BNWL-214
4

AEC
RESEARCH
and
DEVELOPMENT
REPORT

PHYSIOLOGICAL DATA TELEMETRY SYSTEM

N. C. Hoitink and N. S. Porter

JULY, 1966

BATTELLE-NORTHWEST

BATTELLE MEMORIAL INSTITUTE / PACIFIC NORTHWEST LABORATORY

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY

RICHLAND, WASHINGTON

operated by

BATTELLE MEMORIAL INSTITUTE

for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

3 3679 00060 2187

BNWL-214
UC-37, Instruments

PHYSIOLOGICAL DATA TELEMETRY SYSTEM

By
N. C. Hoitink and N. S. Porter
Instrumentation Section
Applied Physics and Electronics Department

July, 1966

FIRST UNRESTRICTED
DISTRIBUTION MADE

806 66

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

Printed in USA. Price \$1.00. Available from the
Clearinghouse for Federal Scientific and Technical Information,
National Bureau of Standards, U. S. Department of Commerce,
Springfield, Virginia

PHYSIOLOGICAL DATA TELEMETRY SYSTEM

INTRODUCTION

This report describes a system that will continuously measure certain physiological parameters of personnel involved in maintenance and modification work performed under adverse environmental conditions near reactors, in heat exchangers, etc. Specifically, a system to monitor body temperature and heart function (ECG) in high temperature areas was desired to fulfill the need described above. Commercial telemetry instrumentation, capable of monitoring either temperature or cardiac function (ECG), was obtained and modified extensively to permit high temperature operation, simultaneous transmission of both parameters, and automatic, time-shared recording of the information. Other solid state circuits, as needed to obtain desired performance, were developed and incorporated into the system.

SUMMARY

A physiological data telemetry system, comprising both commercial and developed solid state circuits, was developed and is being used to monitor, on a continuous basis, body temperatures and heart function (ECG data) of two maintenance technicians working under high temperature conditions.

The completed system includes two miniature transmitters, ECG electrodes, thermistor temperature probes, two FM receivers, a developed demodulator unit, and a dual channel recorder. Satisfactory performance is being achieved over 200 ft ranges in general field operation.

DISCUSSION

The need for some method of monitoring the physical condition of men working under adverse environmental conditions became apparent during maintenance and work in various high temperature areas at Hanford. By observation of body temperature and cardiac activity, it is possible to detect the onset of heat exhaustion due to over-exposure in the hostile environment. Since it would be highly impractical to make measurements of these parameters in the usual manner, it was decided that the logical method for monitoring temperature and ECG was by biotelemetry. The block diagram of one channel is shown in Figure 1.

FIGURE 1. System Block Diagram of One Channel

There are biotelemetry instruments available commercially that meet some of the system requirements of compactness, frequency, range, and function; however, no commercial equipment meets all of the many system requirements. Therefore, it was decided to obtain

some commercial equipment, modify it as necessary, and develop other required circuits to provide a complete, operational system.

The Biocom* Model 334-AS instrumentation was obtained as it could provide monitoring of either temperature or heart function (ECG). This included a miniature transmitter, operating in the 88 to 108 MHz FM band with a range of about 300 ft, an FM tuner with an included Biocom demodulator, and the necessary electrodes, sensors, and accessories. Two instrumentation packages were obtained since the technicians ordinarily work in pairs during maintenance and modification effort.

As received, the commercial equipment operated satisfactorily for the purposes for which it was intended on the commercial market. However, it was not suited for use in high temperature environments, nor was it equipped to transmit both ECG and temperature data simultaneously. The signal recovery stages (demodulators) were inadequate for our application in that slight detuning of the receiver, or variations in signal strength, caused a major deviation in the recorded signals. Also, the signal intelligence recovered rode on a large negative bias since the demodulators were of the count-rate type, which provide an output voltage proportional to the input frequency. This was not acceptable for the Hanford application.

Extensive circuitry modifications were developed and incorporated to satisfy the requirements of the present system. The subcarrier oscillator was temperature-stabilized by using stable capacitors and selected temperature compensating resistors. Simultaneous transmission of temperature and ECG was accomplished by changing the transmitters to allow the temperature signal to determine the center, or quiescent, subcarrier

* Biocom Company equipment using a tradename of "Biolink" for the miniature transmitters.

oscillator frequency and the ECG signal to frequency modulate the center frequency. On the receiver, the demodulator was changed to include flip-flop circuits for pulse standardization, balanced ratio detector demodulators, and signal commutation.

The Biocom instrumentation provided one channel of information at a time. When the temperature transducer was attached to the transmitter, the ECG section was disabled to allow the thermistor to modulate the subcarrier oscillator. In order to transmit both channels simultaneously, the disabling mechanism was removed, allowing the temperature transducer to set the subcarrier oscillator center frequency and the ECG signal to frequency modulate the center frequency. The ECG signal was capacitively coupled to avoid temperature error generation.

These modifications do not adversely reflect the quality of the commercial equipment. The changes were to provide a system acceptable for the Hanford application. It is of importance to note that the detailed diagrams of the commercial equipment are not included in this report as they are considered to be of a proprietary nature.

The transmitters were tested in a temperature chamber to determine stability under the expected environmental conditions. The FM carrier was extremely stable up to 140 °F, the upper testing limit; however, the subcarrier oscillator demonstrated excessive drift which was reduced by substituting Mylar* for ceramic capacitors and by selecting temperature compensation resistors. Subsequently, the resulting drift error, as referred to body temperature, was equal to a predictable 1 °F increase when the transmitter was operating at 140 °F. Although this amount of drift is not desired electronically, it is tolerable from a safety standpoint since it is above, rather than below, the real temperature. Another transmitter

* E.I. du Pont de Nemours, Inc. tradename for plastic film.

modification was the incorporation of a potentiometer in the ECG amplifier; this served to control the signal gain for calibration purposes. The original transmitters used 8.4 V mercury batteries for the power supply. However, the temperature measuring system varies as the supply voltage and a lowering of battery voltage with time is reflected as a lowering of body temperature. In order to improve the stability of the transmitted temperature data over a normal operating period of 7 hr, it was decided to use a voltage regulator. The regulator uses a 9.4 V battery and a Zener diode operating at 6.9 V as shown in Figure 2. This modification reduced the temperature drift due to changes in battery voltage to approximately $1/3^{\circ}\text{F}$ over an 8 hr period.

FIGURE 2. Modified Battery Pack for Transmitter Units

The commercial demodulator circuit in each tuner was of the count-rate type which provides a dc output proportional to the input frequency. Thus, the subcarrier signal was detected and the ECG signal superimposed upon it as an ac signal at a large bias level. The temperature signals were dc level changes of the order of $10\text{ mV}/^{\circ}\text{F}$, however, and their detection required a bucking voltage with the magnitude of the bias level. Loss of the carrier would then impress the bucking voltage directly across the sensitive recorder. To improve this undesired situation, a ratio detector FM demodulator was developed to produce, when properly adjusted, an output voltage proportional

to the frequency change but centered about zero at some quiescent frequency. The output is also zero for frequency excursions beyond the demodulator range; hence, the recording system is protected against loss of signal.

Figure 3 is a schematic of the complete demodulator including a flip-flop circuit (Q1 and Q2) to standardize incoming pulses. Transistor Q3 is an emitter follower coupler stage. The two tank circuits are tuned to two different frequencies, approximately 10% above and 10% below the center frequency respectively. Transistors Q4 and Q5 provide tuned circuit outputs. Their filtered outputs are summed and used to drive the recorder. The actual response curves are shown in Figure 4.

One system requirement was the provision for time-sharing recordings of ECG and temperature for each man. The demodulated signal contains both of these signals; and since the temperature varies quite slowly, the ECG signals can be obtained by recording the total output of the demodulator. The base-line would change, of course, as body temperature changes. For temperature, it is only necessary to remove the ECG signal by filtering, thus removing it from the demodulated output and leaving the dc voltage determined by body temperature. Figure 5 shows the circuits adapted to perform the required filtering and switching.

Three modes of operation, as well as nine ratios of ECG-to-temperature recording times, are available in the system. The signal commutator is an astable multivibrator which when off, locked in one mode, or running, corresponds respectively to ECG only, temperature only, or both alternately. Three time constants are available on both sides of the multivibrator to determine the recording ratio of one signal to the other. The multivibrator operates relay K1 to switch the filter across the signal output. Three controls are located on

FIGURE 3. Ratio Detector Demodulator Circuits

FIGURE 4. Demodulator Response Curves

FIGURE 5. Signal Commutator

the front panel of the demodulator section. A typical recording is shown in Figure 6. Power for the unit is obtained from a regulated ± 15 V dc power supply shown schematically in Figure 7.

FIGURE 6. Typical Recordings

FIGURE 7. Regulated Power Supply

RESULTS AND CONCLUSIONS

The system has been used successfully in laboratory tests and in general field operation. The data obtained from the recordings, Figure 6, provide surveillance to help protect the health and well-being of the workers. The completed system is shown in Figure 8; and Figure 9 shows the system calibrated, in place, and ready for use. The transmitter will operate about 36 hr on 9.4 V mercury battery; however, after about 16 hr of operation, the regulator becomes unreliable due to the supply voltage change. Hence, batteries should be changed every 16 hr of operating time. Field operation with transmitter-to-receiving antenna separation of about 200 ft has been satisfactory. Fifty feet of 300Ω twin lead is provided between the receiving antenna and the receiver. This allows the operator to place the antenna in or near the working area while he monitors the station at a remote location.

FIGURE 8. Physiological Data Telemetry System

FIGURE 9. Complete System in Operation

DISTRIBUTIONNumber of Copies

382	<u>Division of Technical Information Extension</u>
2	<u>Douglass United Nuclear</u> P. S. Jerman M. L. Smith
7	<u>Hanford Occupational Health Foundation, Inc.</u> F. E. Adley W. E. Gill (5) W.D. Norwood
1	<u>ITT Federal Support Services, Inc.</u> G. R. McKinney
2	<u>Richland Operations Office</u> R. K. Sharp Technical Information Library
40	<u>Battelle-Northwest</u> W. J. Bair D. P. Brown L. J. Chockie G. M. Dalen G. E. Driver G. C. Fullmer (2) R. A. Harvey N. C. Hoitink (2) H. A. Kornberg F. L. Palotay R. S. Paul L. D. Philipp N. S. Porter (2) C. A. Ratcliffe E. M. Sheen J. C. Spanner W. G. Spear (11) J. L. Stringer R. L. Wilbur D. C. Worlton L. V. Zuerner Tech Information File (5) Tech Publications