NASA INDUSTRIAL APPLICATIONS STUDY

Industrial Review

for

IMPROVED ELECTRODE FOR BIOPOTENTIAL MEASUREMENT AT THE SKIN

Herman Schneid

8 December 1964

Contract NASw 952

Presented to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Office of Technology Utilization
Washington, D.C.

by

WESTINGHOUSE ELECTRIC CORPORATION
Defense and Space Center
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INTRODUCTION

In the report "A Long-Term Electrode System Suitable for ECG and Impedance Pneumography," J. L. Day and M. W. Lippett of NASA-MSC have described an improved electrode for measuring biopotentials at the surface of human skin. Prior electrodes have introduced artifacts or noise in the electrical signal due to body motion or long-term deterioration in the electrode or electrode-skin interface. This improved electrode maintains uniformly continuous contact with the skin for at least 4 days despite considerable physical activity by the subject. Skin irritation is low and subject freedom is unrestricted. This electrode development makes practical the extended monitoring of unrestricted subjects for alternating potentials on the skin of biological origin.

The following documents refer to work carried out by NASA or their contractors:

- J. L. Day and M. W. Lippett, "A Long-Term Electrode System Suitable for ECG and Impedance Pneumography," NASA Manned Spacecraft Center, prepared for publication in the Journal of Aerospace Medicine. A derivative document is NASA Tech Brief 64-10025, "Improved Electrode Gives High-Quality Biological Recordings," May 1964.
- NASA Report N64-25767, Robert Edelberg, "Development of an Electrode for Long-Term Application in Biological Recording," Baylor University College of Medicine, Contract NAS 9-445, October 1963.
- NASA Technical Translation TT-199, V. I. Bel'kevich, E. Yu Vende, and I. A. Vil'-Vil'yams, "Nonpolarizing Electrodes for Detecting Slowly Varying Biopotentials in Internal Cavities," April 1964.

Potential application is related to the increasingly frequent use of biopotential measurements at the skin surface for medical and physiological research and for patient diagnosis and monitoring. Most frequently monitored are electrical activity of the brain and of the heart. Reduced artifact makes such work more reliable. In addition to the improved research data and diagnostic

data, the electrode makes more practical automatic monitoring of critical patients permitting improved medical care with fewer medical personnel.

NASA-SUPPORTED PROGRAM FOR BIOPOTENTIAL ELECTRODES

The electrode described by Day and Lippett was successfully used in the Mercury program for monitoring biopotentials of the astronauts. More rigorous requirements are inherent in the Apollo program, involving periods over 1 week and substantial physical activity by the subjects. Edelberg has reported fundamental studies aimed toward electrodes for long-term use. His aim was to obtain a uniform, low electrical resistance of the skin to potentials of biological origin. This was to be resistant to change by the normal physiological mechanisms of wound repair, foreign-body rejection, and irritation. Substantial improvements over any existing electrodes in terms of reliability, low noise, freedom from irritation, low resistance, low resistance change, and many other factors are a continuing objective of NASA.

POTENTIAL CIVILIAN APPLICATIONS FOR THE BIOPOTENTIAL ELECTRODE

Monitoring of Cardiac Patients

The electrode makes possible more reliable monitoring of cardiac patients prior to or after surgery. In particular, such patients may be fully ambulatory with associated biotelemetry equipment to trigger a warning signal if heart trouble commences.

Patients at home may have their EKG transmitted by telephone to a recorder in a hospital at any time they experience cardiac distress. This permits remote diagnosis by the cardiologist and the initiation of emergency measures if required.

Potential cardiac patients may record a typical day of electrocardiogram activity on a portable, miniature tape recorder while performing their normal activities. Correlation of activity and EKG may reveal otherwise unsuspected heart trouble and its likely cause.

Reliable EKG recordings of a patient performing standardized exercise is more likely.

Long-Term Study of Heart Diseases

More reliable studies can be made of heart response to physical activity, emotional strain, or physiological disturbance over long periods of time or in the context of substantial subject activity.

Electroencephalography

Typically, the recording of the electrical output of the brain at the surface of the head takes a long time because of the high variability of the source over

a period of time. The NASA electrode promises far fewer artifacts for this use than the expected results of prior electrodes. The latter are highly vulnerable to movement. Electroencephalogram (EEG) signals are in the microvolt range. By minimizing artifacts of electrode origin, the NASA electrode makes possible more reliable diagnosis by both the cardiologist and any computerized diagnosis program.

ADDITIONAL POSSIBLE APPLICATIONS OF PROCESS

Fetal Electrocardiography

The NASA electrode should facilitate the determination of the very faint biopotential (in microvolts) on the mother's abdomen from the fetal heart. This is one of the earliest signs of life that is detectable by an obstetrician. This electrode permits continuous, automatic monitoring.

Electrohysterectomy

In a manner analogous to the heart, the uterus of a pregnant woman is triggered into motion by bioelectric innervation. The potentials at the abdomen surface, if continuously monitored, can characterize the progression of labor in a diagnostically significant manner. The NASA electrode should be highly appropriate to the prolonged labor activity involved. It should help improve obstetrical care in difficult cases. Potentially, continuous monitoring of women in labor is possible by automatic means.

Impedance Pneumography

By passing a high frequency electric current through portions of the body, inferences can be drawn from the measured change in impedance due largely to volume changes of pulsing organs. Thus, the action of the heart and the lung, and the uterus in labor, can be characterized in electrical terms. The NASA electrode should be particularly valuable in long-term studies for its enduring reliability and relative freedom from polarization.

Muscle Biopotentials

The NASA electrode can be used to measure the very low surface biopotentials associated with muscle activity. It can also transmit external electrical

stimulus to muscles for limited forms of exercise where the nerves are defective.

Animal Husbandry

The NASA electrode appears particularly useful for long-term studies of the biopotentials of animals because it permits bodily activity. Biotelemetry data can possibly indicate ovulation, labor, and other physiological factors that may require human attention.

DEVELOPMENTAL PROCEDURE INDICATED TO SOLVE PROBLEM AREAS

Relatively little development appears necessary for civilian use. It would appear that the unit could be made into a widely used disposable form of relatively low cost - below the cost of reclamation. The silicone elastomer of the electrode housing can be replaced by a low cost elastomeric plastic with a thin silicone coating. The electrode can be of thin pure silver foil bonded to plastic for stiffness, wherein the lead is part of the plastic-silver combination. The chloride treatment of the silver surface in quantity should be of negligible cost. Conceivably, the electrolyte can be retained within the electrode assembly by a nonstick protective cover that is peeled away from the skin adhesive in application. Automatic assembly of the electrode appears feasible.

Additional work is indicated for developing an electrode-skin technique of uniform, low resistance for long periods of time to measure slowly changing biopotentials. Current and anticipated biopotential electrode development for the Apollo program should have direct civilian application in the medical field when perfected.

CONCLUSIONS

The NASA bioelectrode developed for the Mercury project has the very desirable long-term features of low resistance, resistance to motion artifact, and low irritation. These characteristics are most appropriate for several newly emerging techniques in medicine. Long-term potential usefulness on active subjects extends the duration of reliable diagnostic monitoring and warning techniques appropriate to the heart, head, lungs, uterus, fetus, muscles, pulse, etc. It helps make practical the biotelemetry of ambulatory patients. This rapidly emerging technology promises better medical care at lower cost.