

## A NEW SIMPLIFIED INSTRUMENT FOR WATER TEMPERATURE MEASUREMENTS

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Through the rapid development in the field of electrotechniques and the development of highly sophisticated precision components it has been possible to design a new simplified electrical instrument for the measurement of water temperature. This instrument consists of a bridge, a probe with leads, and a galvanometer.

The instrument has been used for five years and tried out at SMHI under extreme weather conditions. The instrument has shown very reliable readings, although the galvanometer works slowly at extremely low air temperatures, around approx.  $-30^{\circ}\text{C}$ . The instrument should, during measurements and transport, be protected against precipitation and excessive moisture, which during adverse conditions will have a negative effect on the functioning of the instrument. The most recent version of the probe is possible to use in salt water and at rather great depths, about 200 meters. Measurements can probably be made at considerably lower depths with maintained good functioning of the probe.

### **The bridge**

A Wheatstone bridge (see Fig. 1) especially designed for measuring water temperatures is used. The components were chosen and assembled in such a way that the measuring range is between  $-2^{\circ}\text{C}$  and  $+30^{\circ}\text{C}$ . The bridge is powered

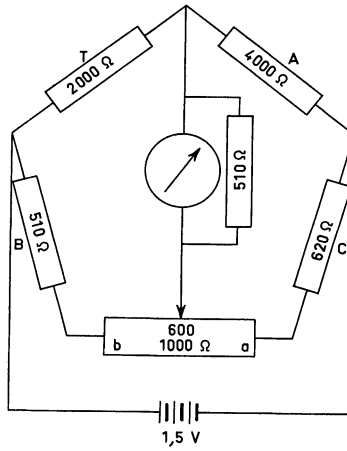


Fig. 1.

Measuring bridge, Wheatstone type.

$$\text{At } 0^\circ \text{C: } \frac{T}{B + 800} = \frac{A}{C + 200} \qquad \text{At } 25^\circ \text{C: } \frac{T}{B + 200} = \frac{A}{C + 800}$$

- T = 2,000 ohm at + 25° C      6,400 ohm at 0° C
- A = 4,000 ohm
- B = 510 ohm
- C = 620 ohm
- a + b = 1,000 ohm potentiometer

by a 1.5 V battery and power dissipation in thermistor is about 0.15 mW (between 0° C and + 25° C).

By choosing a thermistor with a high resistance and a lead with a low resistance and also by placing the resistances quite near each other and in a horizontal plane any compensation may be neglected. With the construction indicated above a very good accuracy has been obtained. Of course, the accuracy depends on the quality of the norms against which the instrument is calibrated.

Taking into consideration the investigations regarding electrical measuring technique published earlier by Mortimer & Moore (1953), Schmolinsky (1954), and Lars-Erik Haeggbloom (1959), the precision of the measurements could be estimated at  $\pm 0.03^\circ \text{C}$  with usual precautions.

### The resistances

The resistances, 0.1 % precision resistances, were twisted from manganin thread

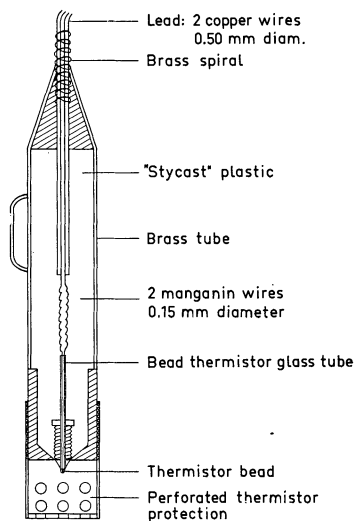
and cast in Epoxy resin, and are sturdy and, according to the contractor, stable (Witrohm type MM-05). The potentiometer is a Beckman helipot, 10-turns, 1,000 ohm.

### **The galvanometer**

The galvanometer used is of "Norma" type, sensitivity about  $2 \times 10^{-7}$  amperes per scale division, resistance about 100 ohm. This type of 0-point instrument is, so far, the most suitable obtainable. However, it is not quite ideal especially while measuring from a boat in rough weather. Furthermore it has a somewhat slow indication at extremely low air temperatures, around approximately  $-30^{\circ}$  C. Experiments are being carried out on a more robust 0-point instrument, e. g. of the "magic eye" type.

### **The temperature probe and leads**

For the probe a 2,000 ohm pearl thermistor type Veco 32 A 1 has been used, see Fig. 2. The weight of the probe has been adjusted so that water-depths up to



*Fig. 2.*  
Water-temperature probe.

100 meters can easily be reached. The pearl thermistor is protected against radiation, bumps, and other damages by a detachable perforated cover. The most recent design of the probe permits measurements in salt water and at relatively large depths, about 200 meters. Measurements can probably be made at considerably deeper levels with maintained functioning of the instrument.

The Swiss-made, plastic-covered, copper two-leader has comparatively great strength. The lead has a resistance of about 8 ohms per 100 meters.

### The test probe

For continuous check of the bridge resistance a test probe has been made, see Fig. 3. The probe and the bridge both have the same type of resistances. With the probe connected a value is read, which is constant as long as the resistances of the bridge are stable.

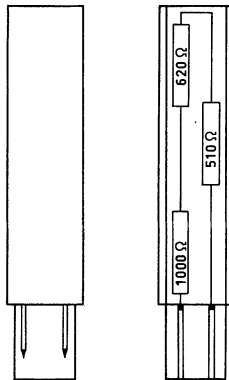
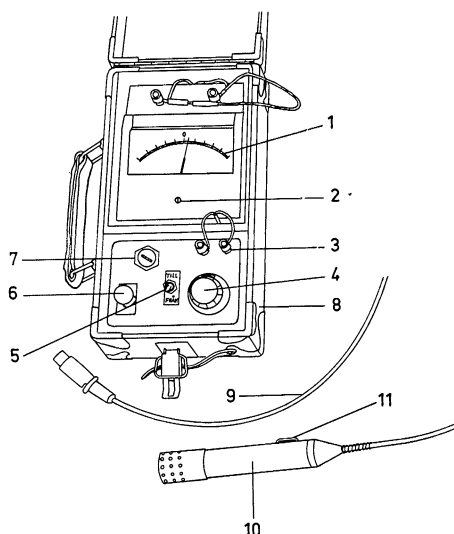


Fig. 3.

Test probe for continuous checking of possible bridge resistance changes.

### The thermal lag of the temperature probe

The adaptation time of the probe has been studied by means of Ultragraph equipment. From an ambient temperature of about  $+25^{\circ}\text{C}$  the probe was put in a 0-point bath. The results of the experiments have shown an adaptation time of 3-5 seconds, see Fig. 5.



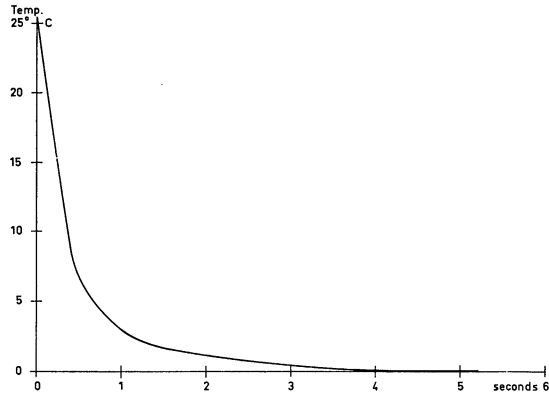
*Fig. 4.*

Measuring bridge with galvanometer, probe, and leads.

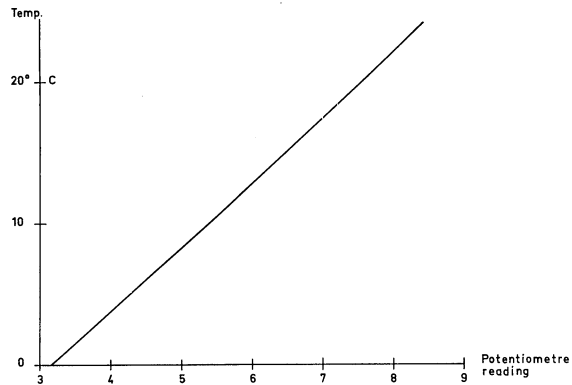
1. Galvanometer "Norma"
2. Zero adjustment
3. Connector between galvanometer and bridge
4. Potentiometer scaler
5. Switch
6. Connector between probe and bridge
7. Battery
8. Transport box (length = 32 cm, width = 17 cm, height = 13 cm)
9. Probe lead
10. Water-temperature probe
11. Device for attaching probe to reel.

### **Calibration**

The instrument is calibrated against three of SMHI's precision normal thermometers. These normals are frequently checked by Statens Provningsanstalt (Bureau of Weights and Measures). A temperature curve is drawn from the values read with an accuracy of  $0.01^{\circ}$  C. If the value changes in any component in the bridge or in the probe, the character of the curve is not changed, only the 0-point value changes; but as the character of the curve does not change, the curve can be displaced in parallel according to the new 0-point value.



*Fig. 5.*  
Lag time curve for adjustment from +25° C to 0° C. The tests were made by an automatic recording Ultragraph.



*Fig. 6.*  
Temperature curve according to calibration values below (°C).

0.00	3.150	9.15	5.270	18.29	7.219
0.77	3.333	10.05	5.475	19.02	7.370
1.99	3.620	11.09	5.703	20.13	7.586
2.86	3.824	11.97	5.897	21.31	7.811
3.97	4.085	12.89	6.100	22.04	7.950
4.84	4.285	14.00	6.336	22.12	7.964
5.87	4.528	14.99	6.542	23.06	8.140
6.94	4.769	16.11	6.780	24.20	8.340
8.13	5.040	17.03	6.970	25.04	8.492

### **Reduction of the heat flow by manganin wires**

The leads are made of copper, which is a good heat conductor – conductivity 0.92 cal/cm · sec · ° C. Manganin has a conductivity 0.05, and therefore manganin wires of small diameter were used as leads close to the thermistor. See Fig. 2.

### **Further developments**

Work is being continued on, among other things, achieving better protection against moisture and outside disturbances, such as may occur during measurement from a boat in rough weather. Also experiments are going on to build a recorder into the probe. It is already possible to connect the bridge to a suitable recorder. The aim of future improvements is to design an instrument able to function during any field conditions.

### **ACKNOWLEDGMENTS**

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