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APPARATUS FOR BLOOD TRANSFUSION

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2 Sheets-Sheet 1

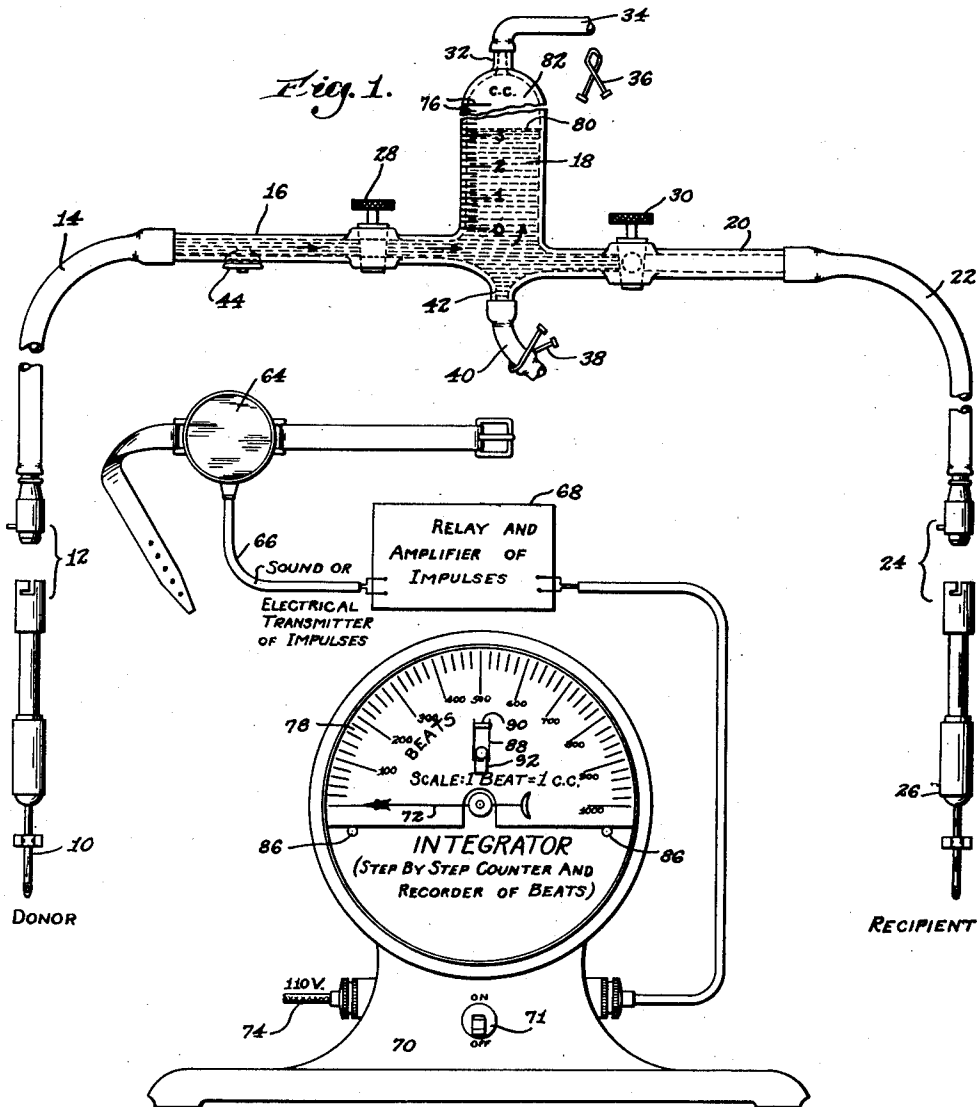


Fig. 2.

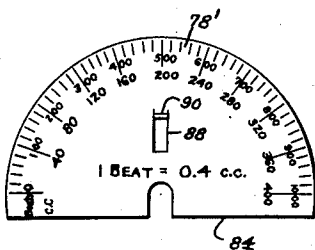


Fig. 3.

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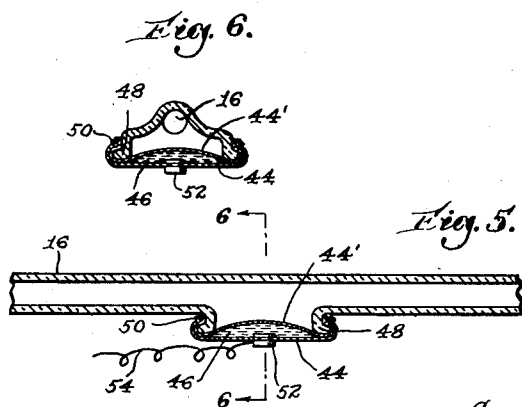
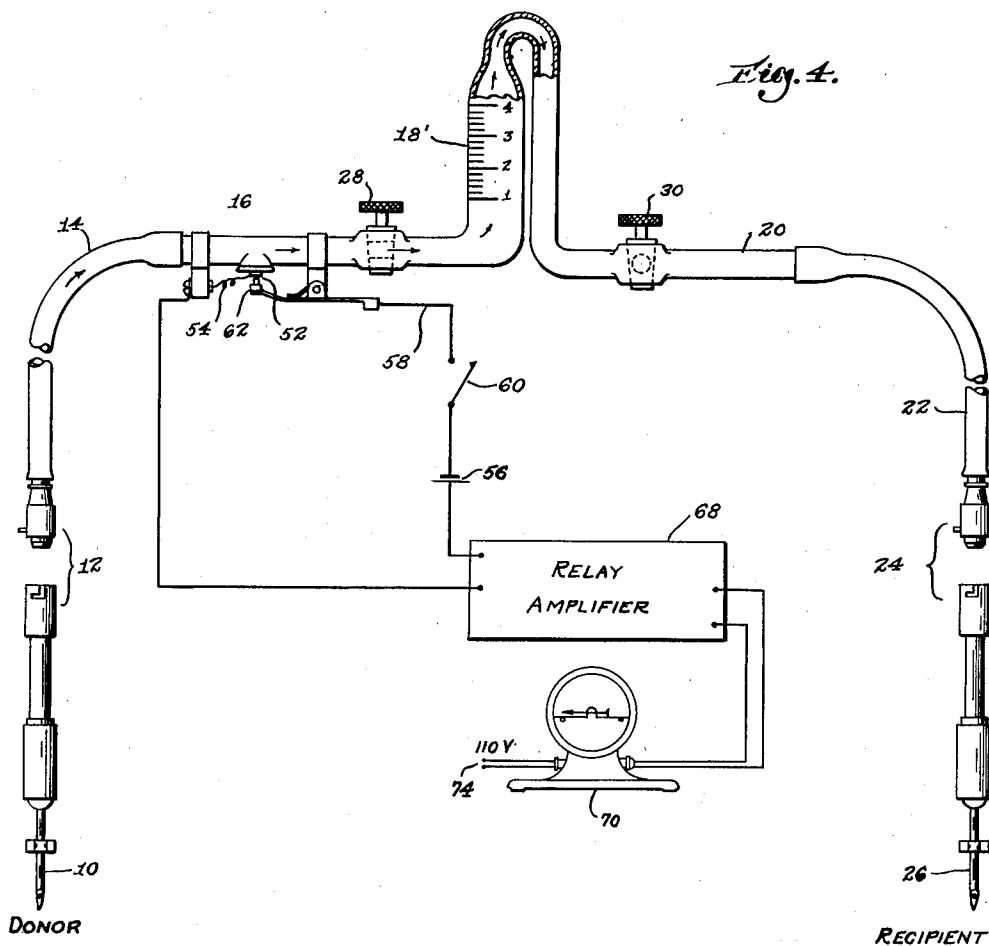
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2 Sheets-Sheet 2



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APPARATUS FOR BLOOD TRANSFUSION

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5 Claims. (Cl. 128—214)

This invention relates to improvements in apparatus for blood transfusion.

The invention provides for continuous flow from donor to recipient, with safety to the recipient, and with means for continued and intelligent observation and control of the transfusion by the operating surgeon.

Prominent features are that the invention avoids the objections that have heretofore characterized direct flow, and greatly simplifies the operative conditions of the transfusion, as compared with the best systems now in use, so far as known to me. In all practice hitherto commonly considered good, I believe, a piston and cylinder are provided, with connecting tubes and a three-way valve, which are manipulated by the operator to draw blood from the donor into the cylinder, and then to push it into the veins of the recipient, step by step. The operator keeps volumetric account of his transfer by observing and recording the volume that comes into his cylinder at each stroke, which varies according to the length of piston stroke each time, and by adding together the successive volumes thus displaced from the cylinder toward the recipient.

The intermittent, suction-compression action of the pump-syringe apparatus, and the intervening valve actuations which must be effected at each stroke, involve dangers and delays which it is among the objects of the present invention to avoid. Such dangers include the damage to the blood which is being transfused, by its corpuscles contacting with or becoming pinched between mechanically moving parts; and danger of its clotting by exposure to air on the walls of the cylinder; and the dangers which arise from irregularities of operative manipulations. The danger of clotting is so great that sometimes the operative piston begins to stick in its cylinder after one or two hundred c. c. of blood have passed. This requires immediate cessation of operations; introduction of salt solution; and thorough washing of interior surfaces, before the operation may be resumed. There are dangers, also, that air may get into the line of flow to the recipient; and that important changes of condition may occur in the patient during the long time required by the operation, and its usual incidental delays when these methods are followed.

It is among the objects of the invention to avoid or reduce all of such, both of dangers and of delays, so that if existing at all they are of very minor import. The invention provides for the ready suspension of transfusion, and substitution of salt solution if and whenever desired; also

for its removal; and for a re-substituting of blood; all with a very low minimum of danger of clotting, of damage to corpuscles, and of introduction of air into the line of flow. It is another major feature that the invention provides a method by which both the rate of flow and the total quantity of elapsed flow may be known instantly and constantly by the operating surgeon.

For preliminary information as to what rate of flow the donor will naturally produce, and for controlling that flow to whatever slower rate is desired, the apparatus provides means by which one may observe visually the flow from the donor, as naturally occurring through the transfusion tube at each pulsation. When this flow occurs freely, as in air, but still within the apparatus, the approximate quantity per pulsation can be observed or computed. This rate of free flow can be reduced by constriction of the passage, means for which is provided. The strength of pulsations may also be observed visually at all times while the flow is proceeding from donor to recipient; and if there be any change of consequence in the force or quantity of each pulsation, that may be discovered. For integrating the quantity of elapsed flow the invention provides means to register the total number of pulsations from the beginning, each being automatically detected, counted and registered. With the knowledge of this total of pulsations, and of the quantity passing at each pulsation, and the knowledge as to whether this quantity per pulsation has changed during the period of direct flow transfusion, the operator is constantly possessed of information as to the volume which has passed into the recipient. If it be observed that a change in the rate has occurred, the apparatus provides easy and quick means for a re-measurement, giving the new current rate of flow into free air per pulsation, without seriously interrupting the internal conditions of safety affecting the blood which is in the apparatus; and with quick elimination of all danger of air. A washing with salt solution may be accomplished readily and quickly before the resuming of transfusion.

For the registering of elapsed flow the invention provides for several choices of the operator for integrating the observed or indicated total flow, being the total of the individual successive discharges of known individual volume which pass from the venous system of the donor. The recurring impulses within the transfusion tube may be observed therein either visually, audibly, or mechanically, as is pointed out more in detail hereinafter; and, for the purpose of totalling their

number, the observations as to their recurrence in the transfusion system are not limited to being made within the actual connecting tube thereof.

It is intended that the patent shall cover, by suitable expression in the appended claims, whatever features of patentable novelty exist in the invention disclosed.

For the better understanding of ways in which the invention may be applied and used, drawings are made a part of this specification, showing schematically the operation of the method, and apparatus that may be employed in it.

In the drawings:

Figure 1 is a schematic showing of apparatus for direct flow from the blood system of the donor through the calibrating, observing, flow controlling, and flow integrating element, to the blood system of the recipient;

Figure 2 is a schematic showing of pick-up and recording apparatus auxiliary to that of Figure 1 for the measuring or integrating of the flow;

Figure 3 represents a dial which may be substituted in the apparatus of Figure 2, being an integrating dial made on a scale different from that of Figure 2;

Figure 4 is a schematic showing comparable to that of Figure 1 with a modified arrangement, and showing a method of attaching thereto one form of the apparatus of Figure 2;

Figure 5 is an enlargement of a detail of Figures 1 and 4, in section on the axial line of the tubing; and

Figure 6 is a section through the apparatus of Figure 5 on line 6-6, perpendicular to the axis of the tube.

Referring to the drawings, Figure 1 shows schematically a device for connection to a vein of the donor, being a needle as represented, or a cannula or other device, which is adapted to be suitably locked as by a joint at 12 to a flexible tube 14 which leads to a glass tube having an intake portion 16, a flow calibrating and observing chamber 18; and a delivery portion 20, which leads through another flexible tube 22 and suitable locking joint 24 to a needle 26 or other device for connection with the venous system of the recipient. In the intake portion is a stop cock or shut off valve 28; and another, 30, is in the delivery portion of the glass tube. The passages in these tubes and through the stop cocks are wholly of glass, smooth, and of whatever size may be approved for the proper and safe handling of blood. A size which I have found satisfactory and which accords with present practice in blood transfusion has a diameter of four to seven millimeters, or thereabouts. The stop cocks 28 and 30 may be conical glass plugs having ground faces fitting against ground glass cones formed in the walls of the tube as seats. These are instantly removable by lifting, giving access for cleaning both plug and seat, as well as adjacent parts of the tube.

The chamber 18 has a tubular projection 32 at the top adapted for connection to rubber tube 34, which may lead to a source of supply of salt solution, or for discharge of salt solution, or to open air; and as this is to be used at times with the tube 34 closed, the drawings represent a hemostat 36 close by, which may be applied to the rubber tube in a manner well known, as is represented, for example, in the case of the similar hemostat 38 applied to the similar rubber tube 40 leading from the tubular projection 42 from the lower end of the chamber 18, which lower tube may likewise lead either to a place of dis-

charge of salt solution or to a place of its forcible supply, or to open air; and is herein referred to as a drain.

At some suitable place, herein represented as being in the receiving portion 16 of the transfusion tube, is a pulsation transmitting device or the like chamber with flexible wall 44 which is exposed interiorly to pressure of liquid within the tube and which can register changes of pressure therein by protruding more or less. This pulsation transmitting device may be built in any suitable way, and will ordinarily be relatively larger than is indicated in the schematic drawings, Figure 1. A more detailed showing of a construction which this part of the apparatus may have is found in Figures 5 and 6. The flexible wall 44 is represented conventionally as being double and having between its two portions a body of glycerin 46, these two membranes 44 and 44' being secured around the rim of a disk-like enlarged side opening of tube 16, marked 48, where they may be tied or otherwise secured as indicated by the ties 50. The purpose of this pulsation transmitting device is to provide a flexible wall which indicates by its tangible movement pulsations of pressure which occur within the tube. In case the pulsations are to be observed and the total flow which they indicate to be integrated electrically, this pulsation transmitting device may have an electrical contact point 52 and may be connected to a flexible pigtail 54 for the passage of electrical current at proper times without this electrical connection being a cause for seriously damping or resisting movements of the device 44.

The fluctuations of the pulsation transmitting device may be observed in any of several ways, two of which are illustrated in Figure 2 schematically by "sound or electric transmission of impulses"; and in Figure 4 an electrical pick-up is represented as being actually applied, by the schematic showing there made, in which there is a battery 56, an electrical circuit 58 leading through a switch 60 to a contact 62 which co-operates with the contact point 52 to complete the circuit whenever the point 52 is bulged out from the tube far enough to engage the contact point 62. Figure 2, however, represents in a more general way apparatus which may be used in which the pick-up element is marked 64 and may have within it a pair of contact points corresponding to 52 and 62 which will be pushed into contact together when the face 64 of the pick-up is resting against the face 44 of the device with proper tension. This pickup 64 is, however, intended to typify a broader range of equivalent devices which may be used for this purpose. Assuming, for example, that it is laid against the device 44, and is itself in the nature of a pulsation transmitting device, the bulging of the membrane 44 will produce an in-bending of the membrane 64, with resulting sound or other disturbance which will be conveyed through the tube 66 as a sound to the apparatus 68 which is marked "relay and amplifier," as sound is conveyed through the tube in a stethoscope. In fact the device 64 may be the pick-up end of a stethoscope, the sound picked up being delivered to the apparatus 68 where, by suitable electrical apparatus, the details of which are not a part of the invention, there may be a conversion of the sound into fluctuations of electrical energy, which may be amplified by ordinary electrical means, such as by relay or by amplifier thermionic tubes, until a current is attained of sufficient

strength to actuate a mechanical step by step counter and recorder of beats in the apparatus shown schematically in the lower part of Figure 2, to which the reference numeral 70 is applied as a whole. This, by electro-mechanical apparatus not shown is adapted to actuate the needle 72 step by step, one step for each impulse received through the pick-up and amplifying system from the pulsation transmitting device 44, or from whatever place else the pick-up 64 is applied in the system of blood flow of the donor which is connected with the transfusion tube and is furnishing the impulses for the flow from donor to recipient. To this end provision is made for an electrical connection 74 to a source of power; and there are within the apparatus details of mechanism in the nature of pawl and ratchet, which it is not necessary to illustrate, in which the pawl oscillates so as to advance the needle 72 one step at each pulsation, or at each double pulsation as may be suitable according to the way in which the apparatus is to be used and the place where the pick-up is made in the donor's system.

The chamber 18 may be in the form of a straight large glass tube having graduations 76 marked on it indicating volumetric capacity in cubic centimeters, the size of the tube in diameter being preferably small enough so that a fifth of a centimeter corresponds to a vertical distance on the tube which is easily distinguishable by the eye of an observer. And the length of the tube may be such as to hold whatever number of cubic centimeters may be found desirable and convenient in the portion which is graduated, and to extend above that as far as may be convenient, for purposes explained hereinafter, leading through the top outlet 32, 34. The purpose of these graduations is to enable the operator to observe visually the approximate volume of blood which is furnished by the donor at each pulsation; and these have a relation to the integrator 70. The scale 78 of the integrator 70 represented in Figure 2 is a scale of cubic centimeters; but this scale is replaceable, by any suitable mechanical arrangement, by any selected one of a series of scales, another one of which is represented in Figure 3 marked 78', wherein each unit advance of the needle 72 corresponds to a different volume, for example to 4 cubic centimeters.

The operation of the apparatus may be as follows, subject to such variations as the individual judgment of the operating surgeon may deem wise or as necessity may cause: the tubular parts being properly sterilized and connected to donor and ready for connection to recipient; the cock 30 for delivery being closed and the hemostat 36 for the drain from chamber being applied closing the drain, and the intake cock 28 being open, blood flowing from the donor under the impulse of his heart beats, aided as much as may be desired by gravity by arranging the relative levels of donor, of chamber 18 and of the recipient, flows through pipe 16 into chamber 18 and rises therein step by step, with the extent of rise at each pulsation being visible to an observer who thus can learn the volume of blood per pulsation which this donor will deliver, approximately, under the circumstances and particular arrangements which happen to be existing. The chamber 18 may be as high as is convenient for making repeated observations in quick succession along the scale 76; and from these a determination may be made of a figure representing the approximate quantity per beat, and then the scale which is

made on the basis of that quantity per beat may be selected for and installed in the integrator. This may be the disk there represented having the scale 78, or some other disk of the series, bearing upon it the selected scale. As the chamber fills, any air that may have been therein will rise and clear itself both from the chamber and from the drain 40, 42 and from the first part of the delivery pipe 20, up to the stop cock 30. This situation is portrayed in Figure 1, assuming the apparatus to be actually connected to the donor at the left, the liquid level being at 80. With such a height of liquid standing above the delivery pipe entrance there is no danger of any air from the space 82 above the column getting down into the delivery pipe 20, when cock 30 is open and transfusion is proceeding. With liquid at a high level, the operator may apply the hemostat 36 to the vent tube 34, imprisoning a body of air in the top of the chamber 18 and in the tube 32, 34; and thereafter each pulsation of flow from the donor, tending to lift the level 80 of liquid, will be resisted elastically by the imprisoned air 82, to a degree determined by the relation of strength of impulse received from the donor and volume of the body of air remaining trapped between hemostat and top of liquid in chamber 18. The chamber 18 may preferably be longer than is represented in the drawings; and, by selecting the point of application of the hemostat to the rubber tube, a relation can be found between impulse and air volume such that, when the delivery cock 30 is open and blood is continuously flowing into the recipient's system, the liquid level in chamber 18, held down by the air under slight compression, will rise at each pulsation and then fall, with the air yielding elastically and then restoring the pre-existent level as the pulsation passes. The recurring pulsations in chamber 18 may have such magnitude as to be seen easily, especially if viewed against a source of light; and the observing of a reduction of amplitude would then be a cautionary signal. It might indicate a lessening of the strength of pulsation, possibly due to a reduction of donor's propelling force, or to an operative maladjustment of the intake needle; while an increase of amplitude might show some obstruction to the delivery flow into the recipient. In either case opportunity for control of the rate of flow is afforded by suitable adjustments of either stop cock, if either happens to be at the moment only partly open. In case a reduction of the volume being delivered to the recipient at each pulsation is indicated, the surgeon may, if he desires, proceed to a re-determination of the rate of flow by closing cock 30, removing the hemostat 36, and, if the location of the level 80 on the scale 76 requires it, temporarily opening the drain 40 so as to reduce that level, incidentally temporarily closing the cock 28 if desired. With the space 82 opened to free air, a calibration of the current rate of flow can quickly be had for comparison with the initial calibration; after which the flow condition to the recipient may be quickly restored by opening cock 30 and reapplying the hemostat 36, for in the interval there will have been no exposure of air to any passage along which the blood is flowing to the recipient, or from which (as from the top of chamber 18) any blood need flow to the recipient, and therefore no clotting nor even incipient coagulation.

Or, initially, if preferred, the blood may be allowed to fill the chamber 18 and to issue thence through 32 and 34 past the place where the hemo-

stat 36 is to be applied, and in that case, when ready, there will be no air whatsoever in the system up to the stop cock 30.

When ready to begin the transfusion the cock 30 may be opened and the flow which then proceeds through delivery tubes 20, 22 and needle 26 will clear air from this delivery passage, making ready for the needle or other connection 26 to be made to the recipient's venous system. At the instant of connection the switch 71 of the integrator may be turned on, the pulsation transmitting device or the pick-up thereof having been suitably applied, and forthwith the needle 72 begins to advance along the scale 78 or 78', showing the approximate total volume in cubic centimeters of blood which has at any instant passed into the recipient's venous system. In view of the constriction of flow by the smallness of discharge passage through needle 26 the initial calibration can be made more accurately than by the illustrative method above described, if in making it the measurement be taken in a graduated tube receiving discharge from the needle 26 at the level at which the needle is to be inserted into the recipient, and with the other operating conditions, including allowance for intake resistance of the recipient's system, accurately foreshadowing those of the actual operation. If a larger delivery means be employed than the usual needle 26 the rate of flow may be controlled by the partial closing of either cock 28 or cock 30; and in case of weakening of the donor's impulses the flow may be enlarged by removing restrictions thus applied.

For the convenient and quick setting of a selective scale in the integrator any suitable device may be employed, or, without changing the scale, a computation based on the observed rate per impulse and the total number of impulses recorded will tell the total of input attained at any moment. In the device illustrated interchangeable semi-circular plates are provided whose lower edges 84 may, in each case, be inserted behind the needle 72 to rest on a pair of pins 86, which position the scale properly with respect to the pointer 72; and in the upper part of this semi-circular disk may be a slot 88, from which a tab 90 is turned up to serve as a handle and which permits passage of a loose hook 92 which can be turned up to go through the slot, and turned down to hold the disk in place.

All connections having been made, the operating surgeon is free to watch carefully the automatic and safe continuance of flow of donor directly to recipient, which proceeds with a practically complete elimination of those dangers to the constituents of the blood resulting from mechanical shock upon corpuscles, or from contact with air or with any surface not wholly sterilized. The pick-up device 64 may be applied either to the place provided at 44 in the flow tube of the system, or to any other tube of the system, which includes any place in the donor's body where the heart impulses can be picked up either audibly or by mechanical oscillation, either of which can be amplified by electrical devices already known, so as to reproduce the impulse in the integrator 70 with sufficient force to operate a pawl back and forth on a ratchet wheel, or other well known mechanism, the details of which do not need to be shown, but which are indicated by the phrase "step by step, counter and recorder of beats" on the face of the integrator 70.

For the cleaning and interior sterilizing of the apparatus, and for the introduction of salt so-

lution at any time, and even for its introduction into the recipient if that be desired, the top and bottom openings of the chamber 18 make ample provision, either of which may be intake and the other outflow, coupled with the stops 28 and 30. If there should be occasion for it it can be quickly done during the operation of transfusion, either by gravity flow or by syringe injection, without removing the connection either to donor or to recipient, while the cocks 28 and 30, or either of them, remain closed.

Figure 4 illustrates a modified form in which the taking of impulse from the flow system is by the electrical pick-up of a pressure pulsation at 52, 62; and a modified form of chamber 18', corresponding to the calibrating chamber 18, is shown having a scale on which the volumetric value of impulses from the donor is observable in a glass tubular course which proceeds within closed walls without openings 42 or 32. In this, any air initially present in the chamber 18' is forced up to the top of that chamber as blood enters from below from the donor; and the diameter of the tube should be small enough so that all such air will be forced on ahead of the flow of blood and will be cleared from the system when the blood has reached the discharge needle 26. The plugs of cocks 28 and 30 are removable and the tubes are separable at 12 and 24, thus affording means for introduction and discharge of salt solution, and interior washing, when desired.

It will be understood that other variations may be made while still employing the invention which is herein disclosed and set forth.

The invention depends upon recognition of the fact that, with connection for continuous flow from donor to recipient, the rate of flow will, nevertheless, be irregular, in that it will occur in pulsations synchronous with the pulsations in the blood system of the donor; and the providing of apparatus to indicate the average rate of volumetric flow per pulsation permits the making of a summation of the total volume of flow during an elapsed period of time by introducing as a factor the elapsed total number of pulsations. The calibration chamber is not necessarily within the continuous passage, although this is a very desirable form which is preferred; and the pick-up of pulsations can likewise be observed elsewhere as above noted and may, if preferred, be accomplished by other means than that herein illustrated.

If the heart impulses of the donor, aided by gravity, do not enter the blood into the recipient's system as rapidly as desired, the rate can be accelerated by first letting a quantity accumulate in the chamber 18, then closing the inlet cock 28, and then applying air pressure through the tube 34 and the space 82 in the top of the chamber. The chamber may then be refilled from the donor, and the pressure injection into recipient repeated. If the weakness of connection to donor's impulses, or the small diameter of needle 10, or other cause, make the inflow to chamber 18 too slow, this can be accelerated by applying bulb, syringe or other mild suction of air to the tube 34, cock 30 being closed. By reversal, air pressure can then inject this into the recipient. By this arrangement none of the blood reaches the bulb or syringe and the blood flowing into the delivery tube 20 may be only that in the lower part of the chamber 18, which has not been in contact with air in the chamber, nor even with any intermittently air-covered part of the chamber wall. In such cases of in-

termittent inflow the integrator would of course be operated only during the periods of flow.

I claim as my invention:

1. In apparatus for blood transfusion, the combination of a tube having terminals adapted for connection to the blood systems of donor and recipient, said tube affording a continuous flow passage for blood from donor to recipient; combined with a chamber, connected with the passage and rising above that part of the passage with which it is connected, and constituting an air trap; there being means for the temporary closing of the passage beyond the place of its connection to the chamber; the top and bottom of the chamber being adapted for connection of tubes additional to the first mentioned tube.

2. In apparatus for blood transfusion, the combination of a tube having terminals adapted for connection to the blood systems of donor and recipient, said tube affording a continuous flow passage for blood from donor to recipient; with a calibration chamber for the volumetric flow per pulsation from the donor's blood system; means for pick-up count of the pulsations, and for summation thereof; there being a flexible portion of wall in the passage, responding by flexure to passing pulsations of flow, with which the said pick-up means coact.

3. In apparatus for blood transfusion, the combination of a tube having terminals adapted for connection to the blood systems of donor and recipient, said tube affording a continuous flow

passage for blood from donor to recipient; with summation means, and means whereby the summation means is actuated in harmony with pulsations of flow through said passage.

4. In apparatus for blood transfusion, the combination of a tube having terminals adapted for connection to the blood systems of donor and recipient, said tube affording a continuous flow passage for blood from donor to recipient; with summation means, and means whereby the summation means is actuated in harmony with pulsations of flow through said passage; and amplifying means connected between pick-up and summation means whereby the insufficient impulses picked up result in impulses strong enough to operate the summation means.

5. In apparatus for blood transfusion, the combination of a tube having terminals adapted for connection to the blood systems of donor and recipient, said tube affording a continuous flow passage for blood from donor to recipient; with a calibration chamber for the volumetric flow per pulsation from the donor's blood system, said chamber being between the said terminals and having the course of flow rising through it; and stop cocks in the passage before and after said chamber; the plugs of said stop cocks and the bodies thereof being separable whereby, by removal of a plug an opening into the tube is made, available for operative needs.

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