May 21, 1963 S. RASTGELDI 3,090,549

CENTRIFUGE APPARATUS

Filed Feb. 24, 1958 5 Sheets-Sheet 1

FIG. 1

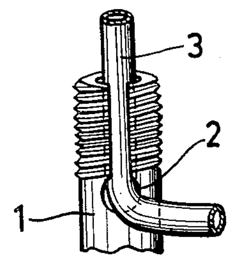


FIG. 2

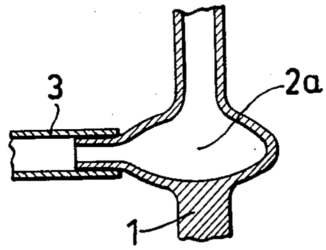
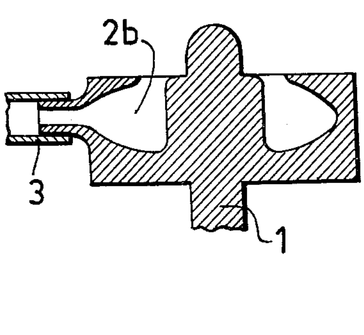


FIG. 3



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Filed Feb. 24, 1958 5 Sheets-Sheet 2

FIG. 4

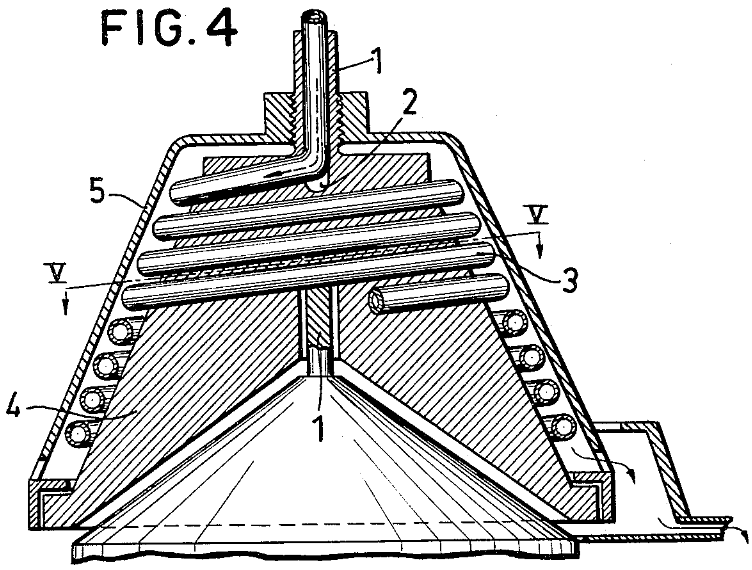
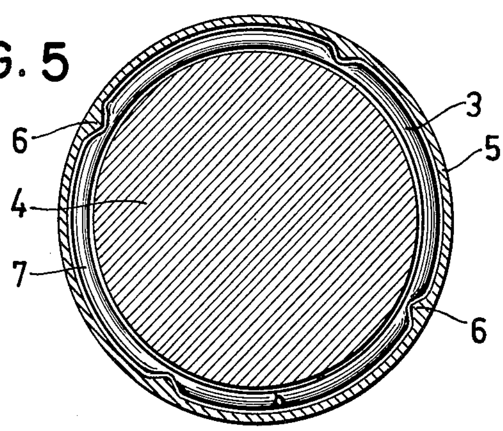


FIG. 5



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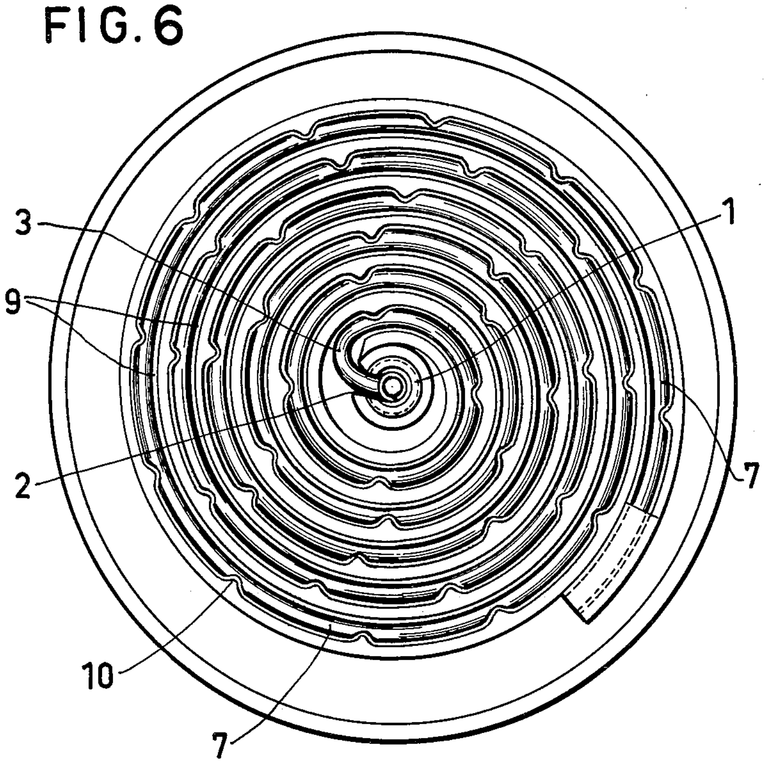
CENTRIFUGE APPARATUS

Filed Feb. 24, 1958 5 Sheets-Sheet 3

FIG. 6



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CENTRIFUGE APPARATUS

Filed Feb. 24, 1958 5 Sheets-Sheet 4

FIG. 7

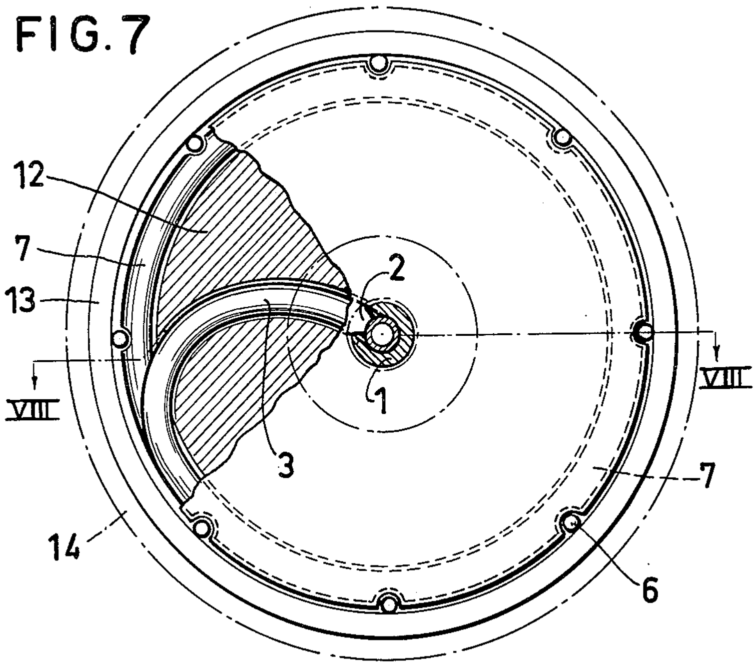
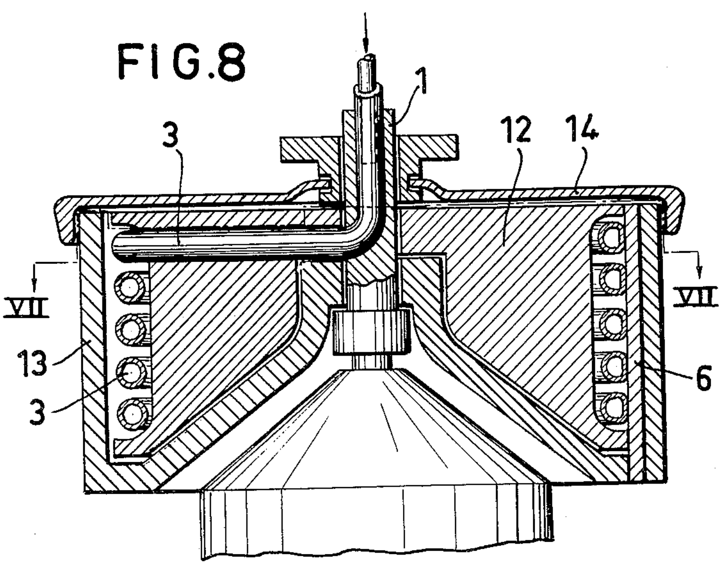


FIG. 8



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May 21, 1963 S. RASTGELDI 3,090,549

CENTRIFUGE APPARATUS

Filed Feb. 24, 1958 5 Sheets-Sheet 5

FIG. 9

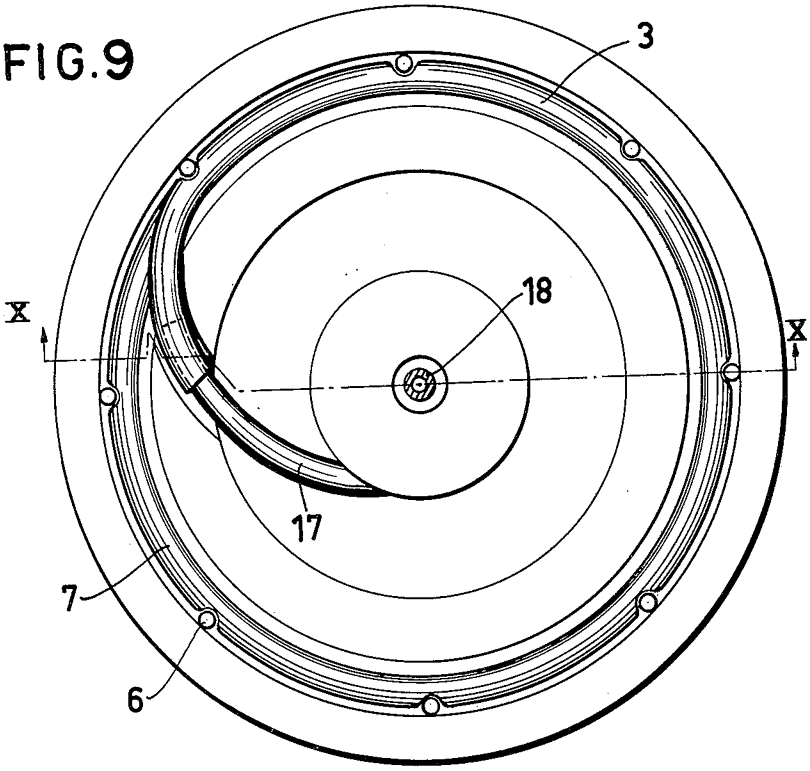
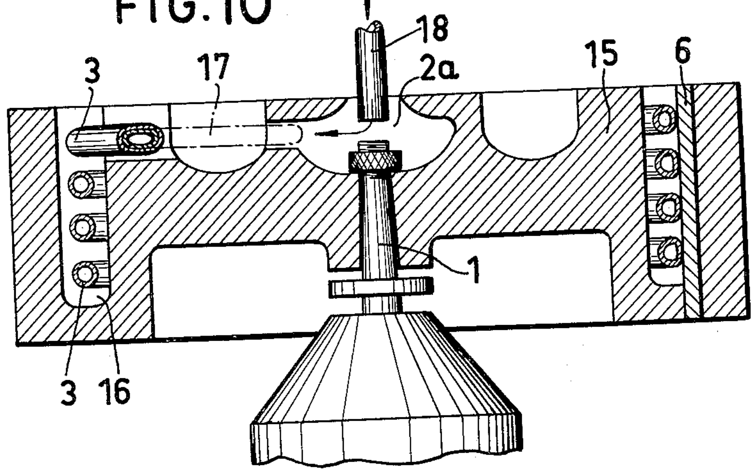


FIG. 10



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1

3,090,549
CENTRIFUGE APPARATUS

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Claims priority, application Sweden Mar. 8, 1957
5 Claims. (Cl. 233—26)

Conventional centrifuge tubes are inaccessible during centrifuging, i.e. it is not possible to fill the centrifuge tubes or change the nature of the contents, while in operation. Often a suspension is centrifuged and it is not possible to maintain a continuous supply during centrifuging. Nor it is possible to develop a suspension from a solution by changing the conditions of solubility to cause a precipitation during centrifuging. A conventional centrifuge tube is restricted to a certain volume and its purpose is to keep the particles precipitated by the centrifugal force in one layer and the suspension agent in another layer. The possibilities of separating different particles according to their size and weight are limited. As a rule, particles of different size are evenly dispersed before centrifuging. In the course of centrifuging, first the heavier particles and then the lighter ones travel to the bottom of the centrifuge tube. If the suspended particles constitute more than a certain percentage of the total volume, the particles will be baked together. In other words, the heavier particles cannot penetrate towards the bottom of the tube and for the same reason the lighter particles cannot rise to the uppermost layer. This is about what happens for example on centrifuging blood.

The present invention relates to an apparatus for treating liquids or dispersions for separation of the constituents according to their specific gravity or size, whereby the above-mentioned disadvantages are eliminated.

According to the invention there is provided an apparatus for treating liquids or dispersions in a centrifuge in order to separate the components according to their density or size, which comprises introducing the liquid or dispersion, during the operation of the centrifuge, centrally into a channel provided in the rotor of the centrifuge and causing the liquid or dispersion progressively to pass a number of projections or thresholds provided in the path of the channel.

The invention also comprises a centrifuge for the treatment of liquids or dispersions in order to separate the components according to their density or size in which the rotor of the centrifuge is provided with a central inlet emerging into a channel arranged in the rotor of the centrifuge or connected to the rotor of the centrifuge, said channel being provided with a number of projections or thresholds in the wall thereof.

The present invention offers certain advantages over the usual centrifuges. The said channel replaces the ordinary centrifuge tube and may be helically shaped (conically or cylindrically) in a horizontal or vertical plane, or it may have a spiral form. Theoretically, an infinitely long channel or hose can be placed in this position in empty condition. The helical or spiral hose may have one open end arranged centrally of the helix or spiral and the other open end arranged at the periphery of the helix or spiral. The said hose may be filled through the shaft of the motor during centrifuging. The suspension is sucked into the hose by the centrifugal force, and the particles slide on the peripheral wall of the hose towards the peripheral end thereof. At a continuous supply through the shaft of the centrifuge the hose will be packed from the periphery towards the centre when the peripheral end is closed and the lighter liquid is thrown out through the central end of the hose. Thus it is possible to pack the hose along its entire length. A small chamber, for

2

example of elliptical or circular vertical section, at the centre of rotation facilitates this procedure. Alternatively, the hose may first be filled with the suspension agent and thereafter a suspension is introduced through the shaft so that the particles move towards the periphery according to their size, specific gravity and friction between the peripheral wall of the hose and the contact surface of the particles. Alternatively, the central end of the hose is filled with a suspension and thereafter the hose is filled with the suspension agent. Alternatively, the hose may be filled with a solution whereupon the properties of the solvent are altered, for example by adding a salt solution changing the pH, admixing various organic solvents, or causing an eluent to flow through a solvent, as is done, for instance, in counter-current chromatography. Different solvents used within the field of chromatography can be used. By the present invention the adsorbent is eliminated and the dissolved or undissolved particles are separated on the wall of the hose and facilitate the process of elution when small amounts of substance are concerned.

The velocity of the particles from the motor shaft towards the periphery depends upon several factors, such as the contents of the hose, its nature, the friction between the particles and the peripheral wall of the hose, and the speed of the centrifuge. The hose may be divided into several intercommunicating chambers, and the first chamber which is located near to the motor shaft may for instance be filled with a mixture of different particles. Thereafter a solvent or solution may be chosen the specific gravity of which exceeds that of certain particles and is below that of certain other particles. During the centrifuging the liquid is supplied through the motor shaft. Lighter particles, which then assume position in the upper layer of the one chamber will be moved to the next chamber, when heavier particles are pressed towards the periphery of the first mentioned chamber. By this technique the lighter particles first move towards the peripheral end of the hose and the heavier ones afterwards. That is, the conditions of movement will be reverse to those generally prevailing when the entire length of the hose is concerned.

Different embodiments of the centrifuge according to the invention will be described below, merely by way of example, with reference to the accompanying drawings.

FIGURE 1 shows the tubular shaft of a centrifuge according to the invention through which a hose is introduced,

FIGURE 2 shows an ellipsoidic chamber provided in the shaft of a centrifuge and communicating with a helical hose,

FIGURE 3 is a modification of FIGURE 2 in which an annular chamber is provided around the shaft of the centrifuge,

FIGURE 4 shows a cross section through a hose centrifuge arranged in a helical shape,

FIGURE 5 is a section along the line V—V in FIGURE 4 with modifications,

FIGURE 6 shows a portion of a hose extending from the shaft of the centrifuge and having a number of chambers,

FIGURE 7 shows a top view of a cylindrical hose centrifuge along the line VII—VII in FIGURE 8 and FIGURE 8 is a cross section along the line VIII—VIII in FIGURE 7,

FIGURE 9 is a modified embodiment of the centrifuge according to FIGURES 7 and 8 and FIGURE 10 is a section along the line X—X in FIGURE 9.

In FIG. 1, there is shown the motor shaft 1 of a centrifuge, the upper portion of the motor shaft being threaded and tubular. A hose 3 of a flexible material, for instance rubber, forming a helix in the centrifuge, is introduced into the motor shaft 1 through a slot 2 and is drawn out through the motor shaft. The lid of the centrifuge rotor is to be screwed on the threaded portion of the motor shaft. When the centrifuge attains a certain speed, a suspension is run directly into the hose through its free or upper end. When leaving the motor shaft 1 the hose 3 is at an angle to the motor shaft. Due to this angle the entering suspension or suspension agent is thrown from the central end of the hose to its outer end. The suspension, the suspension agent or a solvent can be introduced through a tube, a syringe or the like.

According to FIG. 2, the hollow motor shaft 1 is formed with an ellipsoidical chamber 2*a*. This chamber communicates with the hose 3 and is filled by means of a narrow tube. The suspension is thrown against the peripheral wall of the chamber 2*a* and from there into the hose.

FIG. 3 shows an annular chamber 2*b* concentric to the motor shaft 1. The upper part of the chamber 2*b* is open, and a narrow tube can be introduced into the annular opening during the centrifuging. The hose 3 is filled in the same way as stated above.

FIG. 4 shows a centrifuge with a hose 3 wound around a truncated cone 4. A frusto-conical casing 5 is mounted outside the truncated cone 4 so that the hose 3 is retained between the two concentric surfaces. On centrifuging, the upper centrally disposed end of the hose is filled, for instance with a suspension. The particles contained in the suspension will settle against the peripheral wall of the hose. Thereafter the suspension agent is fed continuously into the hose. The suspension attains a constant speed from the upper, centrally disposed end of the hose towards the lower peripherally disposed end of the hose. Particles of different size, on the other hand, cannot travel with the suspension agent at the same rate. The result will be that some particles move more rapidly and some particles more slowly. After a certain time the centrifuging is interrupted and the hose is divided into different pieces, each piece being analysed separately. Alternatively, the suspension agent is supplied in such a quantity that all particles are allowed to move towards the lower, peripherally disposed end of the hose and from there to a suitable collecting device. Particles which adhere to the peripheral wall of the nose can be loosened by introducing a heavy liquid, for example glycerol, chloroform, saturated salt solution, or the like.

FIG. 5 is a section through the structure of FIG. 4 with the modification that in the outer casing 5 a number of longitudinal abutments, thresholds or ridges 6 are provided. During centrifugation the hose 3 is pressed against the casing 5. Those portions of the hose which come into contact with the ridges 6 are constricted, and, between two constrictions, pockets or chambers 7 are formed which communicate with each other. At the beginning of the centrifuging the first chambers in the upper end of the hose are filled. Then the hose is filled at constant speed. The heavier particles are pressed against the peripheral wall of the hose 3 and the lighter particles float above the heavier ones. The suspension agent flowing in at constant velocity conveys the lighter particles from one chamber to another. It is thus possible for example to separate white blood corpuscles from heavier red blood corpuscles. By analysing microscopically each chamber it will be found that the thrombocytes are conveyed the longest distance and the heavier hyperchromic erythrocytes the shortest distance. The lymphocytes lie nearer to the thrombocytes and the leukocytes lie nearer to the erythrocytes. The border line between different blood elements is rather characteristic and a number of chambers gives a representative picture of different solid elements in the blood. The separation is facilitated by the conical form of the centrifuge, so that the centrifugal force increases towards the base, whereby also smaller lighter elements adhere to the peripheral wall of the hose.

In FIG. 6 an embodiment is illustrated in which a flat and horizontal spiral extends from the shaft 1 of the centrifuge. The hose 3 is placed in a spiral groove 9. A number of inwardly facing ridges 10 are formed in the peripheral wall of the groove, whereby a great number of intercommunicating chambers are formed in the hose. In the central end of the hose a minor amount of suspended particles is introduced. The suspension agent is thrown out through the hole and the solid particles will stick to the peripheral wall of the hose. In order to improve the separation a suspension agent may be introduced which washes the lighter particles from the heavier particles. Owing to the increased centrifugal force towards the periphery, lighter particles are caught in the chambers of the hose located more peripherally.

The embodiment shown in FIGS. 7 and 8 comprises an inner reel 12 placed in a cylinder 13 on which a lid 14 is placed. A hose 3 is wound around the reel 12 which extends from the hollow centrifuge shaft 1. The chambers 7 are formed by the action of pins 6 which are provided at the inner wall of the cylinder 13.

The embodiment shown in FIGS. 9 and 10 comprises a rotor 15 which is provided with a peripheral groove 16 communicating with the chamber 2*a* by means of a metal tube 17. The hose 3 is placed in several turns in the groove 16 and the metal tube 17 is introduced into one end of the hose. The liquid or suspension is supplied through a tube 18 to the chamber 2*a*. The chambers 7 are formed by pins 6 provided between the outer wall of the groove and the hose 3.

The embodiments described above may be combined in various ways. It is also possible to use several hoses simultaneously. Furthermore, by a combination of the devices according to FIGS. 1–3 it is possible to introduce liquid or suspensions through several channels from the central part of the centrifuge. The pockets or chambers can be formed as branches to communicate with the central part of the hose. The end of the hose can be bent inward towards the shaft of the centrifuge so that it terminates at a certain point between the periphery and the centre of the centrifuge. A helical, cylindrical or spiral hose can be open at one or both ends. In addition to the forms described above the hose can be wound in several different forms. Where used in the claims, the word "helically" shall be construed broadly enough to include "spirally."

Example 1.—Examination of ascites: An empty hose is mounted in a centrifuge according to FIGS. 4, 5 or 6. The motor of the centrifuge is started and ascites fluid is supplied through the central end of the hose. Cells suspended in the ascites fluid then travel towards the peripheral end of the hose. Cells present in the fluid will settle against the peripheral wall of the hose. The liquid without cells passes above the cells and out through the discharge end of the hose. The particles collected in the chambers of the hose are examined microscopically. The same technique is used in examining urine sediments or punctates from abscesses or fluid from the pleural sac.

The peripheral end of the hose can also be punctured so that the clear ascites fluid separated from the cells is thrown out of the hole made.

Example 2.—Separation of blood corpuscles: An empty hose is placed in a centrifuge, for example according to FIGS. 5, 6 or 7–10. The peripheral end of the hose is bent towards the shaft of the centrifuge and is held in this position. The motor is started and the hose is moistened with a small amount of serum. Thereafter a suspension of red and white blood corpuscles is supplied. Then a volume of a solution of physiological saline or serum is allowed to flow through the hose. Thereby the erythrocytes are pressed against the peripheral wall of the hose, and the lighter solid elements, such as thrombocytes, lymphocytes and leukocytes, are conveyed from one pocket or chamber to the other according to size and weight. Physiological saline or serum passing through the hose is thrown out through the inwardly bent peripheral end without the solid elements being brought along. This is due to the increased centrifugal force in the outer coils which rotate most remote from the shaft of the centrifuge. In other words, a thrombocyte or a lymphocyte has greater weight in the outer coils than in the inner ones and adheres peripherally at the greatest distance from the axis of the centrifuge, while the heavier erythrocytes adhere more centrally and cannot be conveyed any farther by the saline or serum flowing through. By this method one also separates the hypochromic erythrocytes from the reavier hyperchromic erythrocytes. In the same place as lymphocytes or thrombocytes some erythrocytes are to be found. However, they are poor in haemoglobin and more transparent in the microscope.

What I claim is:

1. A centrifuge for separating the components of a fluid dispersion in accordance with their density or size, comprising a frusto-conical rotor having a socket at its lower end for receiving the shaft of a motor, and a stub shaft at its upper end in axial extension of the axis of said socket, said stub shaft having a longitudinal slot extending along its length, a flexible tube helically wound on said rotor and having inlet and outlet ends for receiving and discharging said dispersion, the conical portion of said rotor receiving and supporting the convolutions of the flexible tube thereabout with one end of said tube received in said slot in said stub shaft, said rotor having a peripheral flange at its lower end, a removable conical shield for said tube secured to said rotor and resting on said flange, said shield having spaced projections on its inner wall, said projections engaging said flexible tube at spaced points to form separate communicating chambers therein to receive the weightier elements of said dispersion when said rotor is rotated.

2. A centrifuge of the type supported on the end of a motor shaft for continuously separating the components of a fluid dispersion in accordance with their density or size, comprising a rotor having a socket at its lower end for receiving the shaft of a motor, and a stub shaft at its upper end in axial extension of said socket, said stub shaft having a longitudinal slot extending along its length, a flexible tube of uniform diameter helically wound around said rotor and having inlet and outlet ends for receiving and discharging said dispersion, the rotor receiving and supporting the convolutions of said flexible tube with one end of said tube received in said slot in said stub shaft, and means carried by said rotor in pressure contact with said tube at spaced points along its length to divide said tube into a plurality of permanently formed communicating chambers.

3. A device as claimed in claim 2, in which said dividing means comprises a shield for said tube, said shield having spaced projections on its inner wall, said projections engaging said flexible tube at said spaced points.

4. A centrifuge for continuously separating the solid components of a fluid dispersion in accordance with their density or size comprising a rotor having an axial inlet, a flexible tube of substantially uniform diameter helically wound on the rotor with one open end thereof disposed in said inlet for continuously receiving said fluid dispersion, the other end of said tube being open and disposed on the periphery of said rotor for continuously discharging said dispersion, means on the rotor in pressure contact with said tube at spaced points along its length to form spaced permanently formed communicating chambers in said tube throughout its length, and means for rotating said rotor about its axis.

5. A centrifuge according to claim 4 in which the chambers in the tube are formed from that portion of the wall of the tube most distant from the axis of the rotor.

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