conditions. The conditions also must be such as not to initiate coagulation and the blood otherwise must be protected as completely as possible again deteriorative change.

It has recently become possible to provide for long time banking of red blood cells, on a small scale, by a process involving collection of the whole blood, separation of the red cells from the plasma by centrifugation and conditioning of the red cells for freezing and storage by a glycerolization treatment wherein they are washed with a glycerol solution. Following freezing and separate storage at low temperature, the red cells are thawed, deglycerolized by washing, as with a solution containing material which does not permeate the red cell membrane, to free them from glycerol, and then are resuspended in a suitable fluid medium, such as the separated plasma. Heretofore this procedure has required the use of a special and complicated blood fractionator, designed originally as a versatile research tool, wherein the red blood cells are separated from the plasma by centrifugal force. Its use in this program entails the maintenance of a sizable support team and facility to disassemble, wash and reassemble the reusable components of the centrifuge bowl as well as to assemble and sterilize numerous expendable plastic components. Clinical use of red blood cells so handled has been substantial enough to establish the therapeutic effectiveness of the product and has shown that the product produces a lower incidence of reactions of all kinds than whole blood collected and stored by conventional methods. However, the disadvantages inherent in the processing as presently practiced add up to such complexity and cost as would be prohibitive for general blood bank use. The invention provides a greatly simplified and less costly procedure and a disposable kit for use therewith, such as to be economically and technically practicable for wide scale general blood bank use.

An object of the invention is greatly to simplify the processing, by procedures including centrifugation, of blood for storage and for subsequent use.

Another object of the invention is to provide a process of the character described which is very substantially simpler and more economical to operate than heretofore known processes of this type.

A further object of the invention is to provide such a process wherein the blood and its red cell and plasma components may be continuously but separately retained in the same container throughout such processing and storage operations until withdrawn for the end use, such as administration of the resuspended red cells as a transfusion.

Another object is to provide a unitary kit for use in the collection and centrifugal processing of blood and the storage and subsequent processing for use of blood fractions.

A further object is to provide such a kit which is so inexpensive that it may be disposed of after a single use.

A further object is to provide such a kit which lends itself to mass production under precisely controlled conditions at low cost.

A further object is to provide such a kit on which all required sterilization procedures may be done during manufacture at the factory and in which thereafter all parts which should be sterile will remain so in normal use.

A further object is to provide such a kit which may be manufactured at low cost and yet be reliable as to its sterility and other characteristics important to its intended use.

A further object is to simplify the described procedure for the collection of whole blood, processing of it to separate the red cells, storage of the red cells and subsequent processing of the cells to prepare them for use, to the point where this procedure is practicable for general blood bank use.

Other and further objects, features and advantages of the invention will become apparent from the following description of one particular, presently preferred, embodiment thereof wherein reference is made to the accompanying drawings, in which

FIG. 1 is an elevation of the complete kit, showing its relationship to the centrifuge with which it is used;

FIG. 2 is a vertical sectional view, taken close to a midplane, of the plastic container constituting a principal part of the kit, showing parts of the retainer forms by which it is supported in the centrifuge;

FIG. 3 is a detail sectional view taken on line 3—3 of FIG. 2;

FIG. 4 is a detail horizontal sectional view taken on line 4—4 of FIG. 2;

FIG. 5 is a view similar to FIG. 2 but showing a modification of the plastma discharge mechanism;

FIG. 6 is a mid-sectional view, partly in elevation of a modification;

FIG. 7 is a view in elevation of the modification of FIG. 6 in an alternative conditon;

FIG. 8 is a sectional view of a further modification taken on line 8—8 of FIG. 9;

FIG. 9 is a horizontal sectional view on line 9—9 of FIG. 8;

FIG. 10 is a sectional view of a still further modification, taken on line 10—10 of FIG. 11;

FIG. 11 is a horizontal sectional view taken on line 11—11 of FIG. 10;

FIG. 12 is a detail sectional view taken on line 12—12 of FIG. 10; and

FIG. 13 is a flow sheet illustrating the process.

The invention provides a disposable unitary kit for use in collecting the whole blood, immediately mixing with it any desired other fluid, such as an anti-coagulant, subjecting it to a centrifugal field in a relatively simple type of centrifuge to separate the whole blood into fractions, for example to separate the red cells, processing of a separated fraction, such as the red cells, to condition it for freezing and storage, storage of the frozen fractions and, after storage, processing of a fraction to condition it for use, and finally, if desired, dispensing of the fraction, or a resuspension thereof, directly from the container.

In accordance with the invention I provide a disposable

kit fabricated largely from a flexible, preferably heat-sealable synthetic plastic material including a container, which serves as a liner for a centrifuge and in which the whole blood is collected and subjected to the centrifugal, glycerolization, deglycerolization and storage steps of the described procedure, means for making connection to a source of blood, such as a phlebotomy needle or a connector for making connection to a blood pack, tubing connecting said means, through a drip chamber and an airtight rotary seal, to the interior of the container, other tubing whereby an anti-coagulant may if desired be introduced into the drip chamber with the blood, together with a second container for the separated plasma, tubing connecting the plasma container to the interior of the centrifuge container, and accessory tubing connected to the centrifuge container for leading off as desired a part or fraction of the blood, and for sampling and also for direct administration from the container.

In accordance with the invention the container of such a kit is placed in the centrifuge and the connection is made to the blood source, as to a blood pack or by insertion of the phlebotomy needle. When the source is a donor, other supply tubing is supplied with an anti-coagulant solution, and as the blood is drawn the anti-coagulant may be continuously added to it. With blood from a blood pack an anti-coagulant is not ordinarily required. The blood is introduced into the container of the kit and immediately subjected to a centrifugal field to separate the plasma from the red cells. A constant volume of fluid is maintained in the container during the separation operation and the plasma is continuously withdrawn and collected in the second container of the kit. At the end of the collection step the red cells are glycerolized in the container while still in the centrifuge by introducing into it a glycerolization solution at the proper rate. Following glycerolization, the entire kit with the red cells and plasma separately contained therein is frozen and stored under refrigeration. For reuse, the kit is thawed, replaced in the centrifuge and the cells deglycerolized by washing glycerol from them by flowing a washing solution through the mass of blood cells in the container. The deglycerolized red blood cells are resuspended either in the original plasma or in a resuspension fluid. Finally the resuspended cells or reconstituted blood may be dispensed directly from the original container.

Referring to the drawings, FIGS. 1 and 2, the centrifuge liner, or container portion of the kit is shown at **2**. This container **2** is fabricated from any suitable flexible, preferably transparent plastic material. One satisfactory material for this purpose is 20 mil suitably plasticized polyvinyl chloride sheet. The container **2** is formed from a conical upper wall **4** and a similarly shaped lower wall **6**. The upper and lower walls are inclined, as shown, toward each other in the direction away from the axis of the container. The general shape of the container thus formed I refer to as a "double conical" shape. The upper and lower walls **4** and **6** are joined to each other, as by heat sealing along a generally circular edge **8**. For this purpose the upper wall **4** is provided with a flat annular flange **10** and the lower wall **6** with a similar flange **12**. The general shape of the container **2** is symmetrical about a line which constitutes the axis of rotation of the container when it is in use within a centrifuge. Disposed between the upper wall **4** and the lower wall **6** is a baffle **14** likewise formed of a thin transparent inert plasticized material, for example the same material used for the walls **4** and **6**. The baffle **14** contains a central opening **16** and is provided with an annular flange **18** around its margin, similar in size and width to the flanges **10** and **12**, between which it is received. The flanges **10**, **12** and **18** are permanently secured together, as by heat sealing. The baffle **14** is provided with a plurality of small openings **20** distributed around its periphery just inwardly of the flange **18** and inwardly of the interior surface of the container.

The blood is introduced into the container **2** along its axis through a length of flexible tubing **22**. The tubing **22** leads from a drip chamber **24** into which the whole blood from the donor or other source is introduced through a length of tubing **26**. At its free end the tubing **26** carries a phlebotomy needle **28**. A sheath **30**, of any appropriate type is provided for the needle **28**, whereby the exterior surfaces of the needle and the interior of the needle, and all connecting parts, when once sterilized during manufacture may be maintained sterile. Also leading into the drip chamber **24** through a length of tubing **32**, a Y-fitting **34** and two lengths of tubing **36** and **38** are a pair of connectors **40** and **42**, suitable for making connection to sources of supply of any fluid material which it may be desired to introduce into the container **2**, such as an anti-coagulant, e.g., an acid citrate dextrose solution of known type to be introduced during the phlebotomy and directly into admixture with the blood. The connectors **40** and **42** may be of a type adapted to be plugged into a female connection on the source of supply or they may be in the form of needles to be inserted through a part of a supply container designed for this purpose, as is well known. Sheaths **44** and **46** are provided for the connectors **40** and **42** respectively to serve the same purpose as the sheath **30**.

The container **2** is adapted to be positioned in a centrifuge while the blood is introduced so that the blood can be processed immediately. For this purpose a rotary seal member is provided between the tubing **22** and the container **2** whereby the tubing **22** and its associated parts, including the connectors **40** and **42** and the needle **28**, may remain stationary while the container **2** is rotated in the centrifuge. A length of tubing **48** through which the lighter fraction separated by the centrifuge is conducted from the container **2** also is connected to the interior of the container **2** through this rotary seal member.

The rotary seal member comprises an inner stationary part including tube **50** open at its lower end to the interior of the container for the reception of fluid from a discharge means later to be described. Fast on the upper end of the tube **50** is a stationary cap **52** of moulded plastic or other suitable material, containing a cavity **54** communicating with the interior of tube **50** and with discharge tubing **48**. Moulded into the cap **52** is a vertical tube **56** of relatively rigid plastic material extending downwardly along the axis of the container **2** and through the opening **16** in the baffle **14**. The tubing **22** leads into the tube **56** through the cap **52**.

The top wall **4** of the container **2** is mounted on the stationary tube **50** for rotation thereon by means of a rotatable part of the rotary seal member including a moulded plastic rotary member **58** having an enlarged lower end **60** to the sloping upper surface **62** of which the inner portion of the top wall **4** is connected. Two O rings **64** and **66**, are mounted in a cavity **68** in the member **58** to form a tight seal between the stationary tube **50** and the rotary member **58** while permitting rapid relative rotation therebetween. Flat annular rings **70** and **72** bearing against the O rings **64** and **66** are urged away from each other by a spring **74** to seat the O rings tightly against the upper and lower walls of the cavity **68** and maintain good sealing engagement of the O rings **64**, **66** with the rotary member **58** and the stationary tube **50**. The cavity **68** may be filled with glycerin during assembly to lubricate the O rings and to give visual evidence that the integrity of the seal has been maintained.

As the blood is introduced through the tube **22**, with the centrifuge in rotation, it flows downwardly through the tube **56**. Under the influence of the centrifugal field the blood flows outwardly between the baffle **14** and the lower wall **6** to the periphery of the container **2**. To assure the existence of a free passageway between the baffle **14** and the lower wall **6**, the baffle is provided with a series of spaced radial, downwardly convex corrugations

or ribs 76 (FIG. 3) to maintain the baffle in a spaced position with respect to the lower wall 6 despite the centrifugal force applied to these parts. The blood passes through the openings 20 in the baffle and into the main body of the container 2.

Under the influence of the centrifugal field the inner surface 77 of the liquid assumes a cylindrical form coaxial with the axis of the container 2. The red blood cells concentrate toward the periphery of the container 2 and the remaining fraction of the blood, herein referred to as plasma, concentrates toward the axis of rotation. The feed material enters the processing zone of the centrifuge at the extreme radius and perfuses any heavier material, such as packed red cells, as it passes toward the center.

Liquid is removed continuously from the inner surface 77 of the rotating liquid during processing. For this purpose a pump is provided, comprising two spaced circular discs 78 and 80 of the same diameter fixed on the stationary tube 50 and the stationary tube 56, as appears in FIG. 2. The outer edges of discs 78, 80 are spaced slightly apart and the space between them is in free communication with a cavity 82 in the upper disc 78. Holes 84 in the fixed tube 50 connect the cavity 82 with the interior of tube 50. As blood continues to enter the container 2, the cylindrical free surface 77 advances toward the axis of the container. When it reaches the circular edges of the discs 78, 80 the drag of the stationary edges on the liquid slows down the speed of rotation of the liquid near the surface so that a condition of lowered pressure exists in the liquid at the edges of the discs, causing the liquid to flow into the openings between the discs, through the holes 84, up the tube 50 and out the discharge tubing 48. The liquid within the container 2 thus is held at a fixed volume during the processing, independently of the rate at which liquid is fed to the container.

An alternative form of means for discharging the plasma is shown in FIG. 5. In this modification, the lower end of the stationary tube 50 is turned to extend generally radially of the container 2 and its outer end 86 is appropriately shaped to provide a scoop or "skimmer" to remove liquid from the free surface 77 of the rotating liquid as it moves past the stationary skimmer. By conversion of velocity head into static head by this action the plasma is caused to flow up the tube 50 and out the discharge tubing 48.

The lower wall 6 is provided with a discharge opening into a length of flexible tubing 88, for a purpose which will be described hereinafter. The tubing 88 is connected to the plastic wall 6 by means of a moulded connector 90 having its upper surface united to the wall 6 adjacent the opening therein and containing a normally closed cylindrical bore to which the tubing 88 is secured. The connector 90 is provided with a circular recess 92 for a purpose later to be described.

The centrifuge for rotating the container 2 may be of very simple construction having simple cylindrical walls to provide a rotating cavity. In FIG. 1 an illustrative simple type of centrifuge is shown having a lower wall 94 and a cylindrical wall 96, with a cavity 97 for receiving the tubing 88 and its appendages.

To support the container 2 within the centrifuge I provide a retainer form, shaped in its interior to fit the container 2 and having an outer simple cylindrical surface to be received within the cavity of the centrifuge. To facilitate assembly and disassembly of the retainer form and container 2 the retainer form is split into two halves 100, 102 along a vertical plane 98, FIG. 4, and each of the halves is again divided along a horizontal plane as appears in FIG. 1, wherein the half 100 is shown as comprising an upper portion 100' and a lower portion 100'', and the half 102 as comprising an upper portion 102' and a lower portion 102''. The flange at the edge 8 is tightly grasped between the lower retainer forms 100'' and 102'' and the upper retainer forms 100' and 102'.

To rotate the container 2 with the retainer forms and free the container 2 from torsional stress any simple type of torque drive may be provided between the retainer forms and the rotary seal member 58. In the embodiment shown this takes the form of a square collar 104 formed integral with the rotary seal member 58 and which interfits with a corresponding square cavity in the upper retainer forms 100' and 102'. The retainer forms are maintained in firm position within the centrifuge and in tight fitting engagement with the container 2 by means of a clamp ring 106 threaded on the upper end of the side wall 96. The tubing 22 and its associated parts which are to remain stationary during the processing are attached in any convenient manner to a stationary part of the centrifuge frame. The lower portions of the retainer form are provided with a cavity suitably shaped to receive the connector 90, including a rib 108 to be received within the recess 92. Thus both the upper wall 4 and the lower wall 6 are locked at their apexes in fixed position in the retainer forms. Accordingly, in operation under the heavy centrifugal pressures involved, the container 2 assumes the desired configuration most appropriate for the particular fractionation to be performed as determined by the shape of the cavity within the retainer forms and without having to withstand heavy tensile stress within the walls of the liner material.

The tubing 88, FIG. 1, leads to a Y fitting 110 one branch of which is connected to a length of tubing 112, having a sealed end 114, wherein samples may be collected. The other branch of the Y fitting 110 is connected to a length of flexible tubing 116 having at its free end a sheathed female connector 118 for making a sterile connection to an administration set whereby the contents of the container 2 may be employed directly for transfusion purposes.

The discharge tubing 48 leads to a Y fitting 120. From one branch of fitting 120 tubing 122 is integrally connected to a plasma bag 124 of known type. The other branch from the Y fitting 120 leads to a second Y fitting 126 from which two lengths of tubing 128 and 130 lead to connectors 132 and 134, similar to the connectors 40 and 42. Sheaths 136 and 138 similar in function to the sheaths 44, 46 previously described are provided for the connectors 132 and 134 respectively.

The blood taken from the donor (or from any form of blood pack) through the needle 28 may first be immediately mixed with anticoagulant (if such is to be used), introduced through one of the tubes 36 or 38, in the drip chamber 24 which serves as a sight glass through which the bleeding and mixing rates can be observed by the attending nurse. A suitable anticoagulant is acid citrate dextrose (NIH Anticoagulant Formula A). 75 cc. may be mixed with the 475 cc. whole blood of a donation, over a 10 minute interval. The blood from chamber 24 is introduced directly into the rotating container 2 in the centrifuge and subjected to centrifugal force, as previously described, with separation and collection of the red cells at the periphery of the container. The plasma withdrawn between the discs 78, 80 flows under pressure through the tubing 48, the Y fitting 120 and into the plasma bag 124. when the collection of the sample has been completed the red cells then may be promptly glycerolized, as the centrifuge continues to spin, by flowing a glycerolizing solution into the apparatus through one of the tubes 36 or 38 from which it flows through the tube 56, between the baffle 14 and the lower wall 6, through the red cells and out through the tubing 48. In this step tubing 122 is closed off by a clamp and the glycerolizing solution allowed to be discharged to waste through tubing 128 or 130. Alternatively, the volume of material retained in the container 2 may be somewhat greater than the final volume of the red cells from a donation, in which case the plasma remaining in the container at the end of the phlebotomy is displaced by the entering glycerolization solution and may be run to the plasma bag, or to waste. For a

475 cc. whole blood donation the glycerolizing solution may be 1300 cc. of a glycerol-saline solution passed through the mass of cells over a period of 35 minutes. At the beginning the glycerol concentration may be about 20% and may thereafter be increased at a constant rate during the first 9 minutes to 50% and held constant thereafter. After the glycerolization treatment the entire kit, with the red cells in the container 2 and the plasma in the container 124 may be frozen and stored under refrigeration, as at −80° C., in accordance with known practice. The tubing connecting the plasma bag and container 2 will be sealed off, and may be severed for separate storage or use of red cells and plasma.

When the stored kit is called out for use, the container 2 may, after thawing, again be placed in a centrifuge with appropriate retainer forms and the red cells deglycerolized by flowing an appropriate washing solution into the apparatus through one of the tubes 36 or 38, through tube 56 between baffle 14 and bottom wall 6, through the red cells and out through the tubing 48. The washing solution then may be discharged to waste through tubing 128 or 130. The deglycerolizing solution may initially be a 10% glycerol solution in saline solution, the glycerol being replaced at a constant rate by sodium lactate over a 20 minute interval. The sodium lactate concentration may then be reduced at a constant rate from 10% to zero over the next 20 minutes and the flow continued to pass 600 cc. of saline over the red cells.

Following deglycerolization the red cells may be resuspended in an appropriate fluid medium. The plasma from the container 124 may be returned through the tubing 48 into the container 2 for this purpose, or, an appropriate fluid suspension medium may be introduced through one of the tubes 36, 38. Any deglycerolization solution remaining in the container 2 will be displaced by the entering resuspension medium and may be run to waste. The reconstituted blood, or resuspended red cells, then may be administered from the container 2 through tubing 116 and connector 118, ordinarily after removal of the kit from the centrifuge.

The various connecting tubes may be provided with both manual clamps and spaces for use of automatic clamps for isolating portions of the kit as may be desired. The material of the kit, particularly the tubing, is preferably a heat-sealable material, whereby the various parts may be isolated and sealed off by heat-sealing the tubing, thereby providing dependably sterile seals.

FIGS. 6 and 7 illustrate a modification of the container 2. In this modification the upper wall 140 corresponds to the upper wall 4 of the modification of FIGS. 1 and 2, the baffle appears at 142 and the rotatable part of the rotary seal member at 144. The upper wall 140, when the kit is in place in the centrifuge, is folded to extend downwardly to lie adjacent the baffle 142 at a point intermediate the axis and the periphery of the container. Otherwise, the construction of the container is generally similar to that of the container illustrated in FIGS. 1, 2, 3, 4 and 5. Such shape of the upper wall 140 serves to isolate, to a substantial degree, the lighter liquid fraction 146, at the point where its free surface 152 engages the pump 148, 150, from the centrifugal separation zone at 154 wherein the red cells are concentrated. Thus any turbulence set up at the free surface 152 of the liquid by its engagement with the pump 148, 150 is less likely to disturb the red cells at 154 than would be the case with the structure of FIGS. 1 and 2. The space or volume between the upper wall 140 and the baffle 142 is adequate to accommodate the red cells from a single donation, the plasma having been substantially removed during the centrifugal operation. If a larger volume is required during the resuspension operation to accommodate both the red cells and the resuspending medium, the rotary seal member 144 may be pulled upwardly to or toward the position illustrated in FIG. 7, the upper wall 140 flexing to permit such movement, so that the internal volume of the container is increased as required.

In the modification of FIGS. 8 and 9, a lower wall 156 is joined at seam 158 to an upper wall 160, the two walls being shaped approximately as shown so that the lower wall lies within the upper wall when the kit is in place in the centrifuge. The rotary seal member includes a stationary part 162 having an inlet passageway at 164 and an outlet passageway at 166 and carrying a pump 168 at its lower end, similar in construction to the pump 78, 80 of FIG. 2. The rotatable part 170 of the rotary seal member is mounted for rotation on the stationary part 162 and a flexible seal member 171 is provided to prevent leakage between the two parts 162 and 170 while permitting high speed relative rotation therebetween. The inlet passageway 164 extends downwardly through the stationary part 162 and discharges from its lower end 162' at a point adjacent to and above the upper wall 160, and along the axis of rotation. Surrounding the lower end 162', the upper wall 160 is provided with an upstanding cylindrical wall 172 having an inwardly turned lip 174. Liquid entering the container through the inlet passageway 164 thus is discharged into the space inside the cylindrical wall 172, below the lip 174. For conducting the entering liquid transversely outwardly from the discharge end of the inlet passageway 164, the upper wall 160 is provided with conduits 176 of plastic material opening through and extending in opposite directions from the cylindrical wall 172. The conduits 176 extend downwardly at 176' along the upper wall 160 and communicate at their lower ends, adjacent the seam 158, with the interior of the container, and thus provide a passageway from the interior of the space inside the wall 172 to a point adjacent the periphery of the container so that entering fluid is discharged into the centrifugal separation zone 178 at a point adjacent the periphery. As liquid is introduced through the inlet passageway 164 and conduits 176, it passes upwardly through the space 178 and moves inwardly, perfusing the red cells and forming a free cylindrical surface at 180. The upper wall 160 is provided with openings 182 opening into the interior of the skirt 184 of the rotatable part 70 of the rotary seal member. As the free surface 180 of the liquid moves inwardly and reaches the openings 182, the lighter liquid components escape through the openings 182 and into the interior of the rotary part 170, forming a free surface 186 therein, which is located further from the axis than the surface 180. When the surface 186 has moved inwardly to reach the periphery of the pump 168, the lighter liquid component is pumped, as before, from the container and out through the outlet passageway 166. Thus, in this modification, the pump 168 and any turbulence it may cause in the liquid upon which it is operating are completely isolated from the body of liquid in the separation zone 178 containing the red cells.

The modification of FIGS. 10, 11 and 12 is generally similar to the modification of FIGS. 8 and 9. In this modification, liquid entering the inlet passageway 188 is discharged at its lower end 190. The upper wall 192 is provided with a large central opening at 194, coaxial with the container. The lower wall 196 extends upwardly within the upper wall 192 as shown and carries at its upper end a sheet plastic member 198 having a coaxial opening 200 through which the lower end 190 extends. Leading from the space inside the member 198 are two conduits 202, as shown lying along and secured to the inner surface of the lower wall 196 and terminating at their lower ends adjacent the periphery of the container. Thus the liquid entering the inlet passageway 188 is discharged at its lower end 190 into the space inside the member 198, flowing therefrom downwardly through the conduits 202 to a point adjacent the periphery of the container. The entering liquid rises in the centrifugal separation zone 204 and forms a cylindrical surface 206

which moves inwardly until it reaches the opening 194, whereupon the lighter liquid component flows over the edge of the opening 194 and outwardly into the space inside the rotatable part 208 of the rotary seal member in which it again forms a cylindrical surface 210 which moves inwardly until it reaches the pump 212 whereupon liqiud is pumped out of the container through the discharge passageway 214. Any turbulence that may arise as a result of the contact of the pump 212 with the surface 210 of the liquid is isolated from the red cells which are concentrated in the separation zone 204.

In both the modification of FIG. 8 and the modification of FIG. 10 a very fine separation of the lighter components from the heavier components, e.g., of the plasma from the red cells, can be obtained, as the amount of lighter component remaining in the container at the end of a centrifugal operation can be kept small. In the apparatus of FIG. 8 the red cells concentrating in the space 178 may lie outwardly of a cylindrical surface 215, FIG. 8. The container may be made of such size and proportions, with respect to the volume of a normal donation, that the volume of plasma lying between the surface 215 and the free surface 180 of the plasma is very small. Similarly in the apparatus of FIG. 10 the red cells concentrating in the space 204 may have an inner boundary at 216, the container being of appropriate size and proportions. Again, the volume of plasma between the boundary 216 and the free surface 206 is small, inasmuch as the areas of both surfaces 216 and 206 are relatively small. In each of the modifications of FIGS. 8 and 10, at the end of a centrifugal operation some lighter component also will be left in the pump chamber between the surface 186 and the skirt 184, FIG. 8 (or surface 210 and seal member 208, FIG. 10) and will fall back to combine with the fluid remaining between surfaces 180 and 215 (or 206 and 216), but the amount of such lighter component left in the pump chamber can be kept very small as the pump 168 (212) may be proportioned to extend close to the skirt 184, or otherwise designed or arranged to pump the chamber virtually dry, as the designer is not hampered by any need to avoid turbulence in the pump chamber. Accordingly, the total residual volume between surfaces 215 and 186 (or 216 and 210) can be kept small, thus contributing to fine separation of lighter and heavier components, e.g., plasma and red cells.

Although the invention has been disclosed by reference particularly to its application to human blood it will be understood that it is not so limited. Also, it will be understood that the kit of the invention has utility in any process involving collection of blood wherein a centrifugal step is present in the processing procedure, and is not necessarily confined to the particular red cell banking procedure described.

The various parts entering into the kit and the entire assembly will, of course, be fabricated in accordance with techniques well known in the art. All parts of the kit which are to come in contact with the blood may be appropriately sterilized at the factory and thus will not require sterilization at the point of use.

While I have described uses of the kit wherein the kit remains intact throughout its useful life, it will be understood that the plasma container 124 may, if desired, be separated from the container 2 by appropriately clamping off the tubing connecting them and severing it between the clamps, or, better, by heat-sealing a length of the connecting tubing adjacent each and severing it in the heat sealed portion. Other portions of the tubing likewise may be sealed off.

Other and further uses of the kit will in view of the foregoing disclosure be apparent to those skilled in the art.

It will be apparent from the foregoing that the invention provides an inexpensive, simple and reliable kit for use in connection with the processing of human blood wherein the kit includes all of the parts which come in contact with the blood, the red cells, or plasma. Therefore, the disposable nature of the kit eliminates all the hazards attendant upon reuse of equipment. The kit provides the possibility of holding the red cells and the plasma in the kit throughout the entire process, from the beginning of the phlebotomy to the final transfusion, so that the risks of contamination of or damage to the blood attendant upon transfer from one container to another, or repackaging, can be kept at acceptable levels. The process provides a simple and economical procedure well adapted to large-scale, low cost operation such as to make it practicable for general blood bank use, whereby for the first time glycerolized frozen red blood cells can be made generally available, as is highly desirable. The process provides the possibility of centralized control of the pharmaceutical aspects. Results which are safe and reproducible can be obtained without the need for trained personnel. Blood can be processed directly from a donor or from a blood pack from a remote place. The required bacteriological control is greatly simplified. The centrifugation apparatus employed may be of a simple type requiring little space, and the over-all processing time is reduced.

I claim:

1. A disposable kit for receiving blood, separating heavier from lighter components thereof, storage and subsequent administration of the heavier components of the blood, comprising an integral airtight flexible plastic container, of a shape generally symmetrical about an axis, adapted with the blood therein to be placed in and removed from a centrifuge bowl to be supported thereby and rotated therewith about said axis for continuous centrifugal processing of blood received in the container to separate heavier components from lighter components, a rotary seal member having a rotatable part permanently joined to the top of said container concentric with said axis to form an integral structure with said container for rotation about said axis, and a stationary part adapted to remain stationary during said rotation, a seal coaxial with said axis hermetically connecting said rotatable and stationary parts for high speed relative rotation therebetween and permitting removal of the kit from a centrifuge bowl without breaking of said seal, an inlet connection on said stationary part adapted to be connected to a source of blood, an inlet passageway in said stationary part connected at its upper end to said inlet connection and opening at its lower end along said axis, means fixed to said container for conducting entering liquid transversely of the container from said inlet passageway through a restricted passageway to the extreme peripheral part of the interior of said container, an outlet passageway in said stationary part, and means containing a stationary conduit supported on said stationary part and extending outwardly therefrom for continuously removing lighter liquid components upwardly through said outlet passageway when said container is rotated at high speed about said axis with respect to said stationary part, while heavier components accumulate within said container.

2. A disposable kit in accordance with claim 1 wherein said means for continuously removing lighter liquid components is disposed within said rotatable part of the rotary seal member.

3. A disposable kit in accordance with claim 1 wherein said container includes an upper wall and a lower wall disposed within the upper wall.

4. A disposable kit in accordance with claim 1 wherein said container has an upper wall having an opening therein spaced inwardly from the periphery of the container for the escape of lighter liquid components from the separation zone of the container, and wherein said means for continuously removing lighter liquid components removes such components after they have passed through said opening.

5. A disposable kit in accordance with claim 4 wherein the stationary conduit of the means for continuously removing lighter liquid components extends outwardly beyond said opening.

6. A disposable kit for the collection, centrifugal processing and storage of blood comprising an airtight flexible container of a shape generally symmetrical about an axis and having upper and lower walls inclined toward each other from said axis and joined along a circular edge, a baffle member disposed transversely within said container, joined to said upper and lower walls at said edge, having a plurality of perforations therein adjacent said edge and having an opening in the center thereof, a flexible tube, means on one end of said tube for making connection to a source of blood, an airtight rotary seal coaxial with said axis connecting said tube as an inlet to said container for high speed relative rotation therebetween, said tube extending within said container through said baffle opening, means disposed within said container at a fixed location intermediate said axis and said edge for skimming liquid from the interior free surface of a body of liquid rotating about said axis within said container, a second tube connected at one end through said rotary seal to said skimming means, and a second container connected to the other end of said second tube, said containers and tubes being in free communication with each other and hermetically sealed against the atmosphere and said tubes and second container being adapted to remain stationary while said first-mentioned container is rotated.

7. A process for the collection and centrifugal processing of blood and preservation of the red cells separated from the blood which comprises placing a sterile flexible plastic container in a centrifuge bowl, rotating the bowl and the container at high speed to establish and maintain a centrifugal field in the container, continuously flowing blood from a source directly into the centrifugal field in the container, separating plasma from the red cells by the centrifugal field, removing separated plasma from the container, discontinuing the flow of blood, glycerolizing the red cells retained in the container by flowing a glycerolizing solution through the container while rotating the container, discontinuing rotation of said container, removing the container from the bowl, freezing the red cells retained in the container, and storing the frozen red cells in the container under refrigeration without having removed the red cells from the container.

8. A process for the collection and centrifugal processing of blood and preservation of the red cells separated from the blood which comprises placing a sterile flexible plastic container in a centrifuge bowl, rotating the bowl and the container at high speed to establish and maintain a centrifugal field in the container, continuously flowing blood from a source directly into the centrifugal field in the container, separating plasma from the red cells by the centrifugal field, removing separated plasma from the container, discontinuing the flow of blood, glycerolizing the red cells retained in the container by flowing a glycerolizing solution through the container while rotating the container, discontinuing rotation of said container, removing the container from the bowl, freezing the red cells retained in the container, and storing the frozen red cells in the container under refrigeration without having removed the red cells from the container, thawing the frozen red cells in the container, rotating the container, with the thawed red cells therein, at high speed to establish and maintain a centrifugal field therein, deglycerolizing the red cells by flowing a deglycerolizing solution through the mass of cells in the rotating container, and resuspending the red cells in a liquid medium in the container.

9. A process for the collection and centrifugal processing of blood and preservation of the red cells separated from the blood which comprises placing a first sterile flexible plastic container in a centrifuge bowl, rotating the bowl and the first container at high speed to establish and maintain a centrifugal field in the first container, continuously flowing blood from a source directly into the centrifugal field in the first container, separating plasma from the red cells by the centrifugal field, removing separated plasma from the first container into a stationary second sterile flexible plastic container connected to the first container, discontinuing the flow of blood, glycerolizing the red cells retained in the first container by flowing a glycerolizing solution through the first container while rotating the first container, discontinuing rotation of the first container, removing the first container from the bowl, freezing the red cells and the plasma retained in the containers, and storing the frozen red cells and plasma in the respective containers under refrigeration without having removed the red cells from the first container.

10. A process for the collection and centrifugal processing of blood and preservation of the red cells separated from the blood which comprises placing a first sterile flexible plastic container in a centrifuge bowl, rotating the bowl and the first container at high speed to establish and maintain a centrifugal field in the first container, continuously flowing blood from a source directly into the centrifugal field in the first container, separating plasma from the red cells by the centrifugal field, removing separated plasma from the first container into a stationary second sterile flexible plastic container connected to the first container, discontinuing the flow of blood, glycerolizing the red cells retained in the first container by flowing a glycerolizing solution through the first container while rotating the first container, discontinuing rotation of the first container, removing the first container from the bowl, freezing the red cells and the plasma retained in the respective containers, storing the frozen red cells and plasma in the respective containers under refrigeration without having removed the red cells or plasma from the containers, thawing the frozen red cells and plasma in their respective containers, rotating the first container, with the thawed red cells therein, at high speed to establish and maintain a centrifugal field therein, deglycerolizing the red cells by flowing a deglycerolyzing solution through the mass of red cells in the rotating first container, transferring the plasma from the second container to the first container, and resuspending the red cells in the plasma in the first container.

11. The process of claim 10 wherein the blood source is a human donor.

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