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CALIBRATED BODY FLUID DETECTION DEVICE
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The present invention relates to a device for detecting abnormal external blood loss after surgery or delivery, abnormal loss of fluids in connection with the treatment of severe burn cases, abnormal urine flow in connection with genito urinary surgery, abnormal perspiration in connection with treatment of patients in shock, etc. More particularly, this invention relates to a device comprising in combination (a) a thin sheet of absorptive material containing or printed with a pattern of conductors disposed so that the resistance across the pattern of conductors will be inversely proportional to the area wetted by the blood etc. and (b) an external alarm system pre-set or adjusted by medical personnel so that the alarm is actuated when the resistance drops to less than the set amount, the set amount being less than the resistance for one electrical conductor path across the sheet.

More particularly, in a preferred embodiment, this invention relates to such a device wherein the absorptive sheet conductor pattern comprises a pair of conducting members of grid-like configuration with the fingers of the grids interdigitated close together but not touching. In a most preferred embodiment this invention relates to such a pair of conducting members having fingers of high resistance whereby two advantages are obtained; (1) differences in conductivity of the bridging solution, e.g. blood, do not significantly affect the measured resistance and (2) the location of the area of bridging solution does not significantly affect the resistance since the total length of each electrical path across the thin sheet is the same regardless of whether it is in the middle lengthwise of the fingers or near one side i.e. a short path in one finger is made up for by a long path in the adjacent finger.

The present invention will be more clearly understood from a consideration of the need for this invention. There is no surgeon, obstetrician, or medical doctor in any field who has not had or been aware of patients who have died from external blood loss or who have had a markedly increased morbidity because of excessive blood loss which was not detected in time. Thus, for example, hospital patients immediately following an operation or delivery are taken into recovery rooms wherein they are watched for excessive bleeding, etc. They are next taken, after the likelihood of abnormal bleeding, etc. has decreased, from the recovery room to other parts of the hospital. In both locations nurses and other trained personnel attempt to watch the patient for morbid conditions. However, with the increasing shortage of trained medical personnel and overcrowding of hospitals it is impossible to watch the patients as carefully as is desirable and as is really necessary. Thus, abnormal bleeding, etc. often occurs which is not caught early enough for proper remedial steps to be taken.

As an example of the need for this invention, after childbirth a certain amount of bleeding is normal. The nurses in the recovery room and in the hospital are directed to watch for abnormal bleeding but the amounts are not precisely stated and, due to the number of patients, checking of each patient routinely at set intervals is not done as often as is desirable and in addition some routine checks may be skipped due to emergency calls with respect to other patients. The extreme importance of noting immediately the amount of blood lost can be

seen from the fact that a decision to give blood to the patient itself is fraught with danger. Thus, despite the fact that the proper type blood is given slight antibody mismatching occurs within types and the giving of blood itself may cause death. Therefore, blood is only given e.g. after childbirth when it appears absolutely necessary. By use of the present device continuous monitoring of blood loss permits early detection and stopping of the excess bleeding before such large amounts are lost that transfusions are necessary.

The present invention arose out of the feeling of the present inventors that the problems recited above were avoidable in modern medicine and they set out to devise a system, electrical but intrinsically safe in character, that would automatically discriminate abnormal blood, etc. loss from normal blood etc. loss and which also would be so simple and reliable in application and operation that it could be easily used by hospital nurses without special attention yet which would reduce human error to the minimum. The extensive work and experiments of these inventors have produced a system that will obviate the above grave situation. In a preferred embodiment this system comprises a disposable, cheap sterile paper similar to hospital paper toweling printed with an electrically conducting pattern connected to a simple electrical alarm system. The paper sheet may be either used in the gauze bandaging of the surgical area, or as a sheet placed on the hospital or recovery room bed i.e. beneath, over, or adjacent to the patient, e.g. on a pillow. This paper absorbs blood, etc. and when more than a preset amount of blood, urine, perspiration, vomitus, etc. has been absorbed, sets off a light or alarm system at a central location. This set amount may be a fraction of an ounce or any amount more. This is adjustable by choosing a paper with the proper spacing of conducting lines or preferably by using a standard paper and setting the desired amount by knob adjustment of the electrical circuit. A particularly desirable arrangement is to have 4 or 5 different widths, with the fingers reducing in width in direct proportion to the sheet width, and consequently increasing in resistance per unit length of fingers. Then all sheet widths would have the same resistance along each finger. Thus, hospital personnel would then only have to set the dial for the amount of blood, i.e. a separate setting would not be required for different width papers.

The paper may be of any size to fit the medical need. It is porous and absorptive in character, soft in feel, non-allergic and inexpensive. In the present inventors' work for example, a surgical paper towel was found to be very satisfactory. Upon this was painted a conductive pattern using an ink or paint such as graphite in colloidal suspension. The spacing, width of lines, and concentration of ink may of course be varied to obtain the desired resistance pattern. It is noted that in a preferred embodiment the paper would be supplied as a continuous roll and due to the continuous pattern of the edge line hospital personnel would merely cut off a sheet of the length required.

The present invention will be more clearly understood from a consideration of the accompanying drawing describing a sheet of absorptive material having painted upon it a preferred pattern of conducting material connected to a preferred control circuit. Referring to the drawing, A.C., 115 v. house power lines 1 and 2 are connected to transformer 3 from which a low voltage e.g. 6 volts, is supplied through line 4 to variable or fixed resistance control 5 and thence through line 6 connected by means of e.g. an alligator clip not shown to edge line A of conductive material of electrical indicating sheet 7. Fingers of conducting material B are connected to the edge line A. On the opposite side of the paper is disposed a similar edge line C of conductive material with fingers of conducting material D connected to the said

edge line and interdigitated with fingers B. Line 8 is connected to edge line C by means of e.g. an alligator clip not shown and this line is connected to the control grid 9 of gas filled control tube, preferably a thyratron, 10. The cathode 11 of this tube is connected to line 4 through line 12. The anode of the tube 13 is connected through line 14 to the coil side of relay 15. The other coil side of the relay is connected to the low voltage side of the transformer through line 16. When the relay is operated by flow of current through the coil the controlled circuit is closed and current flows from power supply line 1 through line 17, light or signal 18, line 19 through the relay contacts 20 and 21 back through line 22 to power supply line 2. Obviously, other control systems may be used, the only requirement being that the system discriminate a resistance less than the resistance of at least one path.

Reducing the resistance by blood, etc. spreading across the pattern at any location triggers the electrical circuit to which the paper is attached when a predetermined and adjustable resistance value is reached. It should be noted that this resistance value is independent of the location of the blood spot.

In the most preferred embodiment the fingers are of high resistance and the main effective resistance is the fingers themselves. Thus, this resistance is much higher than that of the blood path. The number of paths depends upon the number of fingers bridged. Although when three adjacent fingers are bridged the effective length is only that of one finger plus the length of the two outside fingers in parallel, nevertheless extremely precise control is obtained. It is noted that by spacing the fingers reasonably close together that accuracies to the desired level are obtained. It is further noted that although not desirable an error of 100% in the volume of blood lost can be tolerated in connection with the use of this device in hospitals. The spacing of the lines can thus if desired be kept sufficiently apart to prevent any slight crinkling of the paper from setting off the signal. It should be noted that any error of this type is on the safe side, i.e. the alarm will go off rather than not go off when danger is present. In any event an excellent device is afforded which in operation will give very infrequent false alarms. It is noted also that the control system used is also preferably of the fail safe type whereby tube failure causes the alarm to sound. Thus, when no blood is present the tube is conducting, and the relay is energized, holding the alarm circuit open. When blood appears, or the tube fails, the relay deenergizes, activating the alarm. It is also preferred to use additional means so that any discontinuity in the system, e.g. by an electrical clip becoming detached will cause the alarm to sound.

Preferred absorptive sheet materials are in general any nonallergic, nonconductive material, e.g. paper or cloth having the property to spread the blood outward, i.e. the more absorptive the better. The sheet is preferably relatively thin, flexible and soft so as to be comfortable to the patient. In some instances such as in use as a sheet on beds it may be desirable to use two absorptive sheets, the bottom sheet being painted with the conducting pattern and the top sheet unpainted to spread the blood, etc. that might otherwise be blocked by the printed lines. In uses in bandages the bandage itself will spread the blood.

Preferred resistance values are as follows: For the high resistance finger embodiment: 10,000–1,000,000, preferably 100,000–500,000, e.g. 250,000 ohms total individual finger resistance.

Preferred conducting "inks" are in general any inks which provide the desired conductivity and which preferably are not dissolved or washed out by the blood etc. Preferred width of fingers is $\frac{1}{8}$ to $\frac{1}{2}$, preferably $\frac{1}{4}$ to $\frac{3}{8}$ inch with a thickness sufficient to provide the above resistance. Preferred distances between edge lines (or i.e. approximate length of fingers) for various embodiments are as follows: (1) For use on hospital beds; width

of widest hospital bed used, e.g. 4 ft. to e.g. 2 ft.; (2) For use in bandages; 2 inches to 4 inches, less preferably 8 inches to 24 inches.

In a preferred embodiment the detection sheet may also be formed (e.g. painted) with nonconducting absorption barrier lines perpendicular to the fingers to cause the blood etc. to spread preferentially perpendicular to the lines. This, of course, increases sensitivity in that more conducting lines will be bridged. It is noted that in connection with most blood etc. discharge this will occur at a single location and the blood etc. will spread as a single spot. It is further noted that in addition to painting or impregnating etc. the conducting pattern on the sheet other methods may be used such as stitching conductors in the sheet, laminating a conductive pattern on to the sheet, etc. The preferred resistance values are obtained not only by choice of conducting ink, etc. but also by the width of lines, amount of ink applied per unit area, etc. Preferred spacing of lines, i.e. distance between fingers in both embodiments are $\frac{1}{8}$ to 1 inch, preferably $\frac{3}{8}$ to $\frac{3}{4}$ inch, e.g. $\frac{5}{8}$ inch.

The present invention will be more clearly understood from a consideration of the following examples representing data obtained with the present device.

EXAMPLE 1—BLOOD RESISTANCE AND SPREADING TIME

1. Materials

- (A) Standard paper kitchen towels, doubled.
- (B) Whole human blood.
- (C) Pad of cotton cloth.
- (D) Salt water solutions— $\frac{1}{8}$ tspn. salt per oz. H_2O ; $\frac{1}{16}$ tspn. salt per oz. H_2O .
- (E) Vacuum tube voltmeter (VTVM).

2. Procedure

VTVM was adjusted to read resistance. Paper towel was placed on cloth pad. Electrodes ($\frac{1}{4}$ " strips of aluminum foil, 6" long) were pinned to the towel $\frac{5}{8}$ " apart at several points along their length. The VTVM test leads were clipped to the electrodes. Two drops of blood were placed on the towel between the electrodes, allowed to spread and form contact between the electrodes, and the resistance reading and bridging time were noted. The same test was repeated using the salt water solutions, simulating perspiration.

3. Results

Blood resistance—25,000 ohms per $\frac{5}{8}$ " approximately.
 Spreading time per $\frac{5}{8}$ "—14 seconds.
 Heavy salt solution resistance—2,000 Ω approximately.
 Spreading time—4 seconds.
 Light salt solution resistance—4,000 Ω approximately.
 Spreading time—4 seconds.
 Note: After 45 seconds, light salt solution had increased to 7,000 Ω

4. Conclusion

Salt water solution spread more rapidly, dried more quickly, indicating perspiration might dissipate in bandages below test area by lateral dispersion; blood would obtain less lateral penetration.

EXAMPLE 2—HIGH RESISTANCE PATTERN PROVIDES UNIFORM MEASURE NOT DEPENDENT ON BLOOD RESISTANCE

A surgical type towel (paper) was placed over a pad made of cotton cloth (scrap bed sheet material) approximately 8 thicknesses, and secured tightly to the work-bench surface with masking tape. One ounce of blood was poured on this surface, and spread from left to right (in about 30 seconds) to a distance of 11 inches. This phenomenon indicated a requirement for a detecting pad pattern that would do more than just short-circuit as blood was applied and the pattern described in FIG. 1 was devised.

The idea was to have the blood actuate a Thyatron relay, which would be sensitive to a change of electrical resistance in the grid circuit, thus changing grid bias and firing the tube and an associated relay (standard level-detecting device manufactured by many companies for use in industrial applications). If the blood merely short-circuited, then any amount of blood could do this; and if the vertical lines of the pattern were spaced too far apart so as to employ the resistivity of the blood (see Example 1) for control, this would not be as predictable as if the number of vertical lines bridged were the controlling factor. The use of a pattern made with a controlled and predictable resistance of a significant value was indicated; then the blood as it spread would parallel an increasing number of vertical legs, so that the network resistance would finally reduce to a value (predictable) that would fire the Thyatron. (At this point it was decided to use the type of Thyatron relay that would cause the tube to stop conducting when this value was reached—then tube failure would also cause alarm actuation. This is a standard device.)

1. Materials

(A) Two samples of colloidal graphite, one suspended in alcohol (I), the other suspended in water (II), were obtained commercially.

I. GRAPHITE-SOLVENT BASE

Dispersed Substance	Carrier	Solids Content, percent	Particle Size ¹	Consistency	Density (lbs./gal.)	Diluent	Flash Pt. (° F.)
Colloidal Graphite.....	Isopropanol.....	20	B.....	Liq.....	7.4	Commercial Alcohols, Ketones, etc.	52

II. GRAPHITE-WATER BASE

Colloidal Graphite.....	Water.....	22	A.....	Paste and Cream.	9.3	Water.....	
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¹ Particle Size—A, B, C, D, range: A=Finest.

(B) Paper towels, surgical type, 13½" x 19",

(C) Vacuum tube voltmeter (VTVM),

(D) Thyatron relay, automatic timing and controls, Series No. 5400,

(E) Strip of aluminum foil 10" x 3".

2. Procedure and results

Two parallel strips ¼" wide, 6" long, 1" apart, were painted on a towel with the colloidal graphite suspended in water, and the same done with the graphite suspended in alcohol. When dry, resistance readings were taken. Resistance was approximately 40,000 ohms per inch of strip along all four strips. Because the alcohol suspension dried more quickly and without wrinkling the paper as the water solution did, a pattern was made with the former as shown in FIG. 1. When dry, resistance readings were taken as pairs of vertical strips were progressively bridged by strip aluminum foil. Since significant reduction of resistance was noted as each successive pair was bridged the probe leads from the Thyatron Relay were connected to the ends of the pattern, and the sensitivity control of the device was adjusted until it was necessary to bridge 4 pairs of strips to cause the tube to fire and the relay to close.

EXAMPLE 3.—IMPROVED DISPERSION DETECTING-PAPER

1. Materials

(A) Paper towels, surgical imprinted (same as Example 3).

(B) Vacuum-tube voltmeter.

(C) Whole human blood.

(D) Thyatron relay (same as Example 2).

2. Procedure

(A) Uniformity of resistance was established in the vertical lines of the pattern on the towels by over-painting as required. The towel patterns were made with the alcohol dispersion, and one with an aqueous colloidal dispersion, but due to wrinkling of the towel, the latter was discarded. Vertical line resistance on the former had a mean value of 50,000 ohms. (It should be noted at this point that horizontal line resistance—the edge lines should preferably be as low as possible, so as to introduce no variable with variations in length of sheet, location of blood spot, etc.).

(B) The first towel (sheet A) was placed over a pad of kitchen paper towels, pattern up, taped down to the table surface, and the leads from the detector circuit of the Thyatron relay connected to the edge lines of the pattern.

(C) One ounce of blood was dripped gradually on the pattern. As the blood spread, the sensitivity of the Thyatron relay was reduced, so that it was sensitive to the full ounce only; but it was noticed that the vertical lines provided a barrier against the spread of blood.

(D) The second towel (sheet B) was then placed over the same kind of pad, but this time the pattern was faced down, and one additional surgical towel without a pattern was placed on top of the first.

(E) One ounce of blood was dripped gradually on the double pad. The same procedure as in "C" above was followed, but this time the barrier effect was eliminated, and the blood exhibited a considerably improved lateral dispersion. This would indicate that the pad should be double; one layer to carry the pattern and the other to provide proper dispersion.

EXAMPLE 4.—RESISTANCES WITH DIFFERENT INKS AND ABSORPTIVE MATERIALS

1. Materials tested

Wool, Dacron, silk, nylon, acetate, rayon, Arnel, cotton, and previously described paper towels.

Patterns painted on these of (1) colloidal graphite dispersion in isopropanol, (2) colloidal graphite dispersion in H₂O (22% solids), (3) colloidal graphite in H₂O (15% solids), (4) alkyd resin 25% solution.

On applying ink: Arnel application was done with greatest ease, while Dacron was the most difficult to apply.

All readings below were taken from edge line to end of finger using the standard aluminum stencil described above.

Ink—20% solid isopropanol:	Resistance, ohms
Wool	50,000
Dacron	400,000
Silk	600,000
Nylon	500,000
Acetate	1,500,000
Rayon	750,000
Arnel	250,000
Cotton	500,000

Ink—22% solid water:		Resistance, ohms
Rayon	-----	5,000
Cotton	-----	7,000
Silk	-----	8,500
Nylon	-----	8,250
Arnel	-----	4,200
Wool	-----	1,500
Acetate	-----	4,000
Dacron	-----	30,000
Ink—15% solid water:		
Nylon	-----	27,000
Cotton	-----	7,000
Acetate	-----	4,000
Silk	-----	17,000
Arnel	-----	10,000
Rayon	-----	4,800
Dacron	-----	25,000
Wool	-----	1,950
Surgical towel	-----	2,400
Alkyd resin—25%:		
Nylon	-----	7,000,000
Surgical towel	-----	4,000,000
Rayon	-----	1,200,000
Acetate	-----	30,000,000
Silk	-----	30,000,000
Cotton	-----	100,000,000
Arnel	-----	4,000,000
Wool, Infinity.		
Dacron, Infinity.		

From above it can be seen that a workable resistance is achieved with 20% solids isopropanol and 15% solids water suspensions with all the tested materials while 25% alkyd resin achieved resistance with all but wool and Dacron. Wool gives the lowest resistance with 20% solid isopropanol and 15% solid water while Arnel gives the lowest with 25% alkyd resin solution.

The two water suspensions gave considerably lower resistance readings with all fabrics when compared to the alcohol and alkyd resin suspensions.

With the exception of the Dacron all readings were the same or lower with the 22% solid water solution when compared to the 15% solid water.

In all of the above examples the reference to FIGURE 1 is to the drawing accompanying this specification.

It is to be understood that this invention is not limited to the specific examples which have been offered merely as illustrations and that modifications may be made without departing from the spirit of the invention.

What is claimed is:

1. An alarm device for detecting abnormal flow of fluids from the body which comprises a thin sheet of absorptive nonelectrically conductive material containing a pair of conductors of grid-like configuration, each grid comprising an edge line near respective opposite edges of the absorptive material from which fingers extend across the absorptive material the said fingers having a resistance from edge line to tip of fingers of 10,000–1,000,000 ohms, and being interdigitated and separated from each other and from the opposite edge line and bridged only by fluid contacting the absorptive material, means for electrically connecting each of a pair of alarm circuit leads to a respective one of said pair of edge lines, the electric alarm circuit being set to actuate the alarm when the resistance drops to less than a set amount, the set amount being less than the resistance for one electrical path between the edge lines.

2. The device of claim 1 in which the fingers of the grids each have a resistance of 100,000–500,000 ohms.

3. The device of claim 1 in which the absorptive material is paper toweling.

4. The device of claim 1 in which the conducting grids in the absorptive material are conducting inks absorbed in the absorptive material.

5. The device of claim 1 in which the distance between the interdigitated fingers is $\frac{1}{8}$ to 1 inch.

6. The device of claim 1 in which the electric alarm circuit is adjustable to detect the bridging of a desired number of interdigitated fingers.

7. The device of claim 1 for detecting abnormal flow of blood.

8. The device of claim 1 for detecting abnormal flow of urine.

9. The device of claim 1 for detecting abnormal flow of perspiration.

10. A thin sheet of absorptive material for use with an electrical warning device for detecting abnormal flow of fluids from the body which comprises a thin sheet of absorptive, nonelectrically conductive material containing a pair of conductors of grid-like configuration, each grid comprising an edge line near respective opposite edges of the absorptive material from which fingers extend across the absorptive material, the said fingers being interdigitated and separated from each other and the opposite edge lines, and the said fingers each having a resistance of 100,000 to 500,000 ohms between the edge lines and the tip of the finger.

11. A thin sheet of absorptive material for use with an electrical warning device for detecting abnormal flow of fluids from the body which comprises a thin sheet of absorptive nonelectrically conductive material containing a pair of conductors of grid-like configuration, each grid comprising an edge line near respective opposite edges of the absorptive material from which fingers extend across the absorptive material, the said fingers being interdigitated and separated from each other and the opposite edge lines, and the said fingers each having a resistance of 10,000 to 1,000,000 ohms between the edge line and the tip of the finger.

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