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ROYAL AIRCRAFT ESTABLISHMENT

A TRUE AIR SPEED SENSOR FOR MINIATURE UNMANNED AIRCRAFT

by

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SUMMARY

This Memorandum describes the development of a laboratory prototype true air speed sensor for use on unmanned aircraft. The sensor works on vortex shedding principles and has a digital output. The vortices are sensed by thick film thermistor elements that are non-critical in the signal circuitry.

This Technical Memorandum is based on a paper presented by the author to the 3rd European Hybrid Microelectronics Conference at Avignon, France, 20-22 May 1981.

This Memorandum expresses the opinions of the author and does not necessarily represent the official view of the Royal Aircraft Establishment.

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1 INTRODUCTION

The basic tenet of unmanned aircraft (UMA) is for a low cost system to be used in large numbers. One result of applying this to the navigation of the UMA, is the proposal for a microprocessor based navigator that correlates the data from a number of low grade sensors to produce an adequate overall system response and accuracy.

One such sensor, used in a dead reckoning navigation system, is the true air speed sensor.

2 THE AIR SPEED SENSOR

An air vehicle is normally flown using 'indicated' air speed. This is a parameter that varies with the temperature, pressure, and to a lesser extent humidity, of the air; as does the performance of the air vehicles lifting surfaces.

The navigation function requires that the measure of the air vehicles movement through an airmass be independent of these variables, and the parameter is known as true air speed.

3 SENSOR DESIGN

The sensor chosen for this application is a vortex shedding device.

A bluff body with end plates produces a stable 'street' of vortices alternately from the edges of the body, Fig 1. The frequency of production of these vortices is directly proportional to the speed of the fluid past the bluff body.

The frequency of production is given by $f = sv/d$

where s is the strouhal number of the sensor
v is the velocity of the fluid
d is the diameter the bluff body presents to the fluid stream.

The strouhal number is a function of the Reynolds number for the sensor, but over a wide range of Reynolds numbers (200-800000) is a constant, Fig 2.

Following Cousins, Foster and Johnson, a triangular bluff body was used. It was placed base forward, across the flow through a circular sensor body of 25 mm diameter. The bluff body has a base width of 0.3 the body diameter and a base to apex ratio of 1.33, Fig 3. This gives a bluffness coefficient 1.4 x that of a circular cylinder and a strouhal number of 0.28 and a gauge factor of 46.7 Hz $m^{-1} s^{-1}$.

4 THERMISTOR DESIGN

The detection of the vortices is made using a pair of self heated thermistors. A printed thick film thermistor was used for cheapness, robustness, and ease of handling.

The thermistors were fabricated on Coors 96% alumina substrates of 0.254 mm thickness with 'as fired' surface. Termination prints were made along two sides using Electro Science Laboratories 9633b palladium silver. The termination was fired for 10 min at 850°C.

The thermistor element was a double print of Electro Science Laboratories NTC 2413, a nominal 1 kΩ per square ink at 25°C with a TCR of approximately -5700 ppm/°C. It was fired at a peak temperature of 930°C with a profile time of 46 min, Fig 4.

The substrates were then cut into 2 mm wide strips (thinner strips are envisaged for further prototypes, 2 mm was chosen for ease of handling for a first attempt), and fine enamelled copper wire attached to the terminal pads by hand soldering with 60/40 lead tin solder.

The resulting devices had an average room temperature resistance of 1.35 kΩ per square, Fig 5.

5 ASSEMBLY AND ELECTRONICS

Two thermistors were mounted either side of an SRBP mounting rod such that they were positioned approximately 1 tube diameter behind the buff body and 0.6 x the bluff body diameter from the centreline of the tube, Fig 3.

The electronics is very simple, the thermistors from the lower two arms of a wheatstone bridge fed from a simply stabilised power supply. Since the vortices are produced from alternate sides of the bluff body, they cool the thermistors alternately, producing an alternating imbalance of the bridge. Thus a capacitive coupling can be used, obviating the need for matched devices and bridge balancing.

The ac coupled signal is amplified through a comparator, band-pass filtered, amplified and peak detected. The frequency of the resulting square wave is a function of the speed of the air through the sensor, Fig 6.

6 RESULTS

Laboratory tests have been made on a prototype sensor which show an excellent linearity of response of over the limited range of air speeds available, Fig 7. Some optimisation has still to be done in both the geometry of the sensor and the signal processing electronics, but sufficient confidence was gained from the laboratory tests to recommend that further work be undertaken.

7 CONCLUSIONS

The use of thick film thermistors has successfully been demonstrated for the detection of vortices in a simple true air speed sensor for UMA applications.

The sensor has a directly digital output and is simple to construct and set-up, requiring no careful matching of sensors or zeroing of the detector bridge.

Acknowledgments

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2	P. Moran	Private communication.
3	J. Taylor	Private communication.
4	S.J. Stein	Improved NTC-thermistor thick film coatings. Paper presented at Hybrid Micro-Electronics Symposium, Dallas, Texas (1969)
5	R.F. Colton	Vortex anemometry. New application of an old principle. 20th International Instrumentation Symposium, 21-23 May 1974, Albuquerque, New Mexico

Fig 1 'Karman street' of vortices

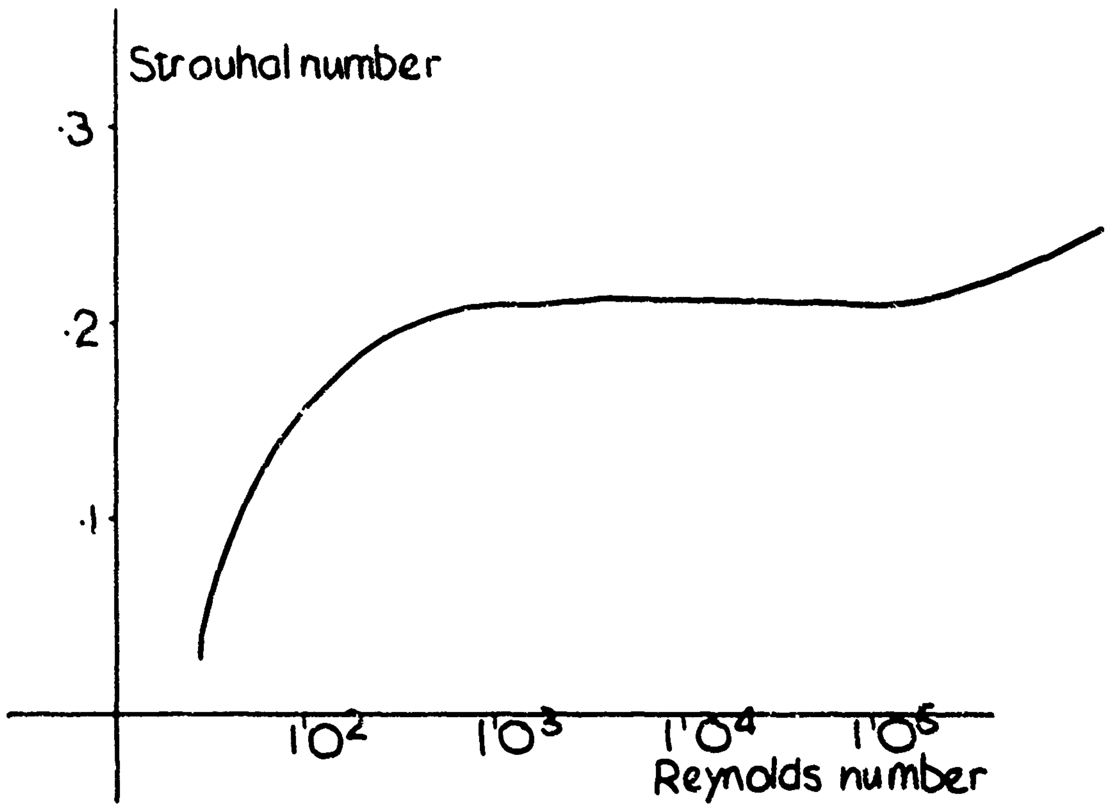

Fig 2 Strouhal number

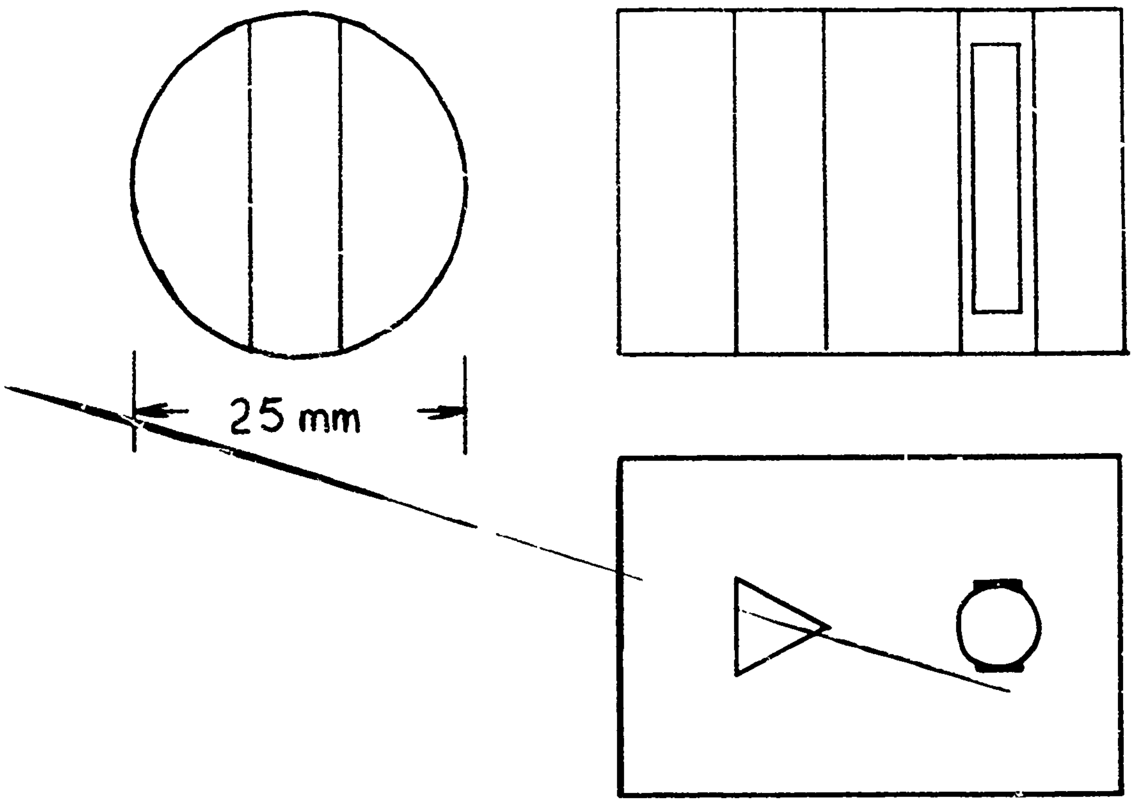

Fig 3 Sensor construction

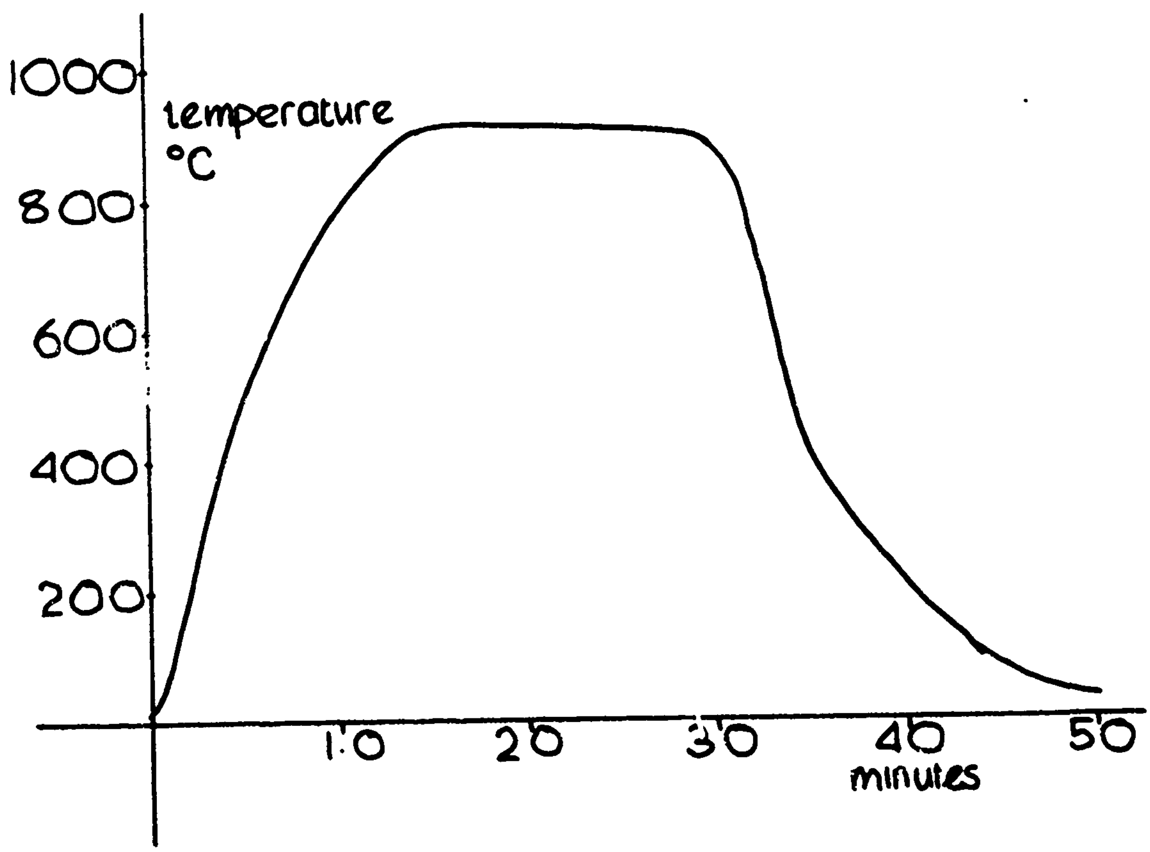

Fig 4 Firing nrofile

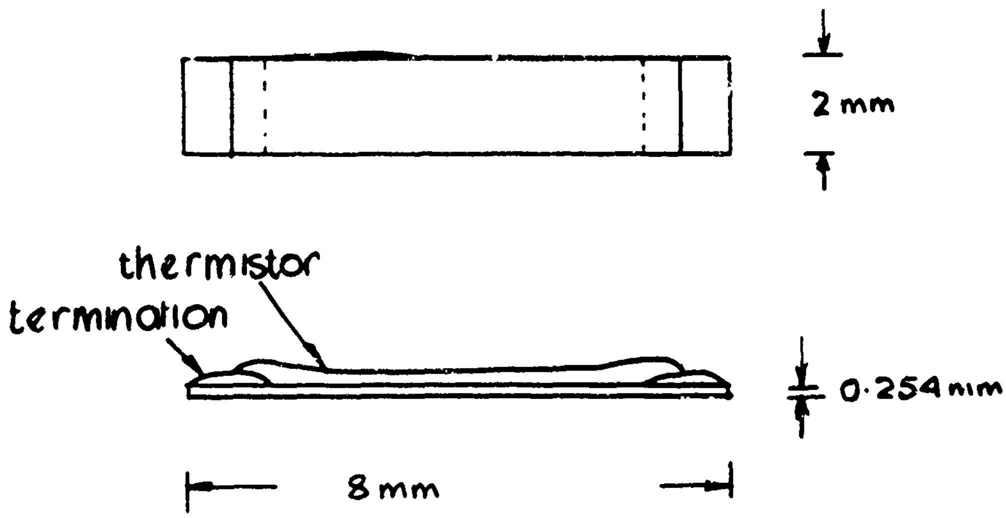

Fig 5 Thick film thermistor sensor

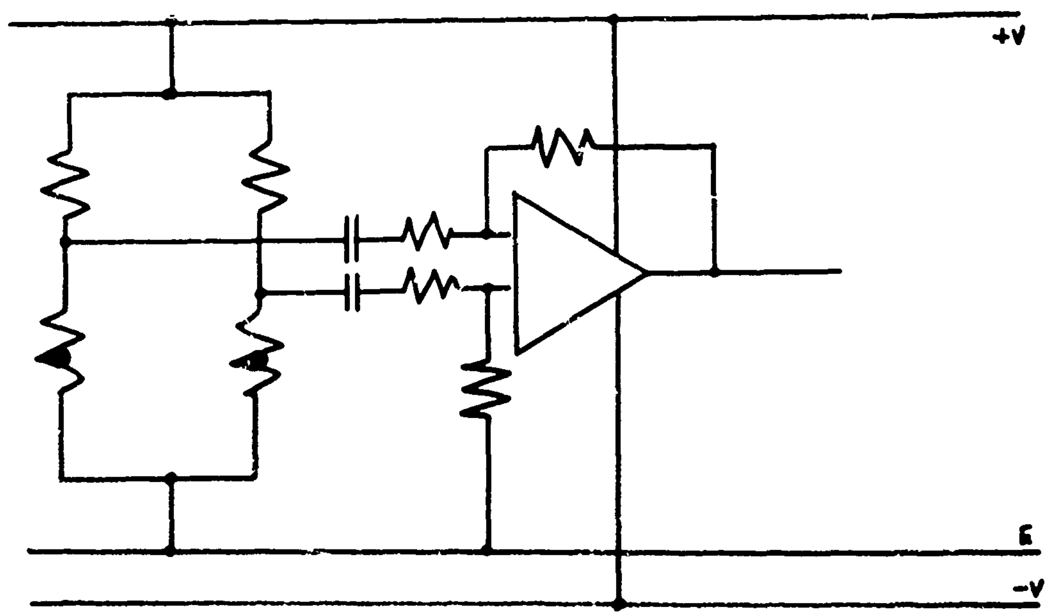

Fig 6 Circuit schematic

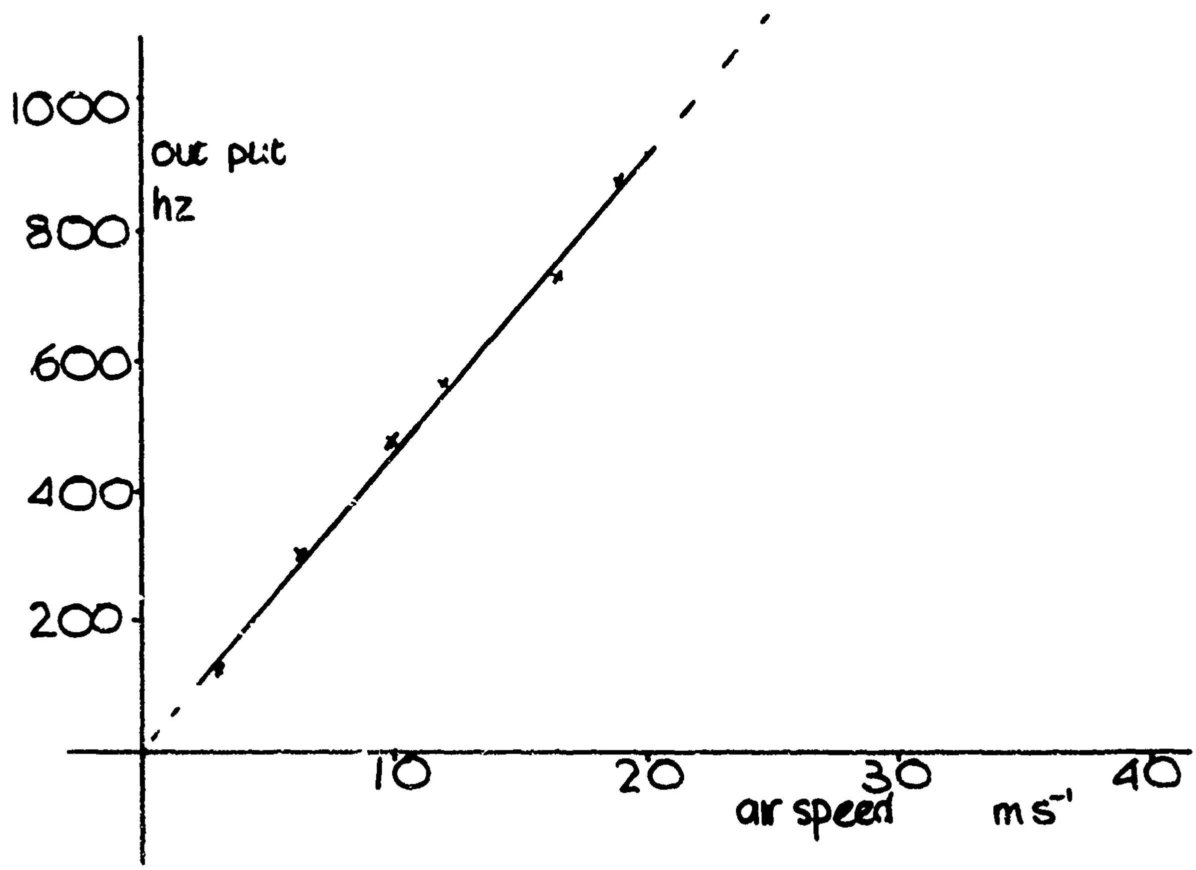

Fig 7 Sensor calibration

REPORT DOCUMENTATION PAGE

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17. Abstract

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