8.3 WINTER TEST OF PRODUCTION ALL-WEATHER PRECIPITATION ACCUMULATION GAUGE FOR ASOS 2003 – 2004

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1. INTRODUCTION

The Frise heated tipping bucket (HTB) is the standard liquid precipitation accumulation gauge used with the Automated Surface Observing System (ASOS). The sensor measures liquid accumulation, but is not specifically designed to accurately measure freezing or frozen precipitation. The accurate measurement of liquid equivalent accumulations in all types of liquid, solid, and mixed precipitation is an important part of weather observations. The National Weather Service (NWS) ASOS Product Improvement team has conducted testing of various all-weather precipitation accumulation gauges (AWPAG) since 1996.

A contract for design and development of ten pre-production gauges was awarded on September 25, 2001, to C.C. Lynch and Associates (CCLA) of Pass Christian, Mississippi, in partnership with Ott Hydrometry of Kempten, Germany. Development testing from January 2002 to October 2003 demonstrated significant improvements in gauge catch, accuracy, increased capacity, and communications. Full production AWPAGs were delivered in October 2003 and included hardware temperature compensation and revised internal sensor algorithm logic to improve gauge sensitivity. Qualification testing of gauges was conducted during the winter of 2003 – 2004, at test sites located in Sterling, Virginia and Johnstown, Pennsylvania. This paper presents the results of the production qualification testing.

2. TEST APPROACH

The production qualification testing was conducted at the Sterling, Virginia and Johnstown, Pennsylvania test sites. One minute data were collected from all test sensors using a personal computer based data acquisition system (DAS). HTB data were included in the data collection. Data from all ASOS sensors at Sterling and Johnstown were available for use in post-processing. Typical reference weather sensors include the following: freezing rain, visibility, temperature/dew point, wind speed and direction, precipitation, identification, and ceilometer. Additionally, a sonic anemometer was installed at gauge orifice height in proximity to the precipitation gauges to assess wind-induced effects. These reference data were used in post-processing, in determining false precipitation reports from the test gauge, and in case study analyses.

2.1 Performance Requirements

The hydro-meteorological performance requirements for the NWS AWPAG (Specification No. D113-SP001) are summarized as follows:

1. The AWPAG response shall be linear over the entire measurement range, with an accuracy of ±4% or ±0.02 inch, whichever is greater, when compared to a standard National Weather Service 8-inch non-recording precipitation gauge installed at the standard height with a National Weather Service Alter shield. Comparisons were made on hourly accumulations and event accumulations.

2. When compared to the standard National Weather Service 8-inch non-recording gauge described above, the AWPAG shall not false report (report accumulation in the absence of precipitation) more than 0.09 inches for a single, continuous 30-day period. The goal is that there be no false reports.

3. It is recognized that smoothing or filtering algorithms may be required in order to reduce false precipitation reports. If such algorithms are required, the maximum acceptable delay in reporting of precipitation due to filtering shall be five minutes.

2.2 Sensor Description

2.2.1 AWPAG

Three 56-inch capacity production AWPAGs were tested at each site. Two AWPAGs were installed as in Figure 1, a configuration typical at an ASOS site, including mounting on a 3-inch pipe, 18 inches high, with a free standing Tretyakov windshield one inch above the 59-inch orifice height. One of the three AWPAGs was placed inside a small scale Double Fence Intercomparison Reference Shield to determine wind effects.

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Figure 1 Production AWPAG

Initially, the Tretyakov windshield was installed one-half inch above the orifice height, but was raised to a height of one inch towards the end of the testing period to account for blowing and drifting frozen precipitation.

2.2.2 ASOS Heated Tipping Bucket (HTB)

Three standard ASOS HTBs (Figure 2) were used as comparison sensors for this test (two at Sterling and one at Johnstown). The HTB gauges were not used to evaluate measurement accuracy of the AWPAGs, but provided data for assessing improvements to ASOS precipitation measurements as a result of AWPAG deployment. HTB gauge data were also used as an aid to determine false reports. The HTBs were installed with the standard ASOS vinyl windshields one inch above the orifice height.

Figure 2 ASOS Heated Tipping Bucket

2.2.3 NWS 8-inch gauge

Four standard NWS 8-inch non-recording gauges (NWS spec. #D040) were used for reference measurements of all types of precipitation at each test site. For each test site, two of the gauges were designated as hourly references and two as event reference gauges. At Sterling and Johnstown, the orifice height was five feet. Alter windshields (NWS spec. #D410) were installed one inch above the orifice height on all of the reference gauges.

3. DATA ANALYSIS

Data were analyzed on an event-by-event basis and an hour-by-hour basis, and reference gauge data were used to validate each event prior to AWPAG evaluations. The reference gauges were located on opposite sides of the test bed and outward from the test gauges to bracket each test bed to verify uniform spatial distribution of precipitation over the sample area. Data from the reference gauges were compared and a valid event was defined as an event in which the two event reference gauges agreed within the greater of ±4% or ±0.02 inches of each other.

Wind speed data at orifice height in each test bed was used in conjunction with the reference gauge measurements to validate results. Wintry events with wind speeds at orifice height that exceeded approximately 10 knots required scrutiny to eliminate possible contaminated results. For example, if blowing snow was a factor during the event, causing the reference gauge measurements to be non-uniform, the event was not used in the statistical results.

4. RESULTS

4.1 Qualification Test Results

During the winter of 2003-2004, AWPAG hourly totals met the NWS AWPAG reporting requirements 97% of the time, while during the winter of 2002-2003, NWS hourly requirements were met 81% of the time. Note that this is a 16% improvement over the prior year through firmware adjustments performed. A total of 2330 hourly observations were taken, with 1448 of these classified as frozen or mixed precipitation, and 892 classified as liquid precipitation.

Fifty-three (53) events were evaluated in Sterling and forty-seven (47) in Johnstown in the winter 2003-2004 test, comprising a total of 100 AWPAG comparisons. Of these 100 comparisons, 81% of the AWPAG event totals met the NWS AWPAG reporting requirements. The gauges were non-compliant 19% of the time because of under-reporting. Overall, the comparison ASOS HTB gauges met the same requirements for event totals only 60% of the time during the test.

Table 1 summarizes the event results at Sterling and Table 2 summarizes the event results at Johnstown. Hourly results will be presented at the conference.

Sterling Event Comparisons															
	Total			Liquid			Freezing			Frozen			Mixed		
Test Gauge	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%
#705	53	42	79	41	36	88	--	--	--	--	--	--	12	6	50
#704	53	45	85	41	38	93	--	--	--	--	--	--	12	7	58
#706*	53	45	85	41	38	93	--	--	--	--	--	--	12	7	58
Totals:	159	132	83	123	112	91	--	--	--	--	--	--	36	20	55
HTB C1	53	39	74	41	36	88	--	--	--	--	--	--	12	3	25
HTB D3	53	36	68	41	34	83	--	--	--	--	--	--	12	2	17
Totals:	106	75	71	82	70	86	--	--	--	--	--	--	24	5	21

Table 1 Sterling Event Comparison
*Production AWPAG 706 location within Double Fence Intercomparison Reference (DFIR)

Johnstown Event Comparisons															
	Total			Liquid			Freezing			Frozen			Mixed		
Test Gauge	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec. #	%	# of Events	Within Spec #	%
#726	47	42	89	20	19	95	--	--	--	15	14	93	12	9	75
#722	47	36	77	20	19	95	--	--	--	15	9	60	12	8	67
#729*	45**	31	69	18	17	94	--	--	--	15	5	33	12	10	83
Totals:	139	109	78	58	55	95	--	--	--	45	28	62	36	27	75
HTB #995	47	23	49	20	13	65	--	--	--	12	6	50	15	4	27

Table 2 Johnstown Event Comparison
*Production AWPAG #729 located within Double Fence Intercomparison Reference (DFIR)
**Production AWPAG #729 was missing two events due to hardware outage

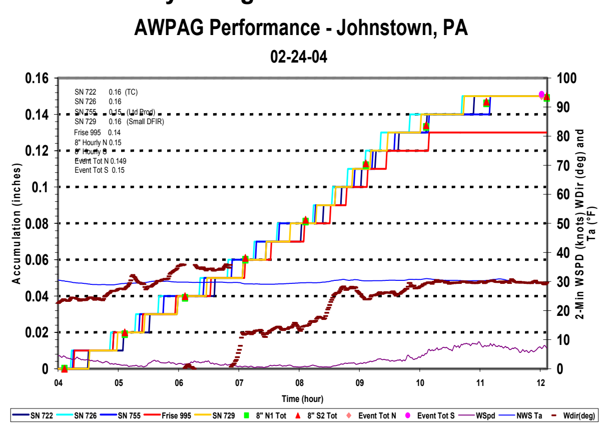
Overall, the AWPAGs at Sterling met the NWS event requirements 83% of the time while the HTB comparison gauges met the same requirements 71% of the time. The AWPAGs and the HTB gauges did not over-report, but failed to meet the event requirements because of under-reporting (ranging from 2.2 to 6.2%). However, the AWPAG compliance was significantly better than the HTB in mixed events by 55% to 21%.

The AWPAGs at Johnstown met the NWS event requirements 78% of the time while the HTB comparison gauge met the same requirements only 49% of the time. The gauges did not over-report, but failed to meet the requirements because of under-reporting (ranging from 2.2 to 6.4%). The AWPAG compliance was better than the HTB in mixed events by 75% to 27%.

5. CASE STUDY

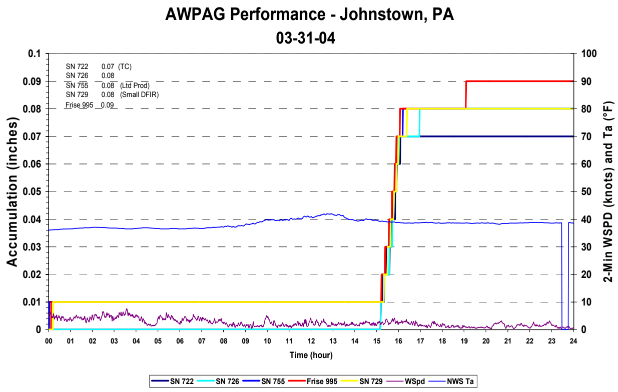
Case study 1 was a light snow and light wind event at Johnstown, Pennsylvania on February 24, 2004.

5.1 Case Study 1 Light Snow Event



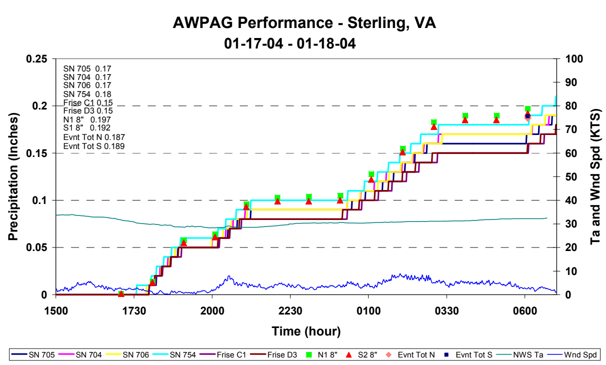
This event shows the comparability between the AWPAG and hourly reference measurements. All production AWPAGs reported a value of 0.16 inches. The HTB (which usually under-reports in frozen precipitation events) had a lower value of 0.14 inches. Also, wind speed steadily increased over the period of this event contributing to the under catch of the HTB in comparison to AWPAG performance. Note that all gauges are within specification (.02 inches or $\pm$4%, whichever is greater) as the manual hourly and event gauges accumulated 0.15 inches.

5.2 Case Study 2 Light Rain Event



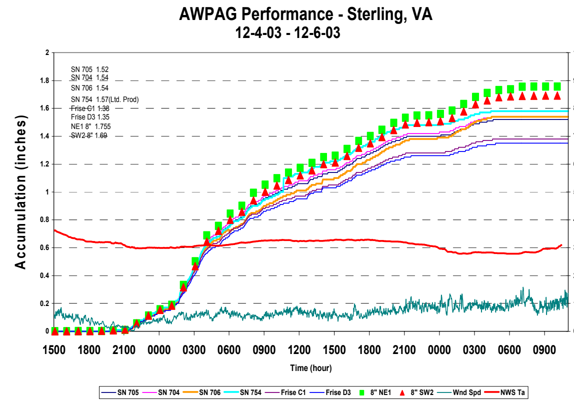
Case study 2 was a light rain / wind event at Johnstown, Pennsylvania on March 31, 2004. All production AWPAGs reported 0.07 to 0.08 in liquid precipitation while the HTB reported about 0.09. Light precipitation was recorded at the beginning of the event along with sustained 6 to 8 knot wind speeds. This possibly was attributed to the recording of an extra “tip” (or .01 inch) nearing the end of the event possibly due to the HTB experiencing oscillation from moderate wind gusts. Manual hourly and event gauge accumulation totals agreed on 0.078 inches. While both AWPAG and HTB were within specification, this event shows the improvement of AWPAG by minimizing the effects of wind with the inclusion of a Tretyakov shield or enclosed within the small scale DFIR.

5.3 Case Study 3 Mixed Precipitation Event



Case study 3 was a mixed precipitation event at Sterling, Virginia from January 17 through January 18, 2004. The progression of precipitation from this event began as rain, progressed to freezing rain/drizzle, snow, back to freezing precipitation, and eventually rain. All production AWPAGs reported an overall amount of 0.17 inches while both HTBs reported 0.15 inches. Manual event gauges reported an overall amount of 0.187 and 0.189 inches. For this event, both HTBs would not have met the event accuracy requirements.

5.4 Case Study 4 Heavy Mixed Precipitation Event



Case study 4 was a heavy mixed precipitation event that lasted from December 4 through December 6, 2003. The precipitation began as rain, changed to freezing rain / drizzle mostly on December 5, and finally changed back to all snow for the remainder of the event. As the event progressed, there was a slow increase in sustained average two-minute wind speed (knots) and subsequent gusts as reported by on-site observers. Manual gauges for this event recorded amounts of 1.545 and 1.56 inches. AWPAG #705 reported an amount of 1.52 inches while #704 and #706 (located within the small scale DFIR) reported 1.54 inches. HTB C1 reported an overall amount of 1.38 while HTB D3 reported 1.35. The HTBs under-reported the entire event by 0.12 to 0.14 inches, or 6 to 8% under specification. The production AWPAGs accumulated from 0.025 to 0.04 inches less for the overall event, but were within the ±4% accuracy requirement.

6. CONCLUSIONS

Production testing at Sterling and Johnstown has shown that the AWPAGs can meet the NWS accuracy requirements for hourly accumulations. Results from the winter of 2003-2004 showed that the AWPAGs met the hourly requirements 97% of the time, an increase of 16% over the previous winter. Further testing will be needed under conditions favorable for frozen precipitation in moderate to heavy winds, to attempt to improve the AWPAGs performance in the future, either by firmware or hardware adjustments.

7. ACKNOWLEDGMENT

The author would like to express the utmost appreciation to Science Applications International Corporation (SAIC), Joseph Fiore and Jennifer Dover for their assistance and support, SAIC personnel Dave Eckberg and Dan Propst for the installation and maintenance of the equipment. The author would also like to thank Jennifer Dover, Aaron Poyer, Stacy White and Robert Wnek for observations that supported the evaluation for this testing period. A special thanks goes to National Weather Service personnel Malcolm D. Gifford, Michael Salyards, and Richard Lewis for consultations.

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.

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