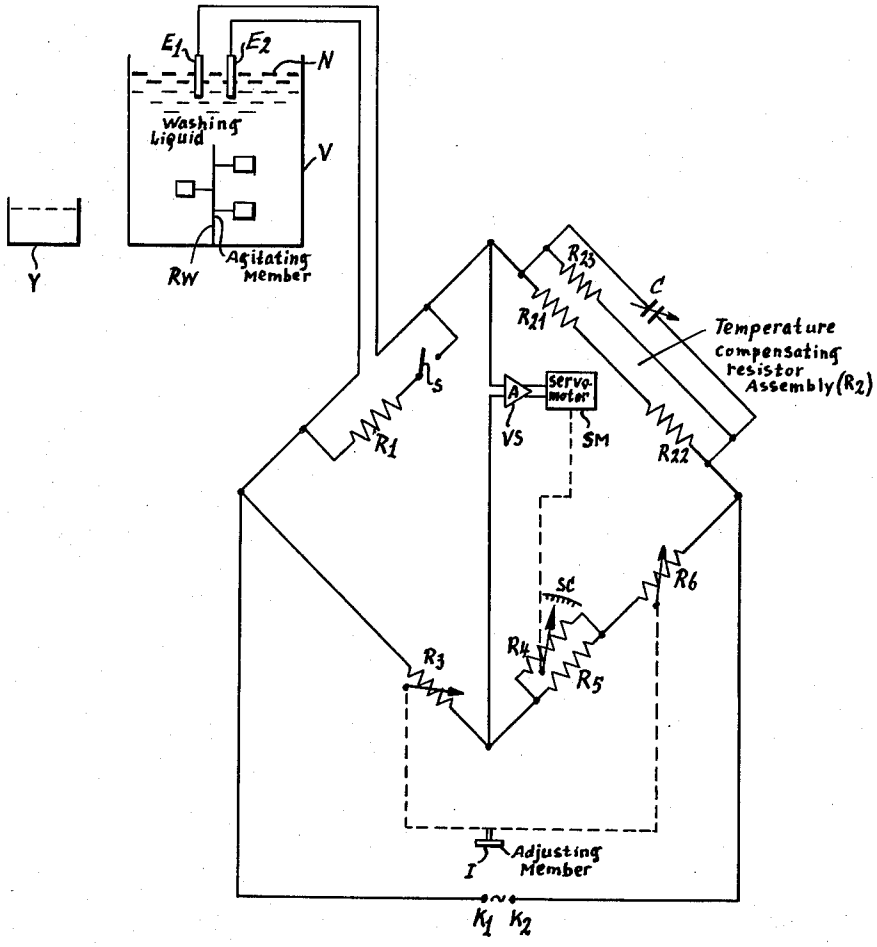
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BLOOD LOSS METER

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BLOOD LOSS METER

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The invention relates to a device for measuring the amount of blood lost by a patient during operations and the like, and more in particular to a conductometer specially adapted to blood loss measurements.

Up to now, the blood loss of a patient during operations and the like was generally determined by weighing the dressings, such as gauzes and tampons, by which the blood lost by the patient had been absorbed, before and after use. This method is complicated and not very accurate.

It is, accordingly an object of the invention to provide means whereby the blood loss of a patient may be directly determined by conductometry.

A further object of the invention is to provide a conductometer especially adapted to blood loss measurements, and having a scale bearing a linear calibration in volume parts of blood.

A still further object of the invention is to provide a conductometer for blood loss measurements which may be easily adjusted to the electric conductivity of the blood of an individual patient.

Another object of the invention is to provide a conductometer for blood loss measurements which may be calibrated in accordance with the electric conductivity of the blood of an individual patient with the aid of a relatively small amount of blood.

Still another object of the invention is to provide a conductometer for blood loss measurements of which the operation is independent of temperature variations and of polarization phenomena.

Still another object of the invention is to provide a conductometer for blood loss measurements wherein the washing liquid may be easily adjusted to the desired conductivity with the aid of the blood loss indicator.

In the apparatus according to the invention, the blood loss of a patient is determined with the aid of a washing liquid having a predetermined electric conductivity. A predetermined amount of this washing liquid, for instance 50 litres, is placed in a measuring vessel provided with a powerful agitating member. The washing liquid may be water, adjusted to the desired conductivity by the addition of an electrolyte. The dressings containing the blood lost by the patient are thrown into the washing liquid immediately after use; by the action of the agitating device, they are rinsed so effectively that the blood is substantially immediately dispersed throughout the washing liquid. This causes the electric conductivity of the washing liquid to be changed by an amount dependent on the amount of blood dispersed through the washing liquid. Thus, the blood loss of the patient may be determined by measuring the conductivity of the liquid mixture in the vessel.

The measurement of the conductivity of the liquid mixture is performed by means of a conductometer comprising an A.C. bridge circuit, of which one of the arms contains the path between two electrodes immersed in the vessel, and which is kept in equilibrium by supplying the voltage between two opposite junctions through an amplifier to a servo-motor controlling a variable resistor, inserted in one of the other bridge arms and coupled with an indicator moving along a scale.

It is extremely important that the resistance value of the variable resistor is a linear function of the blood loss in volume parts. Not only does this condition provide for a clearly readable scale, but in addition, the fact must

be taken into account that there exist large differences between the conductivities of the blood of various patients. The said linear function makes it possible to calibrate the device in accordance with the conductivity of the blood of the patient in a simple and exact manner.

According to a main feature of the invention, this linear dependency is obtained by inserting the variable resistor in a bridge arm which is diametrically opposed to the bridge arm containing the electrodes, and which comprises the series connection of a first and a second resistor of which the resistance values are in a ratio of $(g_2-g_1):g_1$, wherein g_1 is the conductivity of the washing liquid and g_2 the conductivity of the blood of the patient, the variable resistor being connected in parallel with said first resistor.

The calibration of the device in accordance with the conductivity of the blood of the patient may now be performed by adjusting said second resistor simultaneously with a resistor in one of the adjoining bridge arms. This may be done with the aid of a calibrating vessel adapted to receive predetermined small quantities of the washing liquid and the blood, and in which the electrodes may be immersed. Thus, only a few cubic centimeters of blood have to be taken from the patient for calibration purposes.

The conductivity g_1 of the washing liquid prior to the introduction of the blood is selected in such manner as to be higher than the maximum conductivity of water occurring in practice, so that the desired value may always be obtained by the addition of an electrolyte. The adjustment is preferably performed in the measuring vessel, so that use may be made of the blood loss indicator for checking the conductivity. Upon introduction of the untreated water into the measuring vessel, the indicator coupled with the variable resistor will take a position to the left of the zero point of the scale, and the zero point will be gradually reached by the addition of the electrolyte. In order to simplify this operation, it is preferred to connect a resistor in parallel with the path between the electrodes, whereby the zero point is displaced to the right. This parallel resistor is so dimensioned that the indicator is placed opposite to a marking on the scale spaced with respect to the zero point when the conductivity of the washing liquid has reached the desired value by the addition of the electrolyte.

The invention will be more fully explained by reference to the accompanying drawing showing a preferred embodiment thereof.

The drawing illustrates a circuit diagram of a conductometer for blood loss measurements according to the invention.

The device shown in the drawing comprises a measuring vessel V, provided with an agitating member RW and filled to the level N with water which has been adjusted to a predetermined electric conductivity by the addition of an electrolyte. The measuring vessel may contain, for instance, 50 litres of this washing liquid. In the case of operations performed on children, wherein the blood loss is much less, a smaller quantity of the washing liquid may be used, for instance 15 litres. All dressings by which the blood of the patient has been absorbed are thrown into the measuring vessel immediately after use.

The construction of the measuring vessel is not bound to strict requirements, provided that the agitating member is so powerful that all dressings thrown into the measuring vessel are rinsed practically immediately. Good results have been obtained in practice with domestic washing machines having a pulsator or agitator of the usual kind.

The measuring vessel contains a measuring cell (not shown), which comprises, inter alia, the electrodes E_1 and E_2. The path between these electrodes is inserted in a

first arm of a bridge circuit fed with A.C. current through terminals K_1 and K_2. For this purpose, use may be made of the mains current of 60 cycles per second, or of a specially generated A.C. current having a higher frequency for instance of 1000 cycles per second.

A second bridge arm, which is diametrically opposed to the first arm containing the measuring electrodes, comprises a first resistor R_5, a second resistor R_6 in series with resistor R_5, and a variable third resistor R_4 in parallel with resistor R_5. The third bridge arm contains a fourth resistor R_3. Resistors R_3 and R_6 are simultaneously adjustable by means of an adjusting member I, in order to calibrate the device in accordance with the conductivity of the blood of the patient to be treated. Resistor R_4 is controlled by a servo-motor SM fed through an amplifier VS by the voltage between opposite junctions of the bridge circuit. Thus, resistor R_4 is always adjusted in such manner that the bridge circuit is in equlibrium. Resistor R_4 is coupled with an indicator moving along a scale SC calibrated in cm.^{3} of blood. Preferably, scale SC comprises two calibrations, one running from 0 to 3000 cm.^{3} of blood in 50 litres of washing liquid, and the other from 0 to 1000 cm.^{3} of blood in 50 litres of washing liquid. The second calibration may also be used during operations on children for indicating 0 to 300 cm.^{3} of blood in 15 litres of washing liquid. The two calibrations may be obtained, for instance, by using two indicators coupled with the adjusting member of resistor R_4 through different transmissions.

The fourth bridge arm contains a temperature compensating resistor assembly consisting of a fifth resistor R_{21} of which the resistance is dependent on temperature, a sixth resistor R_{22} in series with resistor R_{21} and independent of temperature, and a seventh resistor R_{23} in parallel with the series connection of resistors R_{21} and R_{22} and independent of temperature. The resistors R_{21}, R_{22} and R_{23} have been chosen in such manner that the assembly has the same resistance-temperature co-efficient as the washing liquid. The assembly is enclosed in the measuring cell together with electrodes E_1 and E_2 so that it is always at the same temperature as the washing liquid. By these means, the blood loss measurement is rendered independent of the temperature of the washing liquid. The resulting resistance value of the assembly will be indicated by the symbol R_2 hereinafter. A variable condenser C is connected in parallel with said assembly in order to compensate for the phase displacement caused by polarization of the electrodes E_1 and E_2.

An eighth resistor R_1 may be connected in parallel with the paths between electrodes E_1 and E_2 by means of a switch S, for purposes to be described hereinafter.

In order to obtain a linear dependency between the resistance value of resistor R_4 and the amount of blood in cm.^{3} introduced into the measuring vessel, resistors R_5 and R_6 have been selected in such manner that their resistance ratio is as $(g_2-g_1):g_1$, wherein g_1 is the conductivity of the washing liquid, and g_2 the conductivity of the blood of the patient to be treated. This may be explained as follows:

Assume that the measuring vessel V contains A litres of washing liquid, and that x litres of blood are added. The resulting conductivity is approximately equal to

$$\frac{Ag_1+xg_2}{A+x}$$

so that the resistance measured between electrodes E_1 and E_2 is equal to

$$\frac{k(A+x)}{Ag_1+xg_2}$$

wherein k is a constant determined by the construction of the measuring cell. The condition for the equilibrium of the bridge circuit is now:

$$\frac{k(A+x)}{Ag_1+xg_2}\cdot\left(\frac{R_4R_5}{R_4+R_5}+R_6\right)=R_2R_3 \qquad (1)$$

By introducing the condition that $R_4=0$ for $x=0$, Equation 1 becomes:

$$\frac{kR_6}{g_1}=R_2R_3 \qquad (2)$$

By eliminating R_2R_3 from Equations 1 and 2 and solving for R_4, one finds:

$$R_4=\frac{R_5R_6x(g_2-g_1)}{R_5g_1(A+x)-R_6x(g_2-g_1)} \qquad (3)$$

By selecting

$$R_5g_1=R_6(g_2-g_1) \qquad (4)$$

Equation 3 is transferred into

$$R_4=R_5\cdot\frac{x}{A} \qquad (5)$$

Thus, the resistance R_4 is found to be linearly dependent on the amount of blood x.

In order to be able to use the same scale under all circumstances, R_5 must be constant according to Equation 5. Thus, Equation 4 may only be satisfied for all values g_2 by making R_6 variable. It appears from Equation 2 that one of the resistors R_2 and R_3 must also be variable in this case. Since R_2 is preferably left constant in view of the temperature compensation, resistors R_3 and R_6 are simultaneously adjustable in the embodiment as shown in the drawing. In practice, the adjustment of resistors R_3 and R_6 may be performed by adding constant resistors in a plurality of stages; for this purpose, the adjusting member I is constructed as a tandem switch.

The calibration of the apparatus according to the conductivity of the blood of the patient to be treated is performed by introducing a predetermined quantity, for instance 50 cm.^{3}, of the washing liquid, adjusted to the desired conductivity into vessel Y from vessel V, and by adding a suitable small quantity of blood, for instance 1 cm.^{3}, taken from the patient to be treated. After that the measuring cell is placed into vessel Y. Since resistor R_4 is adjusted, according to Equation 5, to the value R_5, which is proportional to the ratio x/A between the amounts of blood and washing liquid, the scale SC will have to indicate an amount of 1000 cm.^{3} of blood in 50 litres of washing liquid in the present case. Resistors R_3 and R_6 are now adjusted, by means of the adjusting member I, in such manner that this indication is obtained.

In order to adjust the washing liquid to the desired conductivity, vessel V is filled with water, after which switch S is closed, whereby the zero point of the scale is displaced to the right. After that, a suitable salt is added to vessel V until a marking on scale SC has been reached.

Although the invention has been described hereinbefore by reference to a specific embodiment thereof, it is to be understood that the invention is not restricted to this embodiment, which may be modified in various ways within the scope of the invention as set forth in the appended claims.

What is claimed is:

1. A blood loss meter comprising a measuring vessel adapted to receive a washing liquid of known electric conductivity, an agitator in said measuring vessel adapted for mixing the blood adsorbed by dressings with said washing liquid, an A.C. bridge circuit including four junctions and four arms connected between the said junctions, an alternating current source connected between two diametrically opposed junctions, a pair of electrodes in said measuring vessel and connected in a first arm of said bridge circuit, a first resistor, a second resistor in series with said first resistor and connected together with the same in a second arm of said bridge circuit diametrically opposed to said first arm, a variable third resistor in parallel with said first resistor, a fourth resistor connected in a third arm of said bridge circuit, a resistive impedance connected in the fourth arm of

said bridge circuit, an amplifier having an input connected with the remaining diametrically opposed junctions of said bridge circuit, a servo-motor coupled to said amplifier and controlling said third resistor to keep the bridge circuit in equilibrium, an indicator mechanically coupled with said third resistor, a scale calibrated in volume parts of blood and positioned opposite to said indicator, means for adjusting the ratio between the resistance values of said first and said second resistor, so that this ratio may be adjusted, for a given patient, to $(g_2-g_1):g_1$, wherein g_1 is the electric conductivity of the washing liquid and g_2 the electric conductivity of the blood of the patient, and means operated simultaneously with said ratio adjusting means for adjusting the resistance value of an arm of said bridge circuit adjacent to said first arm in such manner that the equilibrium of the bridge circuit is maintained.

2. A blood loss meter as claimed in claim 1 further comprising a fifth resistor, and means for connecting said fifth resistor in parallel with the path between the said electrodes in order to shift the zero point of said scale, so that the electric conductivity of the washing liquid may be adjusted to the desired value with the aid of said indicator.

3. A meter as claimed in claim 1 wherein said resistive impedance comprises a fifth resistor dependent on temperature, a sixth resistor in series with said fifth resistor and independent of temperature, and a seventh resistor in parallel with the series connection of said fifth and sixth resistors and independent of temperature, in such manner that said resistive impedance has the same resistance-temperature coefficient as the washing liquid and is adapted to be immersed in the same together with said electrodes.

4. A blood loss meter as claimed in claim 1 further comprising a variable condenser in parallel with said resistive impedance for compensating phase displacement due to polarization.

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