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PRESENTATION OF CATHETERIZABLE SENSORS

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I. DISPOSABLE EMERGENCY P_{O_2} PROBE OR A "DO-IT-YOURSELF" P_{O_2} PROBE

Minimum interference Biometrology is a (bottom up)-(top-down) conceptual loop. The choice of a measurement instrument is dictated by precision, reliability, sensitivity criteria as well as ease of construction generally for low cost but, in the present line ,for emergency period : when time is expensive in terms of rapid measurements in due time of P_{O_2} in all penetrable media and, particularly, in blood vessels (control of reanimation in hard biotopes,etc.).

The probe relates to electrodes operating according to the classical principle of oxygen polarography. The assembly steps cover less than one hour with a good training of the operator. Refering to the figures 1 and 2 , these steps are the following :

1. A platinum wire having a diameter of 17 microns,for example is soldered at 2 to a copper wire 3 shellacked or enamelled, whose length is adjusted to the total length of the eventual catheter-electrode, and having a diameter of 1/10 mm ,the insulation having first been removed at the soldering points 2. This assembly is threated into a tube 5 made of plastic or other material with an outside diameter of 0.5 to 0.6 mm , in such a way that the platinum wire extends considerably - about 1 cm - beyond this tube-catheter.
2. At a distance of about 3-5 mm from the forward end of the tube-catheter from which the wire extends beyond tube 4 , a small hole 5 is pierced through(preferably of

3/10 mm diameter) at a point on tube-catheter axis, through his hole 5 , a shellacked copper wire 6 of the desired length is introduced having first removed, by sandpapering for example, this shellac from the tube for a length which corresponds favorably to a distance in the order of a few millimeters.
3. A water-repellent cement 7 with fast rigidification characteritics, is then introduced to fix into position, on the one hand, the coaxial copper-platinum wire and,

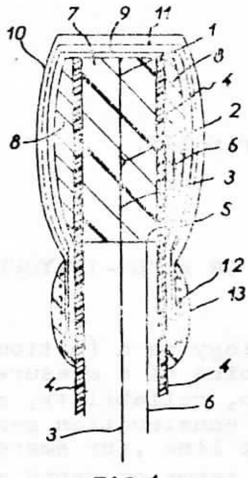


FIG.1

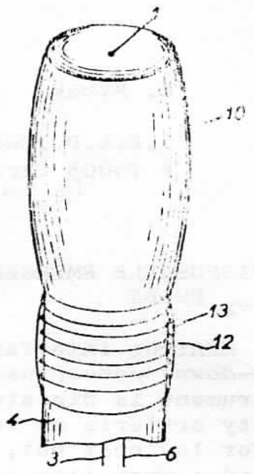


FIG.2

on the other hand, to cement the hole 5 through which the lateral wire 6 was introduced. After drying at a suitable temperature (such as 40 C),there is prepared on a surface of chemically-inert material,a mixture of silver paste of variable proportions of for example one part of powdered silver,consisting preferably of granules in the order of 37 to 160 microns and one part of a f st-drying cement. This mixture 8 is then immediately applied to the forward portion of the tube, care being taken that the lateral uninsulated copper wire 6 is placed along the axis of the cylindrical tube and to carry out this application uniformly over the surface of the cylinder along a sufficient length so that it covers, to the edge of the end of the tube, the extending portion of the uninsulated copper conductor prepared in the previously described manner.
4. After drying, a minimal length of section is sliced off perpendicularly from the end of the sonde,by means of a razor blade so that the platinum wire 1 which serves

as cathode and the silvered coating 8 which serves as the anode after chloridizing, present a fresh cross-section. The silver paste is then suitably chloridized as, for example, by electrolysis of an alkaline chloride at 1.5 V for 20 s or at 6 V for 5 s .

5. No polishing of the cathode is required. For certain high-precision assemblies, this cathode can be centered during the first part of the procedure by use of a narrow tube made of poly-ethylene for example, which fits the internal cylindrical space of the tube having 0.5-0.6 mm outside diameter.

6. The measurement head is completed by : a) dipping the forward portion of the electrode, along the entire length of the dried anodic mixture deposited on it, into a diluted medium such as a diluted etherized solution or sol of collodion (at 0.5 percent for example), or any other similar membranogenic substance, the collodion being immediately distributed by a gas jet (air, oxygen, nitrogen , for example); this collodion deposit 9 suitably replaces the application of a usual cellophane membrane ; b) attaching a membrane 10 permeable only to gas- made of a material manufactured under the trademark of "Teflon" for example - whose thickness is preferably about 6 microns , in such a way that this membrane encases the length of the cylinder which has a 0.5 - 0.6 mm outside diameter , an electrolyte support solution 11 being located between this membrane and the collodion membrane 9 consisting , for example , of potassium chloride of a suitable concentration of 0.2 M impregnated in a support such as a "nylon" network , a gel , or "joseph" paper . This membrane is then wrapped with silk or nylon thread 12 and the wrapping , a rough region , is covered by a layer 13 of collodion in order to obtain a smooth surface to facilitate the catheterization and contributing to its proper functioning.

The polarograms obtained with such micro-sondes for measuring P_{O_2} show the proper shape. These micro-sondes operate generally between 600 and 700 mV . They generally furnish about 80 percent of the response obtained when submerging them, under BTPS(Body Temperature ambient Pressure water Saturation at 37 C) conditions into 100 percent oxygen, the results being obtained in 2 to 4 s, with a four-fold increase of the nanoamperic BTPS value obtained by the kinetic influences of the liquid medium into which they are submerged and also show <u>in situ</u> a long operating life. Sterilization is previously performed advantageously by several immersions of the catheter into 50 % H_2O_2 .

II. DEPENDABLE PHOTOMETERS USABLE IN ANY PENETRABLE MEDIUM

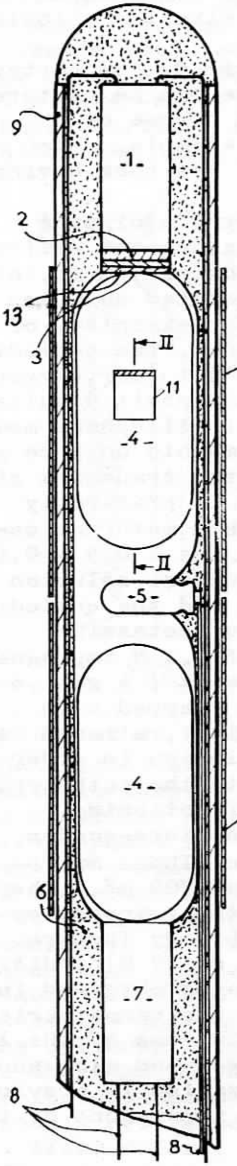


Fig.3.

1. Absolute model

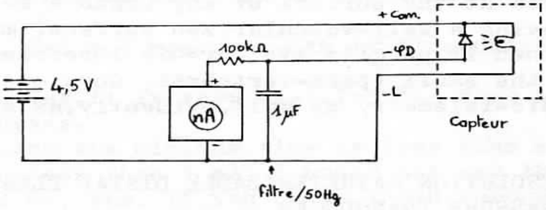
The device (1) is constituted essentially (Fig.3) by at least two photometric assemblies (photodiodes or more sensitive photoresistances of small diameter, for instance 2 mm), and one or two tungsten microlamps - for example from 1 - 1.8 mm diameter , the operating voltage of which may be from 1 to 3 V(DC)- positioned a few millimeters from a photocell. The circulating fluid, blood for example, is passing through two sets of windows managed as indicated in Fig.3 . One photocell works at λ max 580 nm, the other one, filtered by a Wratten filter,at 645 nm when the catheter is used as a [HHb] / [HbO_2] photometer. The windows 1) filled with a gel embodying enzymes or reagents, 2) and covered with a permeable membrane photocell (at adequate λ) and microlamp permits in situ biochemical titrations (2) (3); Figure 4-2.

2. Simple colorimeter and nephelometer

It is the same device with one single aperture where the fluid(gas, liquid or suspension) is passing throughout; Figure 4-1.

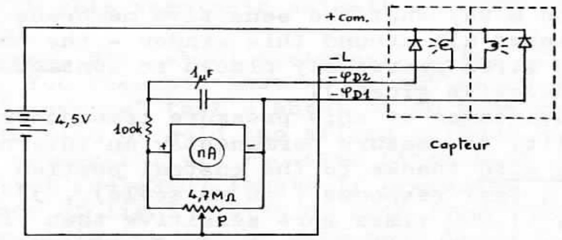
3. Velocity model

The two vicinal open cuvettes - lamps - photocells of the absolute photometer are separated along the catheter to a distance of 10 or 15 cm exactly measured . They have both the same λ max absorption spectrum. In addition is inserted inside the catheter a micro-tubing the distal open part of which is sealed near the first(proximal) colorimetric-nephelometric element thanks to a small hole practised a few millimeters at the highest part of the proximal window; then one can inject easi-



1. Montage du colorimètre

Figure 4



2. Montage du photomètre absolu

ly an opaque index or "Cardiogreen" according to a rigorous timing. The dye occults successively the proximal and the distal apertures, giving t , then dx / dt .

The demonstration is easily done <u>in vitro</u> with dyes at different dilutions (and <u>in vivo</u>).

III. FLAT P_{O_2} EPITISSULAR PROBE

Instead of having a cylindrical geometry as for the P_{O_2} catheter , I made circular and flat the geometry of the P_{O_2} probe . The anode is then an annular silver sheet having the same surface than the usual silver cylinder used as anode in the catheter model ; it is fixed to a latex (flexibility) or a rigid dielectric support ; the platinum ($\varphi = 17\mu$) cathode is centered and maintained vertically by a rigid or flexible dielectric tube. As for the other sensors presented here, the wires are shielded. The polarograms give good results, generally with a plateau at ∿ 80 nA in the range of 0.8 - 1 V for 29.56 % O_2 in H_2O (4).

The advantage of such a flat P_{O_2} sensor is that it can be located at the surface of any organ - even warped - displaying a well-vascularized surface(mouth, etc.) and, then it permits its chronic insertion under the skin or the skull (para-vertebral, dura mater ,etc.) allowing radio-telemetry as well, evidently, as standing-metry.

IV. HIGH RESOLUTION CATHETERIZABLE DISTAL ELASTORESISTIVE PRESSURE TRANSDUCER

For building the mentionned device one has to use the elastoresistance described here(cf.this volume, B.Rybak in the paper dealing with the extensometry of the open heart). On the other hand, I use the silver tube of the type working as cell of the described catheterizable photometers but only with one single window, in such a way that the sensitive membrane is hermetically sticked all around this window - the thin film inside with wires previously placed in contact with it using a conductive glue(5).

The advantages of this pressure transducer are: 1) the capability to measure permanently an internal local pressure in situ thanks to the rostral portion of the sensor, 2) a fast response (in ms scale) , 3) a high sensitivity (1,000 times more sensitive than classical strain-gauges) permitting the control between 0 and 250 torr in vivo and in vitro , 4) linearity , 5) reproductibility , 6) durability , 7) $\varphi_{ext.}$ = 1.8 to 2.4 mm.

Notice that , on the same catheter ,one can have several sensors of this type permitting simultaneous controls inside the same vessel at different levels.

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DISCUSSION

N.Akkas. What are the time scale and the pressure scale of response of your pressure transducers? Can you measure in milliseconds range ?

B.Rybak. The catheter pressure transducer you have in your hands is linear between zero to 250 torr. Then it permits to explore not only hypertension but also the venous blood. It works in ms scale as I said during my talk.

N.Akkas. Can you measure with it fluctuations in pressures ?

B.Rybak. Yes.It is very easy.You can have quasi-instant time courses.

N.Akkas.And the minimum time is less than ms ?

B.Rybak .Less than 1 ms, I would not say that , but around 1 ms, yes. If you do as I did,through the inferior aorta,a retrograde catheterization,the shape of the pressure graph will be different if you approach the aortic cross or if you are far from it,and this can be done iteratively(take care to not maintain too long the catheter in the aortic part when the renal arteries are no more irrigated).The pressure catheter can follow the rabbit cardiac rhythms which are very variable, as it is well known with this vagotonic animal(between 120 and 180 beats/mn).

B.Gautheron. What about hysteresis after stretching ?

B.Rybak. You remember that we demonstrated at the"Palais de la Découverte" that a sheet of an elastomer covered by a thin film of gold can afford without disturbance (= full reversibility) repeated stretching up to 20 % of its initial (relaxed) length.If preserved in relaxation, in absence of light - even at room temperature- , the elasto-resistances can be used many times after several months without changing their characteristics,notably, sensitivity. For continuous non-invasive controls of the ventilo-cardio-circulatory system you locate such elasto-resistances at the strategic points of the skin: two at the right and left temporal pulses region, two at the carotidian regions, two at the radial parts, two at the pedious(if the anatomy of the subject authorizes it), one at the sterno-diaphragmatic region(ventilatory frequence and amplitude) and one on the proper part of the chest to catch the apexogram(without using therefore radio-active tracers). Informations can be easily broadcast.

T.Durali. Do you think that one can use your mechanical transducers for sports ?

B.Rybak. Yes, but I have only a little experience on this important field for the moment. However if to play piano is a gymnastic of the fingers, then I can tell you that I have many morphologic and quantitative results. The transducers work quite well. Elastoresistances as small as 2 mm length can be used. In addition now,at the"Institut d'Etudes linguistiques et phonétiques" of the University of Paris III, I will use these sensors for quantitation of the movements during normal and pathological phonation and also to measure pressure inside the mouth when speaking.

<u>T.Durali</u>. What is the smallest size ?

<u>B.Rybak</u>. Currently it is 3 mm length x 1 mm width for pressure transducers to locate inside the mouth. I must underline that all the results obtained with inserted tubes ,including light guides , within the mouth or the nose are to be rejected because they disturb the air flow. Measurements are, let us say , always possible. But in Biometrology there is one fundamental question : what are we doing when we spend time, money and reason when we do a so-called measurement recognized , after thinking , to be full of artifacts ? On the contrary you can do what could be considered as the most foolish experiment if you know what you do. In Physics , a measurement is always a difficult task, but in Biophysics it is much more difficult mainly because of the enormous variability of the material and because there are many variables which are hidden .

Lesson delivered July 3 ,1978 at 3^{30} p.m.