indicates that when activated by nerve stimulation it has a threshold somewhat lower than that of primary response. Under moderately deep Nembutal anesthesia, slow negativity (evoked by optic nerve or light flash stimuli) disappears and is replaced by a longer lasting positive after-effect. The slow negativity described under these conditions is believed to have an origin in the cortex identical with corresponding slow negative waves evoked by direct surface and midline thalamic stimulation. In Fig. 3 it is placed schematically with relation to other components of visual cortical response previously described elsewhere.

1. Goldring, S., O'Leary, J. L., *EEG & Clin. Neurophysiol.*, 1957, v9, 577.

2. Goldring, S., O'Leary, J. L., Huang, S. H., *ibid.*, 1958, v10, 663.

3. Goldring, S., O'Leary, J. L., Winter, D. L., Pearlman, A. L., PROC. SOC. EXP. BIOL. AND MED., 1959, v100, 429.

4. Bishop, G. H., O'Leary, J. L., *Am. J. Physiol.*, 1936, v117, 292.

5. Goldring, S., O'Leary, J. L., *EEG & Clin. Neurophysiol.*, 1951, v3, 329.

6. ———, *J. Neurophysiol.*, 1951, v14, 275.

7. Bishop, G. H., Clare, M. H., *ibid.*, 1952, v15, 201.

8. Bremer, F., *Physiol. Rev.*, 1958, v38, 357.

9. Brazier, M. A. B., *Acta Physiol. et Pharmacol. neerl.*, 1957, v6, 692.

Received December 14, 1959. P.S.E.B.M., 1960, v103.

New Type Concentric Stimulating and Recording Electrode for Electroencephalography and Oscillography. (25609)

H. J. DAIGLE, L. C. MASSOPUST, JR. AND E. C. HANNAN*
(Introduced by H. S. Mayerson)
Dept. of Physiological Sciences, Southeast Louisiana Hospital, Mandeville, La.

Multipolar electrodes for chronic or acute implanting within the nervous system of experimental animals have always presented problems to investigators of bio-electric phenomena. Some of these problems are: 1) Multipolar metal, glass or twisted wire concentric electrodes are difficult to fabricate because of the problems of insulating one pole from another. Secondly, breakage, shorting and high impedance are common in all of the above types of electrodes. 2) Further, in constructing the concentric electrode of "non-micro" types of more than 2 poles, the diameter of the whole electrode increases in size in such proportions as to be impossible to use in animals with relatively small brains. To overcome some of the above difficulties, a new type of multipolar concentric electrode was developed which employed coats of silver printed circuit paint alternating over coats of insulating material.

Materials. The following materials are necessary for construction of the silver paint type concentric electrode. 1) Straight surgical or hypodermic needle stock of any desired diameter which will give proper rigidity for insertion into nervous tissue by means of stereotaxic devices. 2) Pure silver printed circuit paint. This can be obtained from any electronic parts dealer. 3) Silver solder (No. 430) of the type made by the All-State Welding and Alloys Co., White Plains, N. Y. 4) All-State flux (non-acid) for ferrous and non-ferrous alloys. 5) Insulating baking varnish which resists acids, alkalies, solvents and degreasers. The use of "Epoxylite" made by the Epoxylite Corp., El Monte, Calif. was found to be the best. 6) Lead wire of the miniature variety such as "Tensolite Miniature Wire" manufactured by the Tensolite Insulated Wire Co., Tarrytown, N. Y.

Methods. 1) Arbitrary lengths of steel needle stock were cut to any practical length. Actual lengths were determined later by the depth of structures in the brain stem to be stimulated or recorded from (See Step 4 below). Length and diameter used by the authors for insertion into the brain stems of

* Present address: 8th Naval Dist., New Orleans, La.

cats were 2¾ inches and .025 inch respectively. Silver solder was applied by dipping the electrode first into flux then into melted solder and slowly withdrawing it. When cool, the tips of the electrodes were examined to make sure a homogeneous coating covered them. The tips were then cleaned and degreased, by use of such solvents as xylol and 95% ethyl alcohol. 2) The base end of the electrode was now inserted into a special cork holder for mounting in a mechanical device for applying thin, even coats of insulation over the steel core. This device consisted of a slow, constant-speed (1.16 rpm) electric motor, a rack and pinion and the electrode holder. The electrode core was lowered into a test tube containing Epoxylite, the motor turned on, which withdrew the electrode at a constant speed (1 cm/15 sec.) from the test tube. This operation was repeated 6 times, coating the steel core with micro-thin layers of Epoxylite. A few minutes were allowed to pass between Epoxylite coats to allow each coat time to set. 3) The electrode was then mounted in a vertical position and placed in a drying oven set at 50° to 60°C for a minimum of 24 hours. The longer the electrode is allowed to stay in the oven the harder the Epoxylite coating became. 4) After the first Epoxylite coatings were thoroughly hardened, the electrode was cut to actual length. These actual lengths of electrodes can be determined directly from any acceptable atlas of the brain of the experimental animal being used. After adding the thickness of the skull to the determined length, a point was found where the first lead off wire from the deepest pole was to be soldered to the electrode, each additional lead wire juncture point being distal to this point. One millimeter separations were found to be satisfactory for all additional poles. For example, in cats, length of a bipolar electrode necessary to reach the anterior or posterior hypothalamic area was 22 mm. To this was added another 1.5 mm to allow for the thickness of the skull and 2 more mm to keep the lead off wire joints above the surface of skull. 5) The first coat of pure silver paint was applied over the first insulation coat of Epoxylite with an artist's fine brush and with the aid of a relatively high power binocular dissection microscope. When dry, the silver paint layer was examined carefully to insure complete coverage of the underneath insulating layer. If there were gaps in the silver coat, the entire process was repeated. This silver coat was allowed to dry for at least 2 hours, then the second lead off wire was attached by lightly winding the wire around the silver paint layer near the "chuck" end of the coating. Next, a generous amount of silver paint was applied over the winding and continued down into the silver coating itself. This was allowed to dry for at least one hour. 6) The recording or stimulating tip of the steel core was now scraped clean of the covering layer of Epoxylite to any predetermined exposure and dipped into a thick grease such

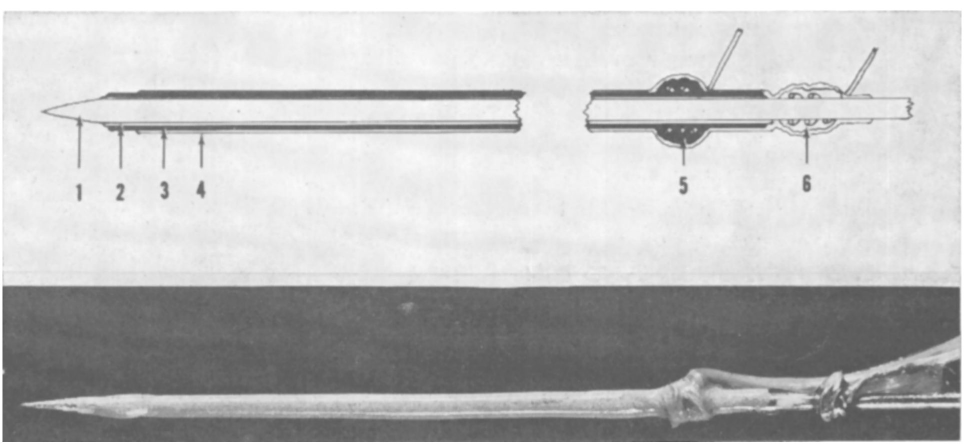

FIG. 1. Top diagram shows a cross-sectional view of construction of bipolar silver paint electrode. Key: 1) Steel core. 2) Epoxylite. 3) Printed circuit paint coating. 4) Epoxylite coating. 5) Lead wire joint of second pole (silver paint pole). 6) Silver solder joint of first pole on steel core. Bottom photograph shows completed bi-polar silver paint electrode.

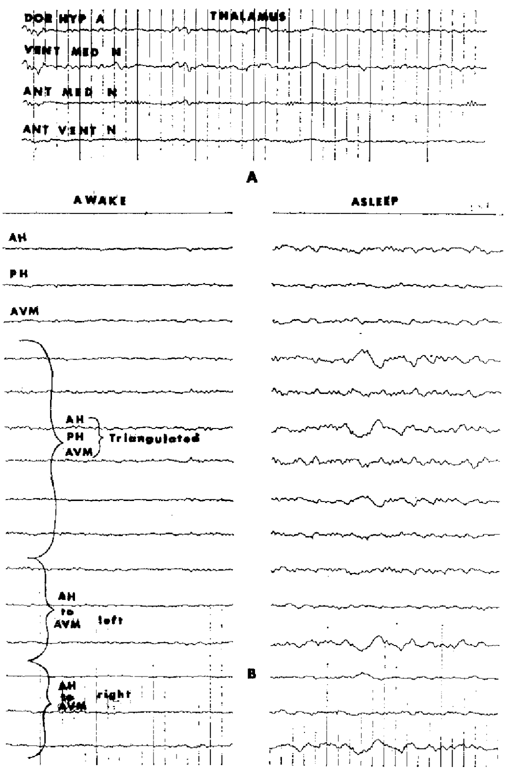

FIG. 2. E.E.G. tracings made from multi-polar silver paint electrode imbedded in posterior thalamic areas (A). The most proximal recording point was located in anterior ventral thalamic nucleus, Ant Vent N; the second recording point, in anterior medial thalamic nucleus, Ant Med N; the third point, in ventral medial thalamic nucleus, Vent Med N; the most distal recording point was located in dorsal hypothalamic area, Dor Hyp A. (B) Pairs of bipolar silver paint electrodes implanted in anterior hypothalamic area (AH); in posterior hypothalamic area (PH); and in anterior ventral mesencephalic reticular formation (AVM).

as Lubriseal. The Lubriseal was allowed to cover the already exposed tip of the steel core and as much of the first silver paint layer as is desired for a stimulating or recording surface (Fig. 1). This grease coating prevents the insulating coat from covering the exposed recording and/or stimulating surfaces. It can be removed later by gently wiping the tip with xylol soaked cotton. 7) The electrode was again run through the Epoxylite dipping procedure (Step 3) and 3 to 4 coats were applied making certain that these layers were carried over the previously made lead off wire joints. The electrode was then returned to the oven at a reduced temperature of 20°C to prevent contraction of the Tensolite insulation on the lead off wires. It is best to allow this coat to harden in the oven for at least 48 hours. Steps 5, 6 and 7 can be repeated for as many poles as desired.

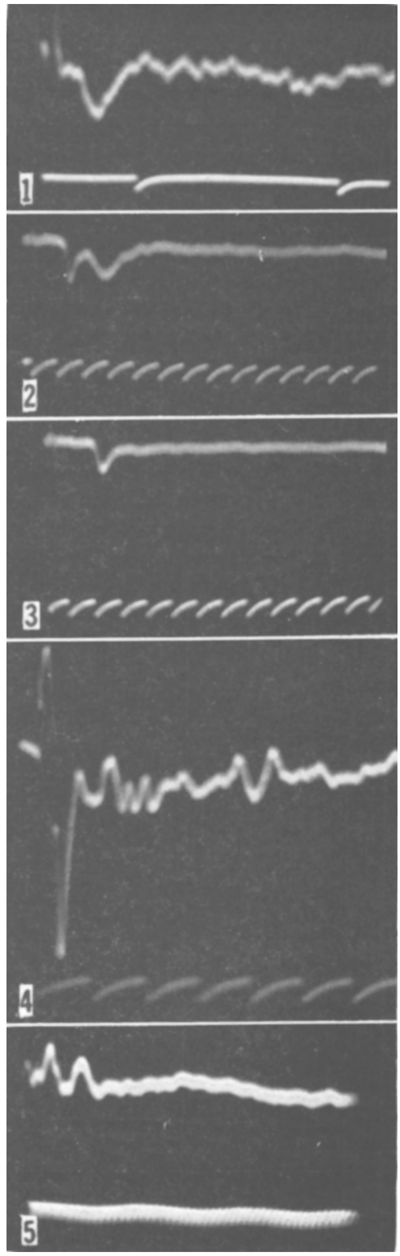

FIG. 3. Oscillographic recordings made from bipolar silver paint electrodes implanted in (1) medial longitudinal fasciculus; (2) sulco-marginal bundle of spinal cord on same side as stimulating electrode; (3) sulco-marginal bundle of spinal cord on opposite side from stimulating electrodes; (4) anterior gray horn of spinal cord; (5) vestibulo-cerebellar pathway.

Results. Generally, it was found that electrodes made according to the above procedure were of relatively low impedance. The silver paint poles were of somewhat higher impedance than the steel silver solder coated core. For example, in a direct current system and using isotonic saline as a conductor, impedance of the steel core pole was about 3,000 ohms while that of the silver paint pole was about 30,000 ohms. This may appear to be high; however, in animal bio-electric systems (*in vivo*) the characteristics are such that passage of current and voltage indicated a much lower impedance than that found in D.C. systems.

Deep electroencephalographic tracings were made from bi-polar silver paint electrodes implanted chronically in the anterior hypothalamus, posterior hypothalamus and the basal-anterior mesencephalic reticular formation of the cat (Fig. 2). Tracings were also taken from the thalamus by a multipolar electrode (4 separate poles) (Fig. 3). One notes that the recordings are stable and free of electrode "noise." Further the electroencephalograph must be attenuated at the pre-amplifier to reduce the sensitivity of the electrode.

Using both bi-polar and multi-polar electrodes in stimulating and recording sites of the brain stem, oscillographic recordings were made in the vestibular nuclei, the medial longitudinal fasciculus, the sulco-marginal bundle and anterior gray horns of the spinal cord. Stimulating voltages of from 0.1 of a volt to 1.0 volt were used in most cases. Clear cut potentials were easily obtained at the above low voltages in the vestibulo spinal system (Fig. 3).

Electrodes in the foregoing positions have been implanted chronically in cats and left in position for up to 5 months without dramatic changes in either the electroencephalographic or oscillographic tracings. Changes do occur in the above recordings for about 2 weeks following implantation. This is probably due to a chemical change on the exposed silver recording and stimulating points thru action of extracellular fluid, because a light film of blackened silver could be scraped from the recording and stimulating points on removal from the brain.

Acute short term experiments have been performed with these electrodes with equally good results.

Summary. A new type of multi-polar stimulating and recording electrode was developed to answer certain technical difficulties arising through use of standard type electrodes. This relatively low impedance electrode was constructed by using silver "printed circuit" paint over coats of insulating material without greatly increasing the diameter of the electrode core. Both acute and chronic bioelectric experiments were carried out employing the above electrodes giving good amplitude, stable electroencephalographic and oscillographic records from the central nervous system.

Received December 14, 1959. P.S.E.B.M., 1960, v103.

Passage of Barbital into Cerebrospinal Fluid.* (25610)

LESTER C. MARK, LEONARD BRAND, PETER G. DAYTON, DOLORES TALLER AND E. M. PAPPER

Dept. of Anesthesiology, Columbia-Presbyterian Medical Center and N. Y. University Research Service, Goldwater Memorial Hospital, N. Y. City and Laboratory of Chemical Pharmacology, Nat. Heart Inst., N.I.H., Bethesda, Md.

Previous studies have shown that barbital given intravenously passes slowly into the brain(1,2). In this report, the latter study was extended to include observations in dogs on passage of barbital into the cerebrospinal fluid.

Methods and materials. Barbital was determined by the method of Giotti and May-

* This work supported by Office of Surgeon General, Dept. of Army, by Nat. Inst. of Neurol. Dis. and Blindness, P.H.S. and by Abbott Lab., North Chicago, Ill.