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A RADIATION COMPENSATED HOT-WIRE ANEMOMETER

by

R. H. Bigmore

Summary

An anemometer has been developed to measure the speed of slow airstreams in positions where it is exposed to thermal radiation. The calibration is shown to be only slightly affected by the radiation up to an intensity of $1\frac{1}{2}$ cal cm^{-2} s^{-1}.

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Herts.

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A RADIATION COMPENSATED HOT-WIRE ANEMOMETER

by

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R. H. Bigmore

1. Introduction

An anemometer has been developed to measure the speed of slow airstreams in positions where the instrument receives radiated heat. Although designed specifically for the measurement of the ventilation of fires in small enclosures, it should be useful in other fields.

The instrument was required to:

(1) measure the speed of air of uniform temperature flowing at speeds between about 15 and 100 cm/s;

(2) avoid disturbing the airflow pattern through an orifice $2\frac{1}{2}$ cm wide;

(3) produce an output which could be recorded continuously;

(4) have a rapid response to change of airspeed;

(5) be unaffected by intensities of radiation of up to $1{\cdot}5$ cal cm^{-2} s^{-1} falling on the sensitive part of the instrument.

The shielded hot-wire anemometer described by Simmons (1) meets all the requirements except the last.

The Simmons anemometer consists of a small twin-bore silica tube which is heated by passing a constant current through a 36 s.w.g. nichrome wire in one bore of the tube. The heater wire also acts as a support for the tube. The instrument is calibrated in terms of the temperature of the tube measured by a thermocouple in the other bore.

As the electric power dissipated in the heater is of the order of $\frac{1}{2}$ watt ($\frac{1}{8}$ cal/s) the heat falling on the instrument at an intensity of radiation of $1{\cdot}5$ cal cm^{-2} s^{-1} is much larger and would cause a large increase in output (Fig. 1), with consequential errors in speed measurements. It is impossible to eliminate the effects of radiant heat by increasing the electric heating because the larger input would increase the tube temperature so much that the increase in cooling by natural convective would make the instrument insensitive at lower speeds.

The effects of "stray" radiation have been eliminated in the required range of operation by using a compensated arrangement of the anemometer.

2. Method of compensation

2.1. Design of instrument

The arrangement used is shown in Fig. 2 and Plate 1. Two small twin-bore silica tubes are supported on a 36 s.w.g. nichrome wire which acts as a heater; a 36 s.w.g. nichrome constantan thermocouple is located in the other bore of each tube.

When the instrument is placed in an airstream of uniform speed so that the amount of heat radiated onto each tube is the same, the net output obtained by connecting the thermocouples in opposition is zero.

When one tube is heated electrically by passing a constant current of $0{\cdot}6$ amp through the heater wire the airspeed can be calibrated against net output.

2.2. Theory of instrument

The instrument is cooled mainly by convection and at an airspeed of 60 cm/s approximately one half to two-thirds of the heat is lost by forced convection. Although the fluid properties determining the heat transfer coefficients for both forced and free convection vary with temperature the total heat lost by convection is approximately proportional to the tube temperature in the working range of the instrument.

To ensure that compensation was achieved over the required range, the instrument was calibrated with various radiant intensities incident on it.

3. Calibration of instrument

3.1. Normal calibration

The normal calibration curve (Fig. 3) for the compensated instrument is identical with the curve for an uncompensated anemometer of the same design.

3.2. Effect of radiation on calibration

The anemometer was supported at the centre of a wind tunnel which generated a uniform airstream with a range of speeds between 0 and 100 cm/s at the working section. A heating element and elliptical reflector were mounted above the wind tunnel so that the anemometer could be uniformly irradiated through a mica window by radiation of between 0 and 1·5 cal cm^{-2} s^{-1}. As the response of the anemometer to radiated heat was very rapid it was possible to detect any effect that the heating had on the output of the anemometer at constant airspeed before the radiant heat disturbed the airflow by heating the tunnel walls.

The tunnel was adjusted to give a steady airspeed and the net output from the thermocouples, connected in opposition, was recorded with a constant current through the heater.

The radiation was then switched on and any change in output was recorded.

At each speed the anemometer was irradiated with five different intensities between 0·35 and 1·5 cal cm^{-2} s^{-1}. This procedure was repeated for six different airspeeds between 15 and 100 cm/s. The maximum change in output was 2 per cent, which represents a speed change of 5 per cent at the highest speeds. This is less than the experimental error in calibrating the instrument.

4. Discussion and conclusions

A pair of shielded hot wire anemometers may be used to measure low airspeeds in the presence of uniform external radiation. For experimental reasons the instrument had to be calibrated with the tubes horizontally, but when placed vertically speeds lower than 15 cm/s may be measured [1]. Non-uniform radiation could to some extent be dealt with by reversing the circuit and taking a mean value of the readings.

For compensation to be effective the temperature difference between the two tubes should be kept as small as possible and therefore the electrical input should be kept as small as is consistent with the sensitivity required in the desired speed range.

5. Acknowledgments.

The author wishes to acknowledge the assistance of the N.P.L. in providing facilities for making the thermocouples, and also his indebtedness to Miss V. E. Roberts and Messrs. C. R. Theobold and R. W. Claridge for assistance with the calibration work.

6. References

1. Simmons, L. F. G. A shielded hot-wire anemometer for low speeds. J. Sci. Instrum. 1949 26 (12) 407-11.

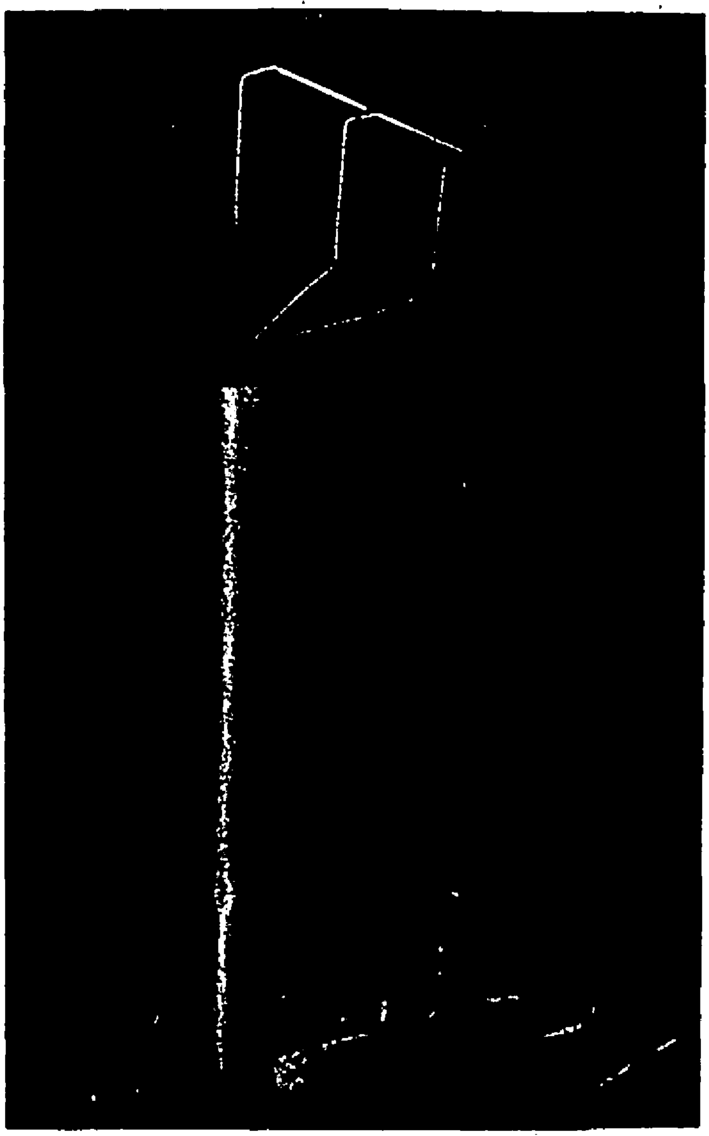

PLATE.I. COMPENSATED ANEMOMETER

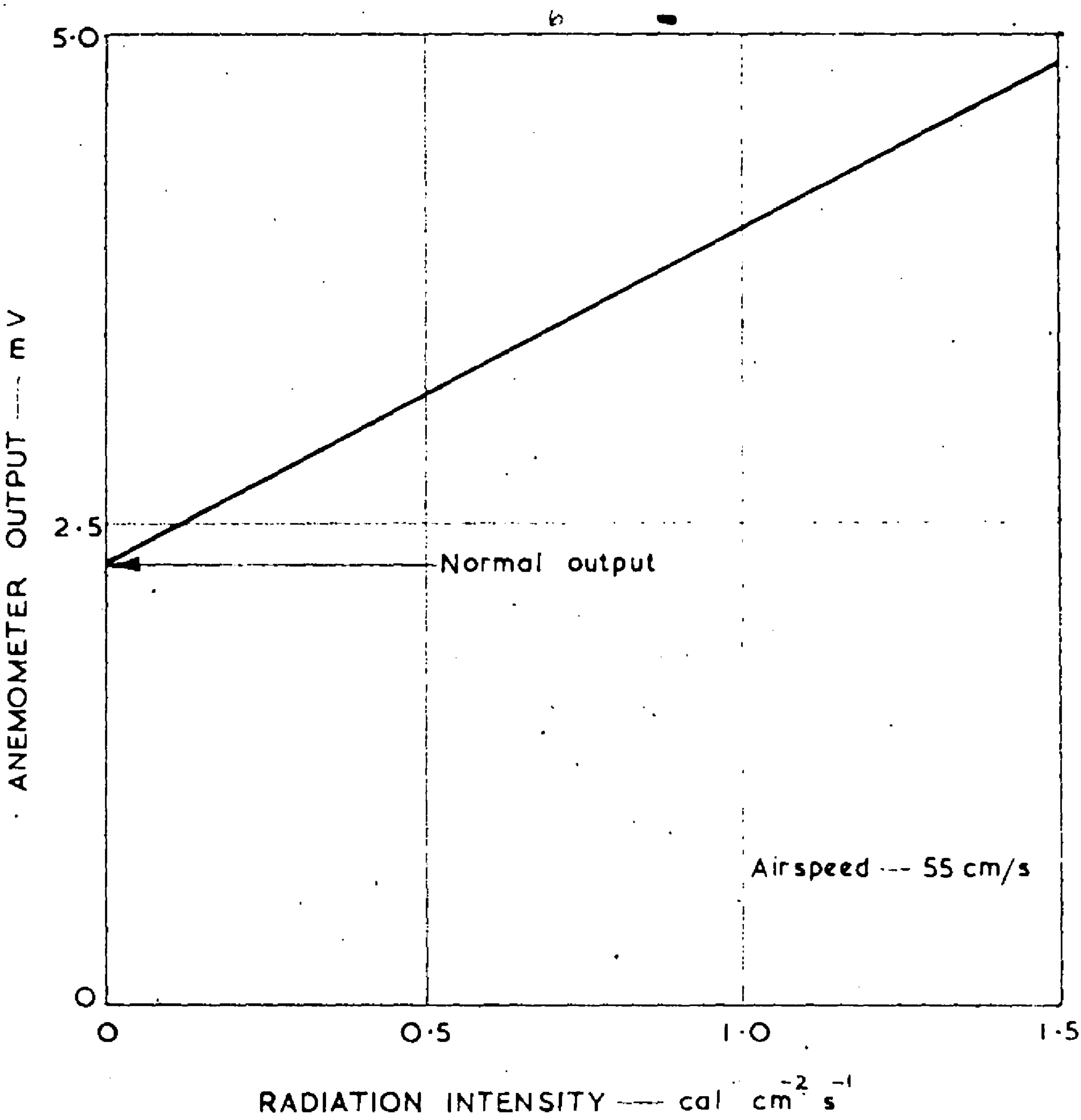

FIG.1. EFFECT OF RADIATION ON OUTPUT OF UNCOMPENSATED SHIELDED HOT-WIRE ANEMOMETER

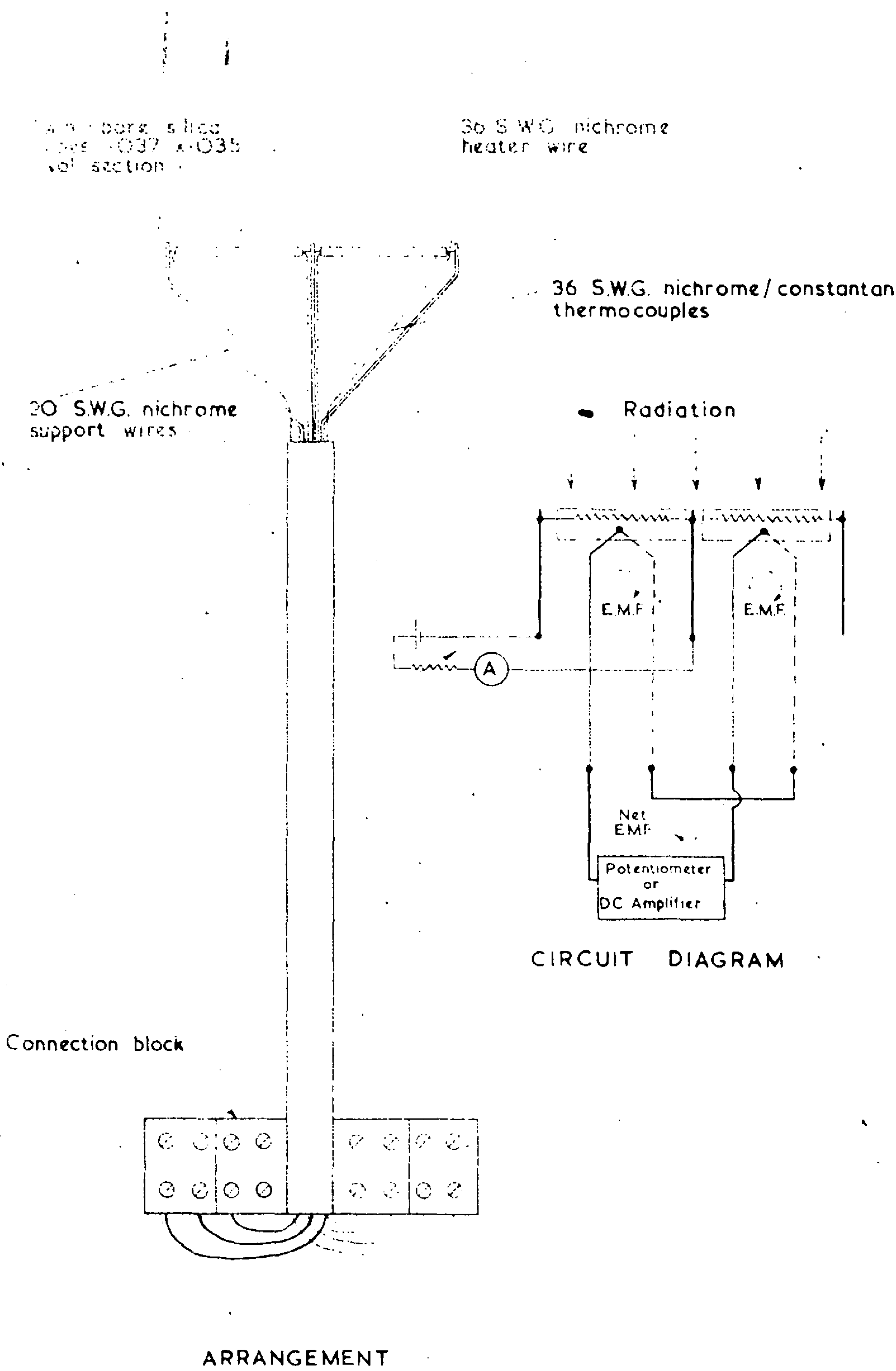

FIG. 2. COMPENSATED ANEMOMETER

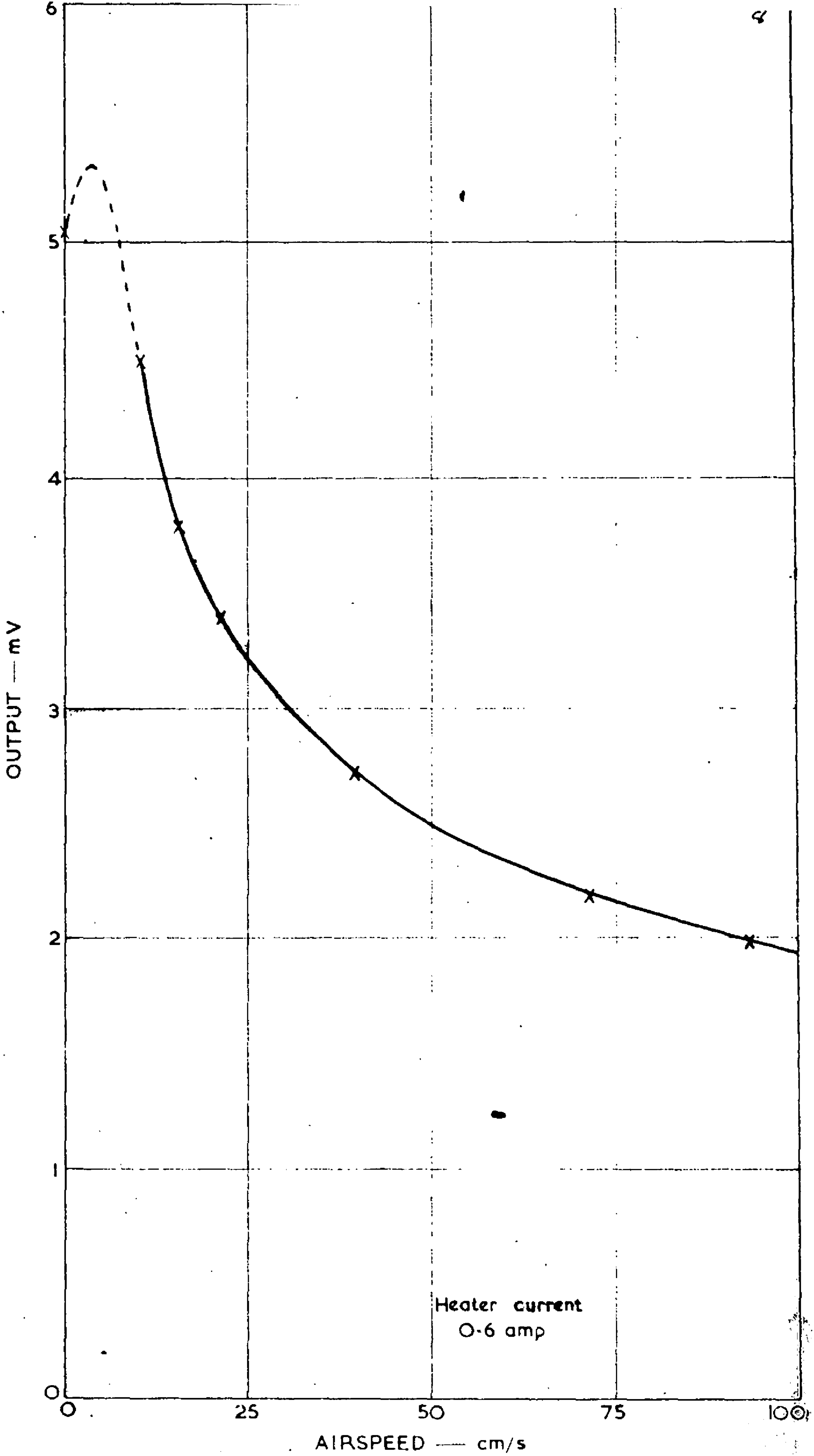

FIG. 3. CALIBRATION CURVE OF COMPENSATED ANEMOMETER