Arctic Aeromedical Laboratory

THERMISTOR THERMOMETRY IN INVESTIGATIONAL WORK

PROJECT NUMBER 22-1301-0002
RESEARCH REPORT

LADD AIR FORCE BASE
A L A S K A

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Contract Number 18(600)–413

PROJECT NUMBER 22–1301–0002
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Alaskan Air Command
ARCTIC AERO MEDICAL LABORATORY
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March 1953

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INTRODUCTION

Experimental work is no more reliable than are the methods by which results can be evaluated. In many experiments, temperature change is a means by which the results must be obtained. It is frequently desirable to measure the temperature change of tissues or organs when these structures or the entire body is subjected to changes in environment. In addition, temperature change may be used to evaluate a variety of changes in a tissue, organ, or even the entire body when the part or parts are subjected to varying conditions. Temperature change may be used as an index to a change in circulation to an organ, to the comparative rate of metabolism of an organ, and to the influence of the sympathetic nervous system upon the circulation of an organ.

Temperature changes may be accurately measured by properly calibrated mercury thermometers. Frequently, however, the location of the medium to be measured makes the use of this type of thermometer difficult, impractical, or even impossible. For years experimenters have been using electrical thermometry to overcome the difficulties frequently encountered with the mercury type of instrument. Bazett and McGlone (1), Wright and

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This work was supported in part by contract #AF18(600)-413 with the Alaskan Air Command Arctic Aeromedical Laboratory, Ladd AFB, Alaska.

Paper No. 2826, Scientific Journal Series, Minnesota Agricultural Experiment Station.

Johnson (2), Clark (3), Fedorov and Shur (4), Martinez and Visscher (5), as well as many other investigators, have used thermocouples to measure tissue and blood temperatures.

More recently thermistors have served in electrical thermometry. Drummeter and Fastie (6) in 1942 reported the use of these instruments in the measurement of blood temperatures. Herick and Glarborg (7) in 1949 stated that thermistors are simple, convenient, rugged, and very accurate. In addition they cite the decided advantage that the temperature to be measured may be observed or recorded at considerable distances from the experimental animal. Mather (8) in 1951 used thermistors in the measurement of temperatures of the blood in the pulmonary artery, left atrium, and rectum of normal dogs.

The purpose of this paper is to discuss thermistors briefly, to describe their instrumentation, to enumerate their advantages, and to point out the manner in which they may be used in electrothermometry.

MATERIALS AND METHODS

In thermistors which are made of various combinations of manganese, nickel, cobalt, copper, and other metallic oxides, the resistance increases rapidly as the temperature falls; vice versa, the resistance decreases as the temperature rises; this relationship is not entirely linear but from a practical standpoint may be considered so over short ranges of temperature variation. This relationship is easily demonstrated when these instruments are temperature-calibrated in a suitable electrical circuit.

Thermistors are manufactured in a number of sizes and shapes. Two types have been used in this laboratory; these are: Western Electric V-642, and Western Electric 11A. The former is an egg-shaped bead type thermistor measuring 0.5 mm. by 1.0 mm. in size and is fitted with two leads 5 mm. in length which extend from the smaller end. This thermistor is suitable for placement within the point of a 17-gauge hypodermic needle, which serves to place the measuring device into the tissues or into vascular structures. Western Electric type 11A thermistor is a metal-tipped rod of semi-conductor material measuring 2.5 mm. in diameter and 23 mm. in length. This device may be employed to measure temperatures in organ lumina, such as the colon, rectum, vagina, uterus, esophagus, stomach, and duodenum. The thermistor is partially inserted into a 5 mm. rubber catheter or a 4 mm. polyethylene tubing, after which the thermistor, together with the adjacent part of the tubing, is treated with latex rubber and collodion to prevent access of moisture.

The thermistor-containing hypodermic needles and catheter is shown in figure 1.

The hypodermic needle thermistor assembly is prepared as follows:

1. Adequate lengths of #28-gauge copper wire covered with nylon and enamel are soldered to the two leads on the bead-type thermistor.

2. These leads and attached copper wires are insulated from each other with collodion, applied by dipping.

3. The wire leads are passed through 1.5 mm. polyethylene tubing in such a way that only the thermistor protrudes from the tubing. The tubing in turn is passed through a 17-gauge hypodermic needle of the desired length until only 1-cm. length of tubing with its protruding thermistor extends from the needle.

4. The protruding tubing and the thermistor are given a final dipping of collodion. The polyethylene tubing and its contents are then pulled into the needle so that the thermistor bead is flush with the bevel of the needle.

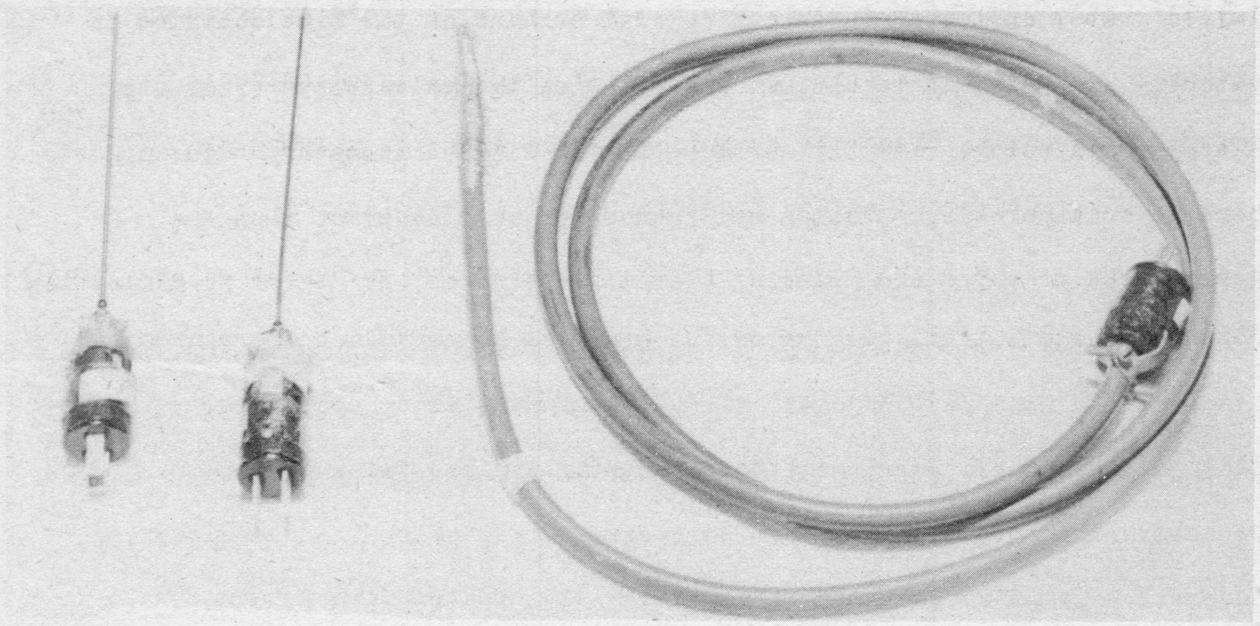

Figure 1. Thermistor containing hypodermic needles.
Thermistor containing catheter.

5. The clamp of a small-sized, two-connector, male Jones plug is fastened onto the hub of the hypodermic needle, and the copper wire leads are soldered onto the plug contacts.

6. The base of the plug, the hub of the needle, and the space between these two structures are then filled with warmed, semisolid paraffin to protect the leads from physical damage and moisture.

The catheter-thermistor assembly is constructed as follows:

1. Lengths of #22-gauge double cotton covered copper wire are soldered to each of the leads on the type 11A rod thermistor.

2. Lengths of 2.5 mm. polyethylene tubing 4 cm. long threaded over the copper wire thermistor leads and the soldered lead connections, to insulate them from each other and from the thermistor.

3. The copper wire leads are then threaded through a desired length of 6 mm. rubber catheter. Approximately one-fourth of the thermistor rod is pulled into the rubber tubing, and the rest is left protruding.

4. The thermistor and 5 cm. of the tubing are dipped in collodion, three coats being applied.

5. This portion of the thermistor and the catheter are then dipped in liquid latex and air-dried, after which the entire assembly is oven-baked for 24 hours at 46° C.

6. The thermistor and rubber catheter tubing are again dipped in collodion, which is allowed to dry.

7. A small-sized two-way, male Jones plug is clamped onto the free end of the tubing after which the copper wire leads are soldered to the connector lugs of the plug.

8. Semisoft, warm paraffin is placed about the junction of the Jones plug and the rubber catheter.

Throughout the construction of the thermistor assemblies, it is necessary to check repeatedly for continuity and for short circuits by means of an ohmmeter.

The resistance of a thermistor may be measured with a Wheatstone resistance bridge, using a circuit as shown in figure 2.

When the resistance bridge is balanced, indicated by a "null" reading (exact mid-scale reading) on the galvanometer, there is equal voltage at points "a" and "b", and the resistance reading of the decade box equals the resistance of the thermistor. Because of the resistance to temperature relationship of the thermistor, it is possible to calibrate the assembly in terms of temperature by means of a variable-temperature water bath, thus making it possible to use the device in thermometry.

It is possible, practical, and convenient to employ a calibrated, non-balanced resistance bridge arrangement in the use of this device; this is shown in figure 3.

The decade box in the galvanometer circuit is adjusted so that a one degree temperature change will cause a 10 cm. deflection of the indicator on the scale of the galvanometer (Rubicon galvanometers equipped with 10 cm. scales have been used in this laboratory). By proper adjustment of both the decade box in the galvanometer circuit and the one in the bridge circuit, it is possible accurately to read temperatures directly from the scale of the galvanometer. With the galvanometer series resistor (decade box)

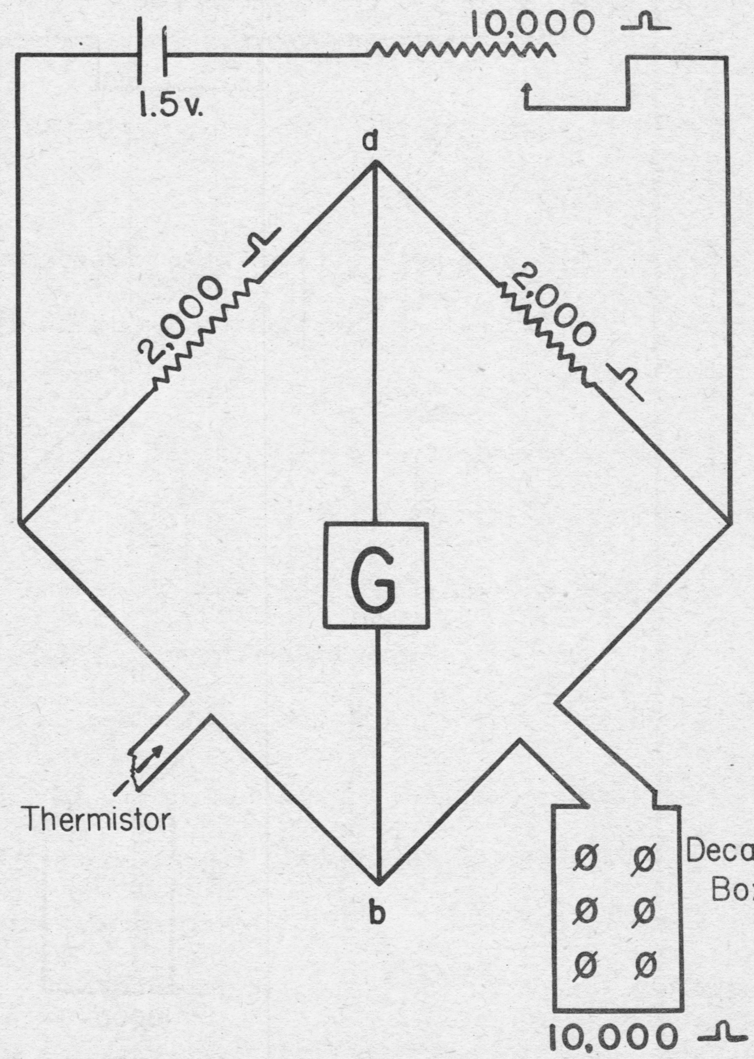

Figure 2. A circuit for measuring the resistance of the thermistor. (The thermistor is represented by the symbol in the lower left portion of the diagram.)

adjusted so that a one degree change will cause a 10 cm. deflection of the indicator, the decade box in the bridge circuit is adjusted so that when the thermistor is maintained at an even degree C.---say at 30° C.---the indicator will be at zero on the left end of the scale. With these adjustments, the indicator will be at the zero or ten, graduation at the right end of the scale when the thermistor temperature is increased to 40° C.; all temperatures between 39 and 40 can then be read directly

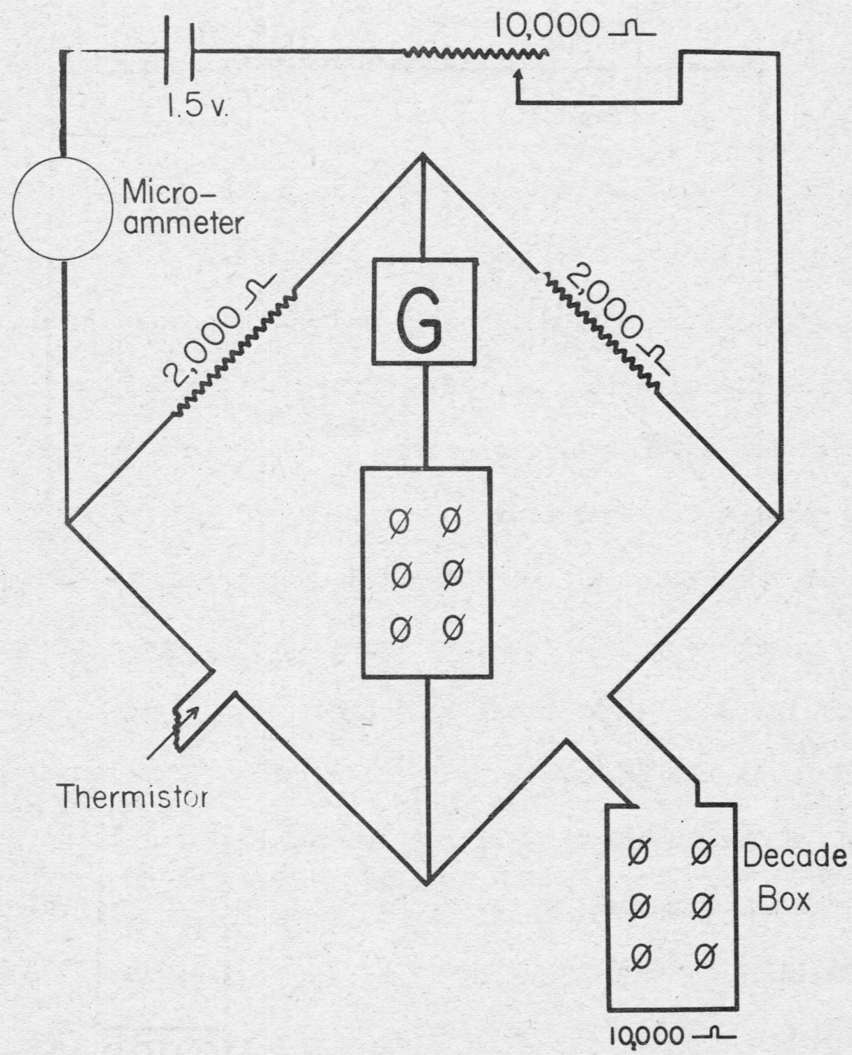

Figure 3. A circuit diagram which when properly adjusted allows the direct reading of temperatures from the scale of the galvanometer. (The thermistor is represented by the symbol in the lower left portion of the diagram.)

from the scale on the galvanometer. It will be necessary to reset the decade box resistances for each different degree of temperature to be measured. The decade box in the bridge circuit will obviously have to be changed; because of the changes of current through the bridge arms it will be necessary to make slight changes in the galvanometer series resistance. In calibrating the instrument it is well to construct a table, an example of which is as follows:

Temp.	Galvo. Series R.	Bridge R.
38-39	18,000 ohm	1875 ohm
39-40	18,200 ohm	1802 ohm
40-41	18,400 ohm	1728 ohm

It is necessary to keep a constant current flow (through the resistance network) from the voltage source. A 200 microampere current is adequate when the V-642 type of thermistor is used, and 400 microampere current is desirable when the 11A type is employed. Minor changes are necessary in the series resistance in the voltage source to maintain a constant current when there are changes in temperature.

If it were desirable to have a continuous temperature recording, a mirror type of galvanometer, a slit-lamp light source, and a photokymograph could be used in place of the Rubicon galvanometer.

Frequently, it may be necessary to read two or more temperatures simultaneously. This can be accomplished by employing two or more thermistor assemblies and an equal number of resistance bridges each of which is preferably equipped with a separate galvanometer. It is possible to employ one galvanometer and a multiple-two-way switch by means of which the galvanometer may be placed in any individual bridge circuit at any time. The use of a single galvanometer has several disadvantages. First, it makes impossible the exact simultaneous reading of several temperatures. Secondly, only a limited number of temperatures can be read because of the time consumed in switching from circuit to circuit and allowing the galvanometer indicator to stop oscillating. Finally, because of the several necessary adjustments there is considerable confusion and chance for reading error when the temperatures measured are changing from a fraction of one degree to a fraction of another, for example from 39.97 to 40.01.

Figure 4 shows a picture of a three-way thermistor assembly together with controlling bridge circuits and a variable temperature water bath by means of which the assemblies are calibrated.

TEMPERATURE MEASUREMENT

By employing thermistor thermometry, it has been possible accurately to measure temperatures in the pulmonary artery, the left atrium, and within

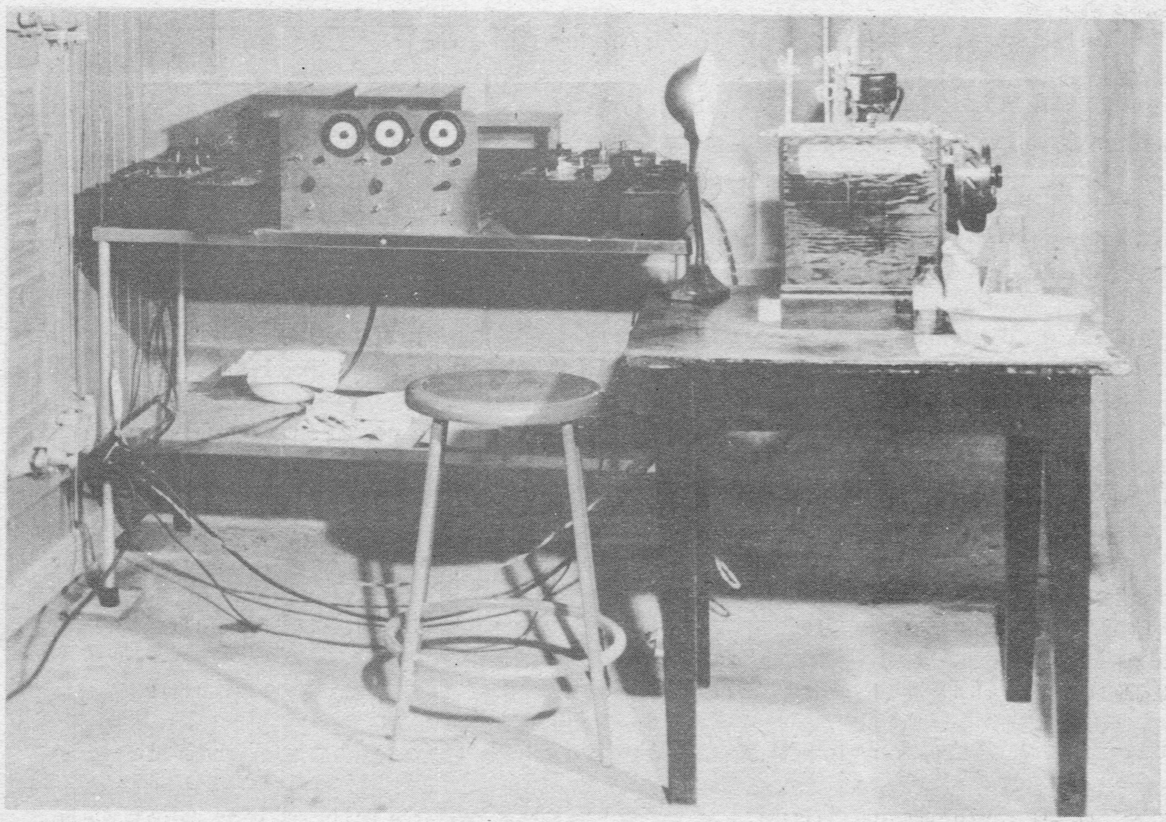

Figure 4. A three-way thermistor assembly together with controlling bridge circuits and a variable temperature water bath.

the lumen of the rectum. It is believed that temperatures in any area of the body that are accessible by needle or catheter could be similarly measured.

ACCURACY

Accuracy of 0.01° C. is not difficult to obtain. The limiting factor is the accuracy with which the calibrating thermometer controlling the water bath can be read.

STABILITY

Thermistors show good stability. Once properly constructed they are reliable and show constant electrical properties. Daily calibrations show negligible changes in the characteristics of the thermistor assemblies.

CONCLUSIONS

1. Thermistors are semiconductors made from various metalic oxides that exhibit an inverse temperature-to-resistance relationship.

2. Thermistors because of their temperature resistance relationship are suitable for use in electric thermometry.

3. Thermistors can be placed within hypodermic needles, rubber catheters, and plastic tubes which in turn can be placed in most any location in or on an animal at which point the temperature can then be measured.

4. Temperatures may be read directly from the scale of a Rubicon galvanometer with an accuracy of 0.01° C.

5. Thermistors are sturdy in construction and reliable in temperature and electrical characteristics.

Summary

1. Thermistors are described and briefly discussed.
2. The instrumentation of thermistors is discussed.
3. The use, accuracy, and stability of thermistors are discussed.

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Distribution Number 1891
March 1953

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