14.3

A NEW LOW MAINTENANCE DEW POINT SENSOR FOR THE NATIONAL WEATHER SERVICE (NWS) AUTOMATED SURFACE OBSERVING SYSTEM (ASOS)

Jennifer M. Dover* and Barbra Childs
Science Applications International Corporation (SAIC), Sterling, Virginia

1. INTRODUCTION

The National Weather Service (NWS) Automated Surface Observing System (ASOS) was deployed in the early 1990's with chilled mirror dew point sensors manufactured by Technical Services Laboratory. At the time of deployment, ASOS had a design goal for periodic maintenance to be conducted at intervals of 90 days. As the number of deployed ASOS's increased through the mid 1990's, it became apparent that the sensors required more frequent mirror cleanings than anticipated, resulting in higher maintenance costs.

In an effort to reduce maintenance costs, and to increase sensor availability, an initiative was generated by the ASOS Product Improvement Program to identify a replacement technology for the chilled mirror dew point sensor. A solicitation was issued in August 1998; commercial-off-the-shelf sensors from competing contractors were tested in the spring of 1999; and the successful contractor, Vaisala Inc., was awarded a development contract for pre-production sensors in February 2000. Sensor development was completed in December 2000, and pre-production sensors were delivered for qualification testing. This paper outlines the pre-production sensor qualification test.

2. TEST APPROACH

2.1 Performance Criteria

The performance requirements for the ASOS dew point sensor include a measurement range from -80°F to +86°F with accuracies based on three ranges of dew point. Accuracies are specified in terms of root mean square error (rmse) and maximum error, and vary from 1.1°F rmse and 2.0°F max error at high dew points and small depressions to 7.9°F rmse and 13.9°F max error at low dew points and large depressions. The maximum temperature and dew point depression capability is specified at 63°F.

2.2 Sensor Description

There was a total of eight sensors; four test sensors, and four comparison sensors. These sensors were tested in a field environment for a period of three months. In addition to the field test performed at Sterling, Virginia, laboratory calibration testing was conducted on the four pre-production test sensors in the temperature/humidity facility at Sterling prior to the test and upon completion of the test.

2.2.1 NWS Model 1088

Two NWS Model 1088 hygrothermometers were used as comparison sensors during this test. This model sensor is one of the two standard hygrothermometers installed on the ASOS. This instrument is a chilled mirror design which uses a temperature-controlled mirror with an imbedded platinum resistance temperature device and electro-optical system to measure dew point temperatures. During this test, the mirrors on these sensors were cleaned weekly to ensure accuracy.

2.2.2 Vaisala HMP243

The HMP243 is a commercial-off-the-shelf (COTS) sensor offered by Vaisala. The sensor is based on a solid state capacitive relative humidity element that incorporates a small heater so that the sensing element is always above the ambient temperature, eliminating the formation of dew. The sensor reports directly in dew point through a calculation based on measured relative humidity (RH) and the measured temperature of the heated capacitive element.

Two Vaisala HMP243 COTS dew point sensors were assessed as part of the technical proposal evaluation for the dew point replacement solicitation. This sensor performed very well during the assessment, and was proposed by Vaisala as the basis for development of the pre-production sensors (Model DTS1). These sensors were used for comparative purposes to ensure that the DTS1 was as good as, or better than, the COTS sensors.

2.2.3 Vaisala DTS1

The DTS1 was developed to meet the requirements of NWS Specification H300-SP1000. The design is based on the existing Vaisala commercial sensor HMP243 with modifications to meet the requirements of the NWS specification. Changes include a stainless steel hermetically sealed probe, the latest Humicap 180 RH sensor, re-designed probe interface electronics, and an extensive built-in-test (BIT) capability for maintenance purposes.

* Corresponding author address:
Jennifer Dover,
43741 Weather Service Rd.
Sterling, Virginia 20166
email: jennifer.dover@noaa.gov

3. DATA ANALYSIS

Field test data were analyzed against the ASOS dew point accuracy requirements in two sections: root mean square error (rmse) and maximum error. To compute these statistics, an analysis program was developed. All data analysis was based on five-minute averages of dew point. These statistics were only calculated when the sensor was determined to be fully operational.

Laboratory calibration tests were performed to validate the reporting resolution and accuracy of the Vaisala DTS1 sensor by subjecting the sensing element to a precisely controlled environment. A five-minute average was computed from the reported dew point temperatures. The absolute difference in the five-minute averages between the reference sensors and the test sensor should not have exceeded the rmse for the appropriate dew point and depression categories specified by the ASOS specification. Laboratory calibration tests were conducted at the beginning and at the end of the field test period.

In addition to the field test and laboratory calibration tests, the sensors were also monitored for any failures reported by the BIT diagnostics. The data files were reviewed on a daily basis to verify complete data sets for all sensors under test. Occurrences of erroneous data were investigated immediately to ensure a valid test.

4. RESULTS

4.1 Field Test Statistical Analysis

Table 1 summarizes the results of the statistical analysis when 1088 #451 and 1088 #592 were within ± 1°F of each other.

These results show that the Vaisala DTS1 compares more favorably to the 1088s than the older HMP-243 COTS sensors. The COTS sensors were operated in a field environment for eighteen months prior to the start of this test. During the test, their performance declined to where they were reporting 2 to 4°F lower than the 1088s and the new DTS1 pre-production sensors, especially at higher temperatures near saturation. Vaisala recommends annual recalibrations, but the COTS sensors were part of a long term test to develop data sets for making judgements on required recalibration intervals.

			rmse		Maximum Error	
		Vaisala Sensors	number of categories	% time sensor met rmse specification	number of minutes	% time sensor met maximum error specification
Test Sensor vs. Reference Sensor						
vs. 1088 #451	DTS1	#6	223	99.6	111,766	99.9
		#9	224	99.6	114,868	99.9
		#10	211	99.5	99,134	99.9
		#12	215	99.5	100,110	99.9
	HMP-243 (COTS)	#33	224	79.9	114,886	96.1
		#34	224	81.7	114,886	97.9
vs. 1088 #592	DTS1	#6	226	99.1	112,058	99.9
		#9	227	99.1	115,161	99.9
		#10	215	99.1	99,432	99.9
		#12	219	99.1	100,120	99.9
	HMP-243 (COTS)	#33	227	93.8	115,179	98.8
		#34	227	96.0	115,179	99.1

Table 1 Statistics for rmse and maximum errors

Sensor Precision					
		rmse		Maximum Error	
		number of categories	% time sensor met rmse specification	number of minutes	% time sensor met maximum error specification
Reference	1088 #451 vs. 1088 #592	224	100	114,876	100
DTS1	V#6 vs. V#9	198	100	88,342	100
	V#6 vs. V#10	173	100	74,910	100
	V#6 vs. V#12	178	100	79,405	100
	V#9 vs. V#10	181	100	77,384	100
	V#9 vs. V#12	177	100	81,710	100
	V#10 vs. V#12	163	100	70,120	100
HMP-243	V#33 vs. V#34	196	99.5	91,267	100

Table 2 Sensor Precision

Table 2 summarizes the statistical results computed for sensor functional precision, defined as the ability of collocated, like sensors to measure the same quantity accurately**.**

Sensor precision was outstanding for all sensors.

4.2 Laboratory Analysis

4.2.1 Pre-Test Calibration Check

Figure 1 displays the laboratory calibration checks for Vaisala DTS1 sensors number 006 and 010 that were installed in the field for the duration of the test. These results show performance before the start of the test. The error bands depicted on the Figures are based on rmse limits.

The results show the sensors met rmse specification 100% before the test. Vaisala DTS1 sensors number 009 and 012 also met rmse specification 100% before the test.

4.2.2 Post-Test Calibration Check

Laboratory calibration checks for all four Vaisala DTS1 sensors were performed at the conclusion of the test. Vaisala 6 & 10 were subjected to two rounds of testing, the first with original firmware v.0.10 (Figure 2) and the second with modified firmware version v.0.21 (Figure 3).

V.0.21 was released to correct two deficiencies discovered during the test. The first was a dew point oscillation exhibited on one sensor during laboratory calibration checks around a very narrow temperature range near -30° F. Vaisala was able to replicate the problem and introduced a fix to disable the probe heater current for several milliseconds during a probe capacitance measurement.

The second deficiency was an erroneous report of an enclosure heater failure that was traced to a coding error in the heater diagnostic algorithm.

When comparing the two firmware versions, there were no differences in results. Figures 2 and 3 show that DTS1 sensor number 006 met rmse specifications 100% of the time and DTS1 sensor 010 met the specifications 94% of the time. Vaisala DTS1 sensors number 009 and 012 met the specifications 94% of the time as well. The sensors did not meet the rmse specifications at the highest reportable dew point near saturation. All three sensors reported near the accuracy limit, exceeding the rmse by a maximum of 0.1°F, approaching the measurement uncertainty of the lab, which is ± 0.18°F.

5. CONCLUSIONS

The results from this test show that the pre-production Vaisala DTS1 sensors met the ASOS specification for rmse and maximum error more than 99% of the time. Sensor functional precision was outstanding, indicating a solid design with very good sensor-to-sensor consistency.

In laboratory testing, the pre-production sensors met the ASOS specification 100% of the time when tested against a limited set of data points before the test started. At the conclusion of the test, one of the DTS1 sensors met the ASOS specification 100% of the time. The remaining three sensors met the specification 94% of the time.

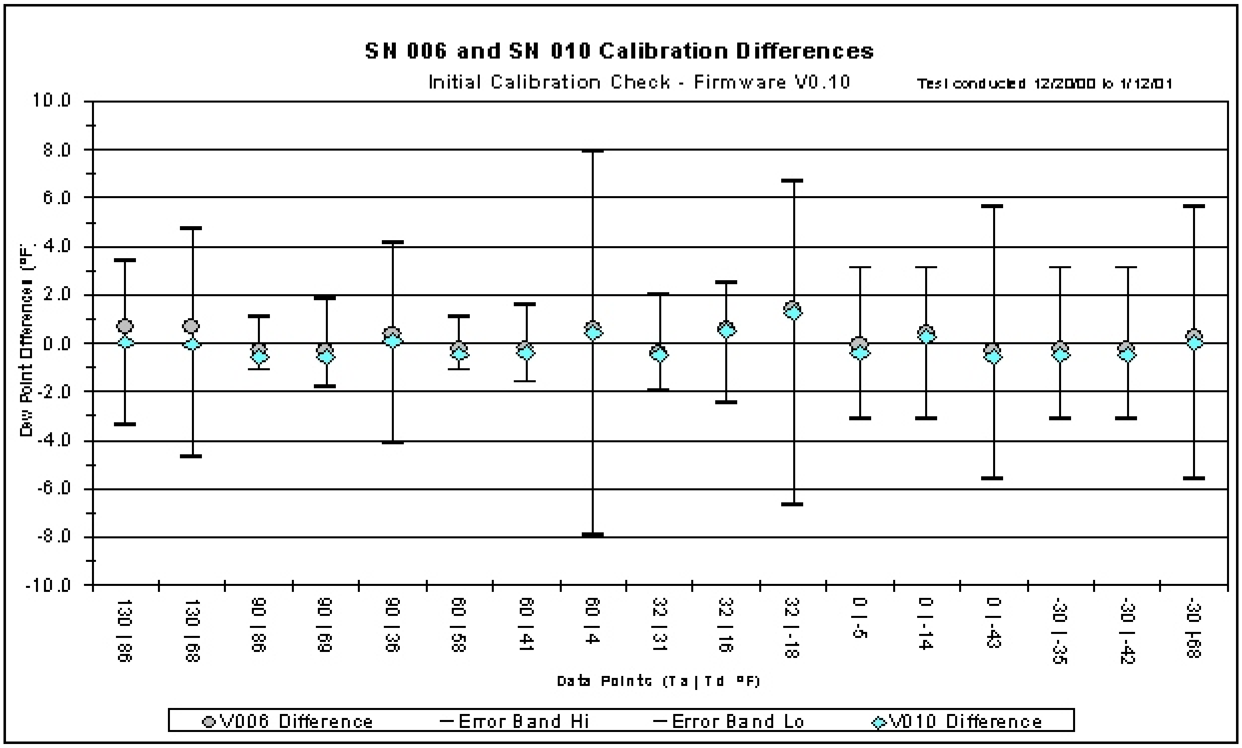

Figure 1 **Initial Calibration Test Results for Sensor #006 and #010**

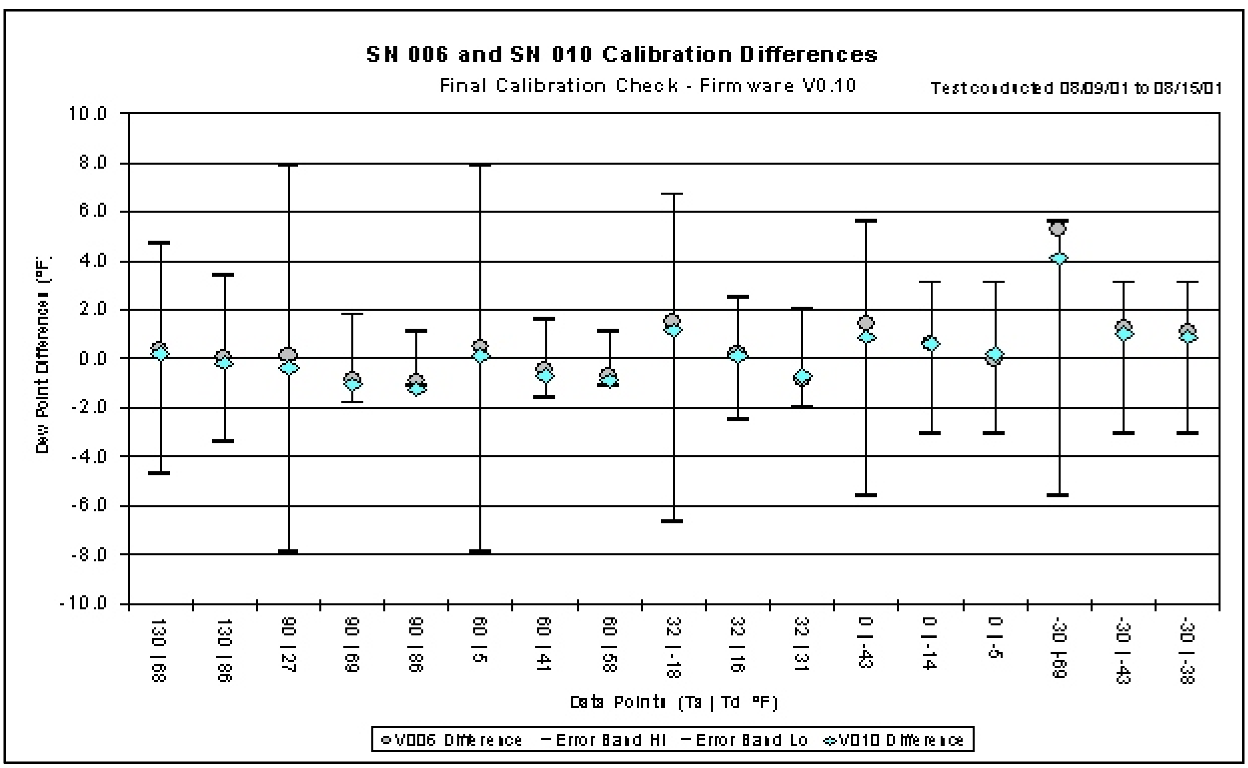

Figure 2 **Final Calibration Test Results for Sensor #006 and #010, V0.10**

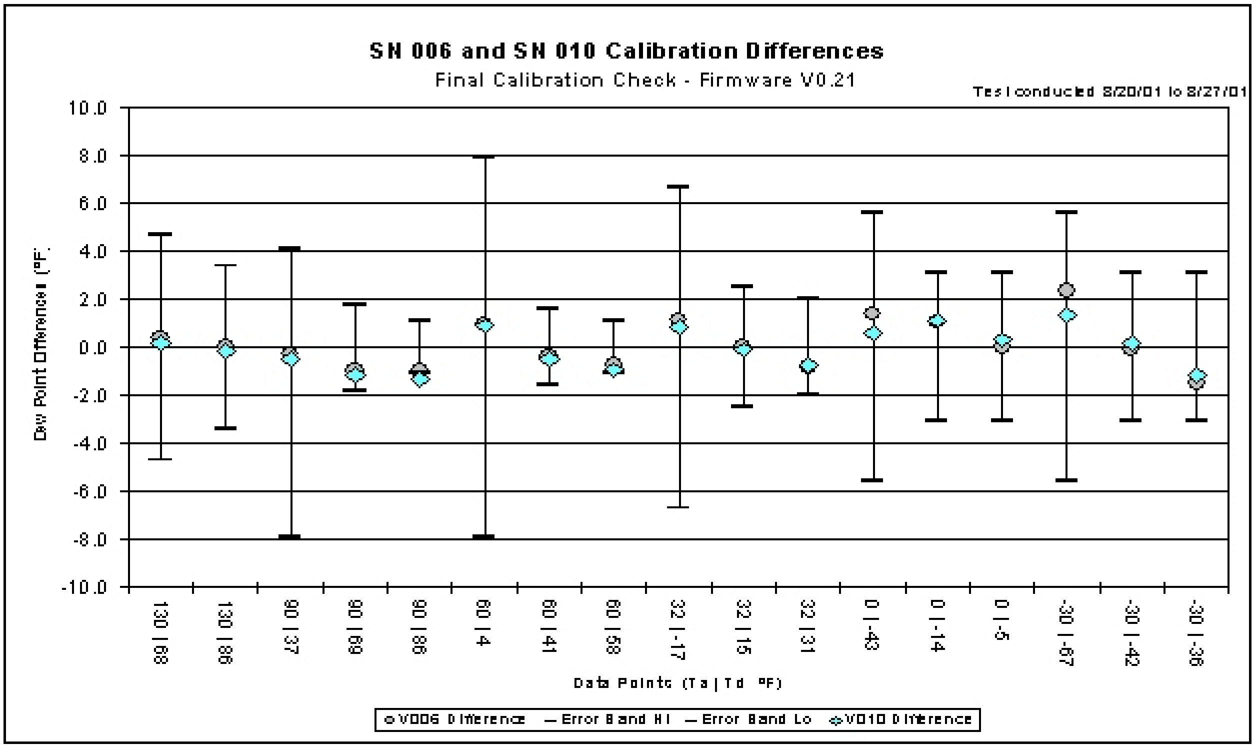

Figure 3 Final Calibration Test Results for Sensor #006 and #010, V0.21

6. REFERENCES

Raytheon ITSS, 2001: Test Report for Automated Surface Observing System (ASOS) Pre-Production Dew Point Sensor Qualification, January 2001-March 2001.

7. ACKNOWLEDGMENT

This work was sponsored by the National Weather Service ASOS Program under Contract Number 50-DGNW-6-90001. Opinions expressed in this paper are those of the authors, and do not necessarily represent an official position or endorsement by the United States Government.