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Summary Report on ALMOS A.W.S. Tests

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1. INTRODUCTION

At ALMOS's factory, from the 26 to the 28 of April 1994 a sequence of environmental tests and calibrations were performed by Jane Warne on an ALMOS Automatic Weather Station (AWS) electronics serial number 11. These tests along with early tests in the Physics Laboratory, (from the 7 to the 10 March 1994) were part of the prototype testing of the new AWS electronics.

ALMOS unit 11 was using version 3D of the software and the unit tested in Melbourne was using version 3C.

2. EXPERIMENTAL

The tests included the evaluation of the of the two four wire temperature channels, the digital channels, particularly the rainfall channel and the relative humidity voltage channel. Calibrations of ALMOS's voltage supply and the Bureau of Meteorology decade box serial number 3621 (On loan to ALMOS from the Physics Laboratory) were also performed.

The ALMOS box was tested at 15 temperatures between -10 and 55°C. For temperatures above 25°C the electronics were placed inside ALMOS's water jacket incubation oven; for temperatures between 20 and 0°C a standard commercial refrigerator was used and below 0°C the electronics were placed in ALMOS's commercial freezer. During all tests the door of the electronics box was open a minimum of 5 cm.

A HP3457A precision multimeter was used to monitor all resistance and voltage tests performed in Perth. The uncertainty of resistance measurements[1] and cable resistance was ± 0.003 Ω or ± 0.008 °C and of voltage measurements was ± 10 μV or ± 0.001 %RH.

Calibrations of the decade boxes 3311 and 3621[2] were performed prior to testing the ALMOS electronics. Decade box 3621 was found to have biases of between -0.002 and -0.006 Ω or -0.006 and -0.018 °C. Similarly decade box 3311 had biases between 0.0096 and 0.014 Ω or 0.025 and 0.035 °C. All biases in the decade boxes were taken into account when determining accuracy of the ALMOS electronics. The resultant uncertainty in the resistance sources is ± 0.0002 Ω or ± 0.0004 °C.

A decade box was connected to each four wire resistance channel; decade box 3621 (on long term lone to ALMOS from the Physics Laboratory) to the dry bulb channel and 3311 to the wet bulb channel. For each test condition the decade boxes were set to seven nominal resistance settings between 96.09 and 121.70 Ω and the output of the two channels connected to a laptop PC. The wet and dry bulb values were record along with nominal relative humidity, wind speed, wind direction, battery voltage and rainfall counts. The later had static inputs and the results were treated as a functional test of the electronics.

An ALMOS built voltage supply was used as the voltage reference for testing the relative humidity channel. Once the supply's significant drift in voltage with time was compensated for, the uncertainty in the voltage reference was determined to be less than ± 0.3 mV or ± 0.03 %RH. A six step resistance potentiometer was used to vary the voltage input between 0.09 and 1V, this allowed simulation of relative humilities between 0 and 100%. With the ALMOS AWS electronics under various temperature conditions the voltage input was adjusted and the output of the voltage channel monitored using a laptop PC.

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[1] Uncertainties in this report are quoted as the uncertainty in the mean with a confidence level of 95% unless otherwise stated. It is calculated using the formula U_{95} = Stdev * t_{95} / sqrt (N). Total uncertainty is interpreted as the uncertainty in the data.

[2] Calibration certificate for decade box 3311 is 94/001/R and for decade box 3621 is 94/003/R.

A function generator connected to a reed switch was used as the reference for the rainfall digital channel of the AWS. The function generator was turned on and the number of reed switch closures were counted for a set period of time. At the end of the period the generator was turned off and total number of counts compared to the rainfall recorded by the AWS electronics.

The digital wind channel was tested in Melbourne. A function generator was connected to the wind channel input and the wind speed measured by the AWS was noted.

During evaluation in Melbourne, a number of tests of the systems ability to cope with faulty sensors were performed. The tests were designed to mimic sensors which become open circuit in the field. Decade box 3311 was connected to one of the four wire resistance channels and a 100 Ω standard resistor 1812439 to the other. Systematically, the individual wires were disconnected and the temperature measured by the AWS was monitored.

3. RESULTS AND DISCUSSION

3.1 Resistance Channels

The mean correction for all input resistance for all temperatures is -0.007 ± 0.006°C[3] for the dry bulb channel and -0.018 ± 0.003°C for the wet bulb channel. Examination of the errors for all temperatures and resistance inputs, reveals that 2% of dry bulb and 9% of wet bulb channel measurements were in error by greater than ± 0.05°C. To meet specification A2671[1] no more than 5% of data should have errors greater than ± 0.05°C. Examination of the temperature dependence of the results showed no trend in the corrections however both the wet and dry bulb channels demonstrated an increase in the standard deviation at extreme temperatures, particularly below 5°C.

ALMOS provided the Bureau with basic data on the maximum errors for units 6 to 19. The maximum error is defined as the largest positive and largest negative errors for a unit, for a given input resistance over a variety of test temperatures. Typically for all units tested 3% of dry bulb maximum errors were greater than -0.05°C and 42% were greater than 0.05°C. Similarly, 6% of wet bulb maximum errors were greater than -0.05°C and 40% were greater than 0.05°C. The tests performed at ALMOS showed that Unit 11 was representative of the other units and that the results were comparable with earlier tests of Unit 11 for the wet bulb channel but slightly better for the dry bulb channel.

These maximum errors were translated into an estimate of the minimum number outliers for all measurements. This was calculated by assuming each unit was tested at a number of different temperatures and that the only errors greater than ± 0.05 °C were those which have been identified as maximum or minimum errors. The results of tests of Unit 11 indicate, that there will in fact, be approximately two readings greater than ± 0.05 °C for each maximum or minimum error. This method of estimating the minimum number of outliers indicates that at least 5.4% of dry bulb and 5.5% of wet bulb measurements are in error by greater than ± 0.05°C. Of these outliers 94% and 88% of dry and wet bulb measurements will overestimate the temperature indicating a skewed distribution of errors.

The results of the above tests means that the total uncertainty of the resistance channels are -0.06 to + 0.1 °C to 95% confidence. This result demonstrates that the unit does not conform to specification A2671 [1]; which requires that the AWS be accurate to ± 0.05°C.

Table 3-1 is a summary of the results of the functional test of the AWS electronics to determine how the system would deal with faulty sensors. These tests highlighted a significant problem with the electronics and software design. Disconnecting a wire (indicated in the table by N) caused, under some situations, the AWS to introduce a bias into the faulty channel or more importantly the non-faulty channel. This bias was as much as ± 1.8 °C in some tests. The values were reproducible but varied

[3] Uncertainties are quoted as the uncertainty in the mean to 95% confidence unless other wise indicated.

depending on circumstances; for example the state of the auto calibration function or the prior status of the connections. In many cases the auto calibration functions did not activate when the wire was disconnected and if activated when reconnecting the wire resulted in a different bias.

Another problem was identified by adding a small resistance, 5.2 Ω, to each wire in turn to determine the effect of lead resistance on the accuracy of the AWS. This resulted in a bias of -0.31°C in the dry bulb temperature when the resistance is added to the positive voltage wire of the dry bulb channel. No effect was found when the resistance was added to the other wires of the channel.

Theses results are of considerable concern. Failure of a sensor or cable by breakage of a wire is not uncommon. An AWS operating as above will result in significant data errors. These cable failure errors will be difficult to identify from the data on a day to day basis but will impact on the climatological record. Similarly the errors introduced by varying lead resistance are important; ideally the electronics and software of the AWS should be capable of removing the lead resistance from the measurement.

Table 3-1 Faults resulting from disconnection of particular dry bulb channel wires.

The first four columns are the status of the wires, N means not connected, Y means connected. The Dry and Wet columns are the output from the AWS under the given conditions. Error means the AWS displayed 99.9; Bias means a value was displayed but was not the correct value for the input resistance; Correct means the expected value was displayed.

V+	S+	S-	V-	Dry	Wet
N	Y	Y	Y	Error	Bias
Y	N	Y	Y	Error	Error or Correct
Y	Y	N	Y	Bias	Correct
Y	Y	Y	N	Bias	Correct
Y	N	Y	N	Error	Bias
N	Y	N	Y	Error	Bias
Y	Y	N	N	Nothing	Correct

3.2 Voltage Channels

All data was adjusted for drift in the voltage supply, once adjusted all the corrections were between -1.5 and 3 mV or -0.15 and 0.3 %RH. The mean correction for all humidity measurement for all temperatures was 0.4 ± 0.3 mV or 0.04 ± 0.03 %RH. The data showed a temperature dependence across the range of temperatures -10 to 55 °C. The dependence varied slightly with the input voltage being linear for 1000 mV or 100 %RH and becoming quadratic in form as the input voltage decreased.

These uncertainties (-0.15 and 0.3 %RH) are significantly greater than the ± 0.1 %RH accuracy specified in section 3.1.3 of Bureau Specification A2671 [1] for relative humidity measurements and would be critical for other low signal voltage sensing devices.

3.3 Digital Channels

Tests of the rainfall digital channel demonstrated that the AWS underestimates the rainfall. This error was partly dependent on rainfall rates, with higher errors normally being associated with higher rainfall rate. Errors were as large as 14 tips out of 60 over a one minute period. This error reduced significantly when messaging was turned off in the software, reducing from 4% to 1%. This indicates that the AWS is not recording pulses when it is sending or receiving messages. The greatest concern about this problem is that it will compound the errors. A similar problem was observed in the wind digital channel. The frequency generator input the equivalent of 19.6 m/s but the AWS recorded the wind as 7 m/s.

4. CONCLUSIONS

a) The performance of the resistance channels of the ALMOS AWS does not meet Bureau Specification A2671 [1] requirement for electrical system accuracy over the full scale range of -10 to 55 °C.

b) No significant temperature dependence was observed in the resistance channels of the AWS.

c) Tests of the ALMOS AWS electronics and software revealed it was unable to deal with faulty sensors and introduced errors into either resistance channel. This is a non-conformance against specification A2671 [1] section 2.1.3.

d) Evaluation of the relative humidity voltage revealed that the voltage channel did not meet the specification requirement of ± 0.1 %RH, having a typical total uncertainty of greater than ± 0.2 %RH and a range of mean corrections between -0.01 and 0.16 %RH. This is partly due to the temperature dependence of the channel.

e) Both the digital channels exhibited a fault of not recording all pulses transmitted by pulsing type sensors. This is a significant fault giving unacceptable errors.

5. RECOMMENDATIONS

a) All the above faults to be rectified by ALMOS.

b) That ALMOS redesign their voltage reference to eliminate the significant drift.

c) That ALMOS revise the test method for the digital channels so that the precision of the testing is greater and faults such as those already identified will be detected in future.

6. REFERENCES

1 Bureau of Meteorology Equipment Specification A2671. (27/3/91)
Provision of a Automatic Weather Station Type I (High Performance Version)