MORU Cardington Technical Note No. 6

An evaluation of "humicap" sensors for use on balloon-borne turbulence probes

by

M.J.Brettle

1 September 1992

Met. Office Research Unit
RAF Cardington
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Beds, MK42 0TH

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Note

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1 Introduction

This report summarises the evaluation of Vaisala "Humicap" relative humidity sensors (Type HMM30D) for use with turbulence probes operated by MORU Cardington. The turbulence probes are balloon borne and operate over the following approximate range of atmospheric variables

Temperature	0°C to 30°C
Relative Humidity (RH)	30% to 100% (inc. flights into cloud)
Pressure	1050mb to 700mb.

The main advantages sought from "Humicap" sensors were logistic - ie. eliminating the need for regular wetting and changing of wicks on the wet-bulb thermistors previously used. It was also important that the "Humicap" sensors should be robust and able to survive wetting in cloud and the accuracy and frequency response should also be at least as good as that from the wet and dry bulb thermistors.

The sensors are to be used in housings based on those previously used for wet and dry thermistors. These have been wind-tunnel tested to ensure that the sensors are clear of stagnant air in any possible orientation of the probe in flight and designed to shield the sensors from solar-radiation. A still air flow rate of $2ms^{-1}$ is produced by a fan. The sensors are modified as in Fig. 1 before use on turbulence probes.

2 Resistance to Wetting

On 8.3.90 and 13.3.90 a garden spray gun was used to produce a fine spray of water droplets onto a "Humicap" sensor. Droplets with a diameter of approximately $\frac{1}{4}$mm collected on the surface. The sensor gave a high output (90 - 100% RH in air at room temperature with a RH of about 40%) until all visible droplets had evaporated. Then the sensor output rapidly returned to an accurate value. Total recovery time was about 4 minutes in an airstream of about $1ms^{-1}$ with the sensor perpendicular to the flow and about $3\frac{1}{2}$ minutes with the sensor in line. The sensor is always mounted in line with the airflow for use with turbulence probes.

The sensor used in the above tests was also used with probe 5 for the following 18 months with no sign of damage despite 10 successive "wettings" with the spray gun and other tests involving wetting the sensors.

On the 8.11.90, during a test flight, excessively high RH values were given by a probe with a "Humicap" sensor after flying through cloud.

Subsequent tests showed that water drops could form in the area between the metal legs holding the sensor surface and on the end of the sensor. These "water bridges" caused erroneous high humidity to be recorded. Fig. 2 shows the location of these water bridges. Bridge 1 could not form with the sensor mounted legs down and this orientation was subsequently used on all installations. The legs of the sensor and the solder attaching them to the sensor were covered with epoxy to seal them. Flights into cloud on the 6.3.91 and subsequent tests showed that the sensors could now rapidly recover from wetting in cloud. A flight into cloud on the 7.1.92 with 3 sensors unprotected by epoxy produced fixed, high, relative humidity readings which persisted when the probes were moved into dry air.

It is worth noting that problems also occurred with dry thermistors accumulating water droplets and giving effective 'wet-bulb' values.

It is clear that the "Humicap" sensor, if suitably modified can perform reliably after being wet by flight in cloud.

3 Resistance to Electrical Interference

There has been no direct evidence of any problems with the "Humicap" sensors being susceptible to electromagnetic interference or causing interference to other equipment.

However when a unit was first installed in a housing for use with probe 5 serious errors were noted on several occasions but only when the probe was flying at about 300 metres. The trace for the flight on 14th May 1990, Fig. 3, is typical of the very large RH values produced.

The GRP box used to house the sensor electronics had not been sprayed internally with conductive paint as is normal practice. As soon as this was done the problem disappeared and the "Humicap" gave good results at all heights. The form of the interference and where and how it affected the probe system remain unknown.

4 Temperature Sensitivity

The "Humicap" sensor shows a significant response to temperature. The difference in calibration between 5 and 25°C is up to 8% RH. The largest difference may occur at either high or low RH values.

Temperature sensitivity varies from one sensor to another with some showing none measurable. Others show temperature sensitivity for both calibration gradient and offset.

Calibrations carried out at fixed temperatures produce good straight line (first order) fits (standard deviations less than 1% RH). Therefore, for use during experimental periods, "Humicap" sensors are calibrated at about 5°C and again at about 25°C. These calibrations enable straight line coefficients at 0°C to be calculated along with temperature coefficients for calibration gradients and offset. All this information is then incorporated in probe calibration datasets.

It is assumed that the variation of these coefficients with temperature, at least over the range of temperatures of interest, is linear. A calibration of the "Humicap" sensors in probes 5 and 12 on 30.7.91 and on probes 5 (new sensor) and 10 on 13.4.92 at 15°C which produced results closely half way between those at 5°C and 25°C confirm this.

5 Accuracy

Since "Humicaps" used at MORU Cardington are always calibrated before use accuracy is dependent on calibration and sensor repeatability rather than accuracy as supplied by the manufacturer. The accuracy of the "Humicap" sensors, in use with turbulence probes, is required to be at least as good as that of the wet and dry thermistors they replace. The parameter ultimately of interest is humidity mixing ratio (ie. gms of water per kg of dry air). Neither system measures this directly.

A possible error in the wet and dry bulbs of $\pm 0 \cdot 1$°C (probably optimistic) is equivalent to an error in RH of between 1 and 3% over the range of temperatures and mixing ratios of interest (see Table 1). There is some evidence to suggest that "Humicap" sensors are achieving this level of accuracy:-

1. Standard deviations of straight line fits to calibration data points are of the order of 1% RH or less at temperatures of 5°C and 25°C covering RH values from 50 to 95%.

2. Calibrations before and after the Vale of Evesham experiment in 1991 showed drifts generally less than 1% RH over the range of interest over a period of about 16 weeks (drift and accuracy are obviously not the same thing but the low drift measured in this case does imply good repeatability and therefore accuracy).

3. During intercomparison flights at Cardington, when probes are flown within a few metres of each other, the standard deviation between probe RH values is about 1%

for 10 minute means at fixed levels. At present this only applies to temperatures below 15°C and RH above 60% as no flights with many "Humicap" sensors have been made at warmer temperatures or lower RH.

"Humicap" sensors are calibrated against a Michell 3020, cooled mirror dew point hygrometer and absolute accuracy (as opposed to relative accuracy, repeatability or consistency between sensors) is dependent on the stability of this instrument. This is likely to be very good as it measures dewpoint (hence mixing ratio) directly and has an up to date NAMAS approved calibration.

6 Drift

"Humicap" sensor calibrations do show noticeable drift in gradient and offset and also in temperature coefficients. The "Humicap" in probe 5 between 6.3.90 and 31.1.91 drifted by about $3\frac{1}{2}$% at 60% RH and 6°C. The temperature sensitivity was also reduced from about ·2% per 0°C to about ·1% per °C over the same period. However calibrations before and after the Vale of Evesham experiment in 1991 of 3 sensors showed drift less than 1%. Therefore a policy of calibrating "Humicap" sensors before and after experimental periods will be enough to ensure that calibrations are always sufficiently up to date and accurate for scientific use.

7 Frequency Response

This has been measured in two independent ways, laboratory tests and field trials.

Laboratory tests involved using the sensor in a probe housing. This was positioned to draw air from an environmental chamber at room temperature but at a much higher RH. The probe is then rapidly moved to give the sensor an effective step-change in RH. By monitoring the output on a storage oscilloscope it is possible to estimate the time taken until (e-1)/e of the change in "Humicap" output has occurred. This gives the time constant directly assuming a response of the form Output = Constant x exp (-t/T) where t is time in seconds and T the required time constant.

This is a simple, accurate, procedure but it only allows a measurement of the response to a step fall in RH at room temperature. Four tests of this type produced time constants of between 1 and 2 seconds.

It is possible to estimate the frequency response by examining humidity spectra taken during actual flights and making simple assumptions about the real atmosphere. In practice the measured response appears to be limited by noise in the probe system (which also effects other data channels) rather than the "Humicap" itself.

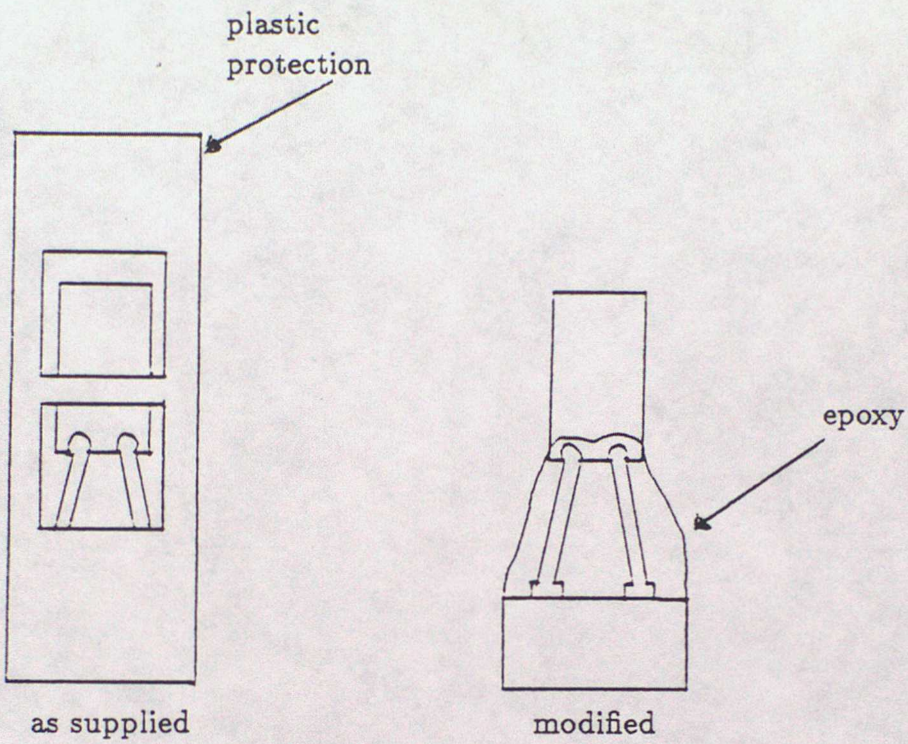
However, spectra from 5 flights covering temperature from 4°C to 22°C and RH from 60% to 90% indicate that the "Humicap" in actual use responds down to a period of 8 seconds or less, shorter period fluctuations are contaminated by noise.

On three occasions probes with "Humicap" sensors have been operated on a mast mounting near the ground, at 12 metres height. This has enabled spectra to be derived with less noise contamination. These indicate a response down to at least 5 seconds, much nearer the laboratory derived value. This is also similar to the response time of the dry thermistors used on MORU turbulence probes so that the required quantity, humidity mixing ratio, can be measured from a combination of these sensors with a response time of about 5 seconds. Fig. 5 shows a typical Q spectra taken using a "Humicap" equipped probe on a 12m mast.

8 Conclusion

"Humicap" sensors type HMM30D are suitable for use with MORU Cardington turbulence probes. In particular they are robust and resistant to wetting and their response time and accuracy are at least as good as the wet and dry thermistors they are intended to replace. In view of the logistic advantages (no need for wick changing and wetting) the use of "Humicap" sensors will benefit the work of MORU.

Fig. 1.



Modifications to humicap sensor prior to use
with turbulence probes

Fig. 2.

Water "bridges" on Humicap sensor after
flight through cloud on 8.11.90

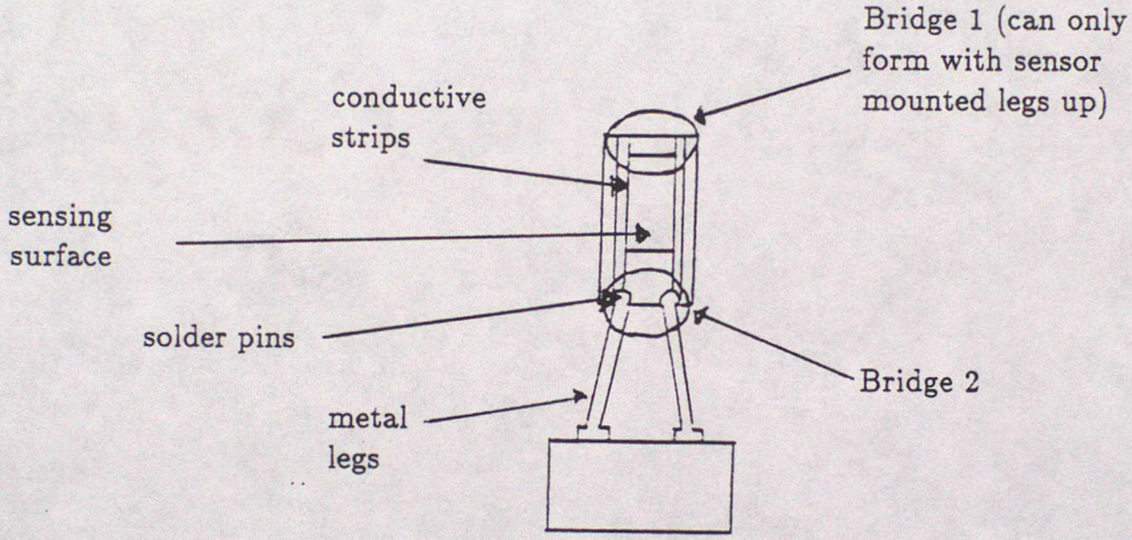
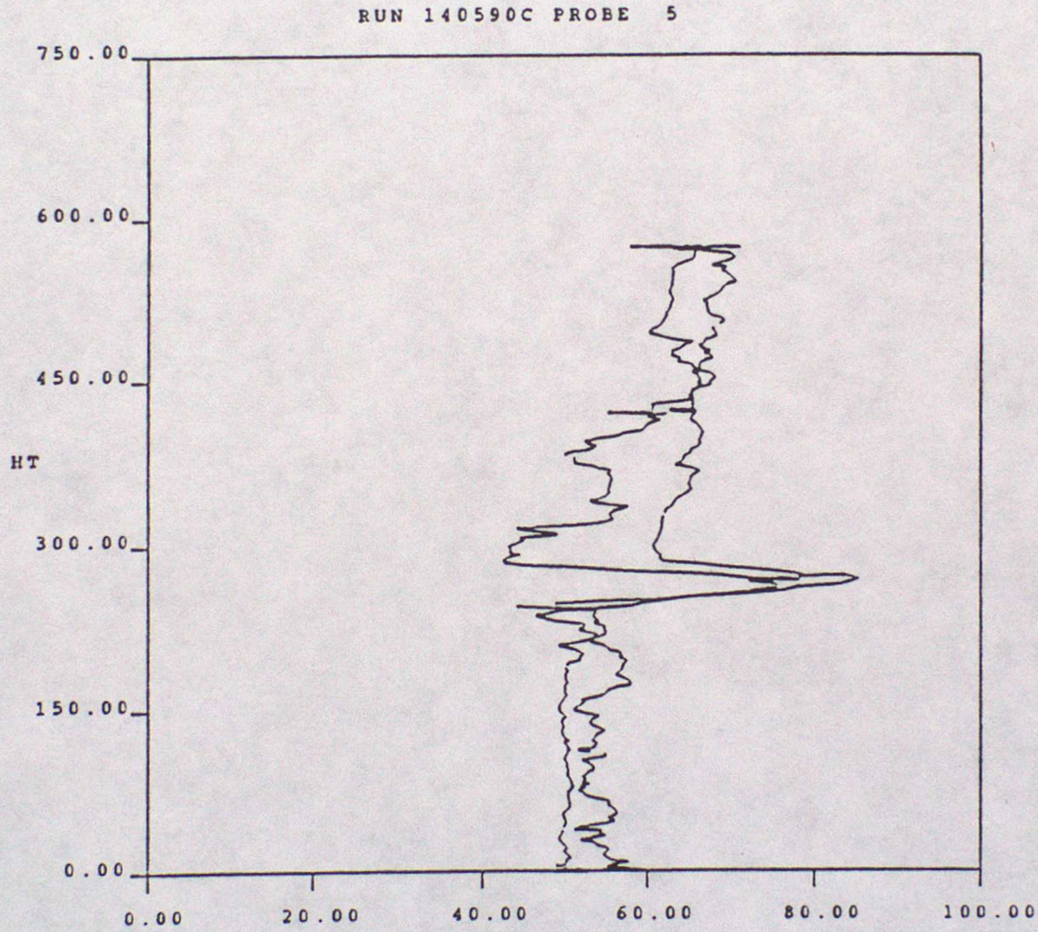


Fig. 3.

Ascent and descent of "Humicap" sensor on probe showing interference problems at 300m.



RH

Fig. 4.

Spectrum of Q variance from "Humicap" on probe mounted on 12m mast. Dotted lines are for variance falling off as $f^{-\frac{5}{3}}$
The spectrum is not normalised and units of Q are gms/kg (dry air).
Data collected on 16.3.92.

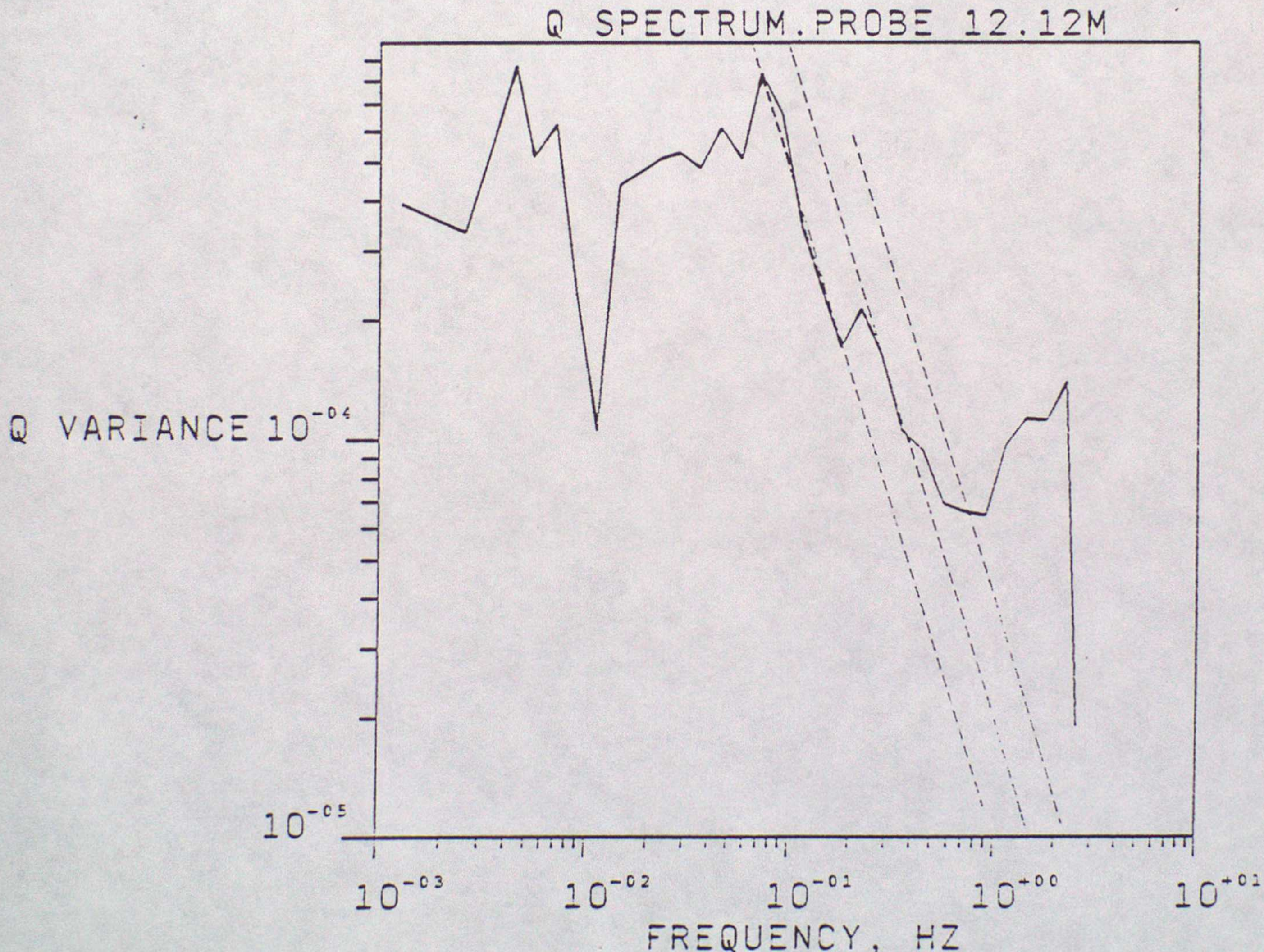


Table 1.

DRY BULB / RH	5°C	15°C	25°C
95%	3·0% (4·7°C) (5·1gm/kg)	2·1% (14·6°C) (10·0gm/kg)	1·6% (24·3°C) (18·5gm/kg)
50%	2·8% (1·5°C) (2·7gm/kg)	1·8% (9·9°C) (5·2gm/kg)	1·3% (18·2°C) (9·7gm/kg)
20%	2·8% (Ice Bulb) (1·1gm/kg)	1·6% (6·4°C) (2·1gm/kg)	1·1% (13·0°C) (3·9gm/kg)

Errors in relative humidity equivalent to an error of $\pm 0 \cdot 1$°C in wet and dry bulb temperatures. Values in brackets are actual wet bulb temperatures and mixing ratios.