# JP1.11 WINTER TEST OF PRODUCTION ALL-WEATHER PRECIPITATION ACCUMULATION GAUGE FOR ASOS 2005 – 2006

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## 1. INTRODUCTION

The heated tipping bucket (HTB) was the initial precipitation accumulation gauge used when the Automated Surface Observing System (ASOS) was deployed. The HTB 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) awarded a contract for design and development of an All-Weather Precipitation Accumulation Gauge (AWPAG) 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, and increased capacity. Full production AWPAGs were delivered in October 2003 and included hardware temperature compensation and revised internal sensor algorithm logic to improve gauge sensitivity.

## 2. TEST APPROACH

The purpose of the 2005-2006 winter test was to assess various wind shield designs to improve the catch of a standard production AWPAG with Tretyakov wind shield in conditions of wind-driven, dry snow when compared to the NWS field reference gauge, an 8-inch non-recording precipitation gauge (Specification No. D040) with a 4-foot diameter Alter wind shield. Early winter test results indicated an 8-foot diameter Alter-style wind shield surrounding a production AWPAG / Tretyakov configuration equaled or exceeded the catch of the NWS reference gauge. Based on the preliminary results, CCLA/Ott Hydrometry designed and fabricated prototype 8-foot diameter Alter-style wind shields that bolted directly to the existing Tretyakov wind shield mounts. This configuration was the primary focus for the winter 2005-2006 AWPAG compliance test.

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The production qualification testing was conducted at the Johnstown, Pennsylvania test site. One minute data were collected from all test sensors using a personal computer based data acquisition system (DAS). Data from all ASOS sensors at 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. 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 standard 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 $\pm$4% or $\pm$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 are 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 Production AWPAG

Two 56-inch capacity production AWPAGs were tested at Johnstown. Figure 1 depicts an installation of an AWPAG that would be typical at an ASOS site, including mounting on a 3-inch pipe, 18 inches above grade, with a free-standing Tretyakov wind shield one inch above the 59-inch orifice height.

**Figure 1 Production AWPAG**

#### 2.2.2 ATDD 8-foot Diameter Alter Shield – Production AWPAG

Two production AWPAGs were modified with an 8-foot diameter Alter style shield designed by the National Oceanic and Atmospheric Administration's Atmospheric Turbulence and Diffusion Division (NOAA / ATDD) (Figure 2). This configuration was proposed by NWS to further reduce wind speeds around the orifice during wind influenced frozen precipitation events to increase AWPAG catch. The 8-foot Alter style shield is 2-¼ inches above the height of the production AWPAG Tretyakov shield.

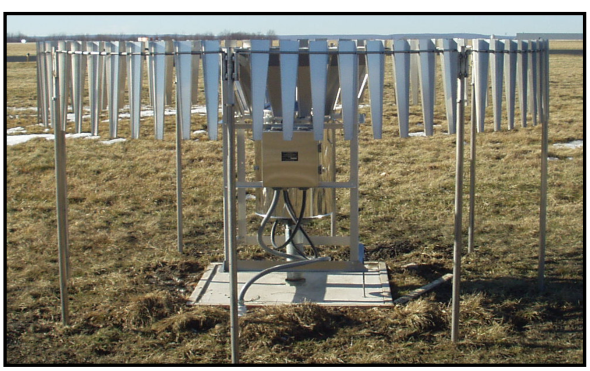

**Figure 2 ATDD Shield – Production AWPAG**

#### 2.2.3 NWS 8-inch Manual Gauge

Four standard NWS 8-inch non-recording gauges were used for reference measurements of all types of precipitation (Figure 3). Two of the gauges were designated as hourly references and two as event references. All manual reference gauges were installed with the orifice height at five feet. Alter-style wind shields were installed one inch above the orifice height on all of the manual gauges.

**Figure 3 NWS 8-inch Manual Gauge**

#### 2.2.4 Production AWPAGs in DFIR

Two production AWPAGs were installed at each test site in a small and large scale Double Fence Intercomparison Reference (DFIR) wind shield (Figure 4). Both DFIRs were built to minimize wind-influenced measurement losses (precipitation under-catch). These sensors were used only for comparison and not qualification.

**Figure 4 Production AWPAG in DFIR (Small DFIR)**

## 3. DATA ANALYSIS

The data were analyzed on an event accumulation basis and an hourly accumulation 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 the test bed to ensure uniform spatial distribution of precipitation over the sample area. Data from the reference gauges were compared to each other, 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.

## 4. RESULTS

### 4.1 Qualification Test Results

Nineteen events were evaluated in Johnstown during the 2005-2006 test. The AWPAG with the 8-foot diameter outer Alter shield met the event requirements in **35** out of **38** events, while the AWPAG with Tretyakov shield met the event requirements **25** out of **38** events. The production AWPAGs under-reported within a range of 0.02 to 0.14 inches.

The hourly results indicated that AWPAGs with 8-foot diameter Alter shield were within NWS accuracy requirements **113** out of **116** hourlies and for the AWPAG with Tretyakov shield, **106** out of **116** hourlies. The amount of hourly under-reporting for production AWPAGs ranged from 0.004 to 0.02 in Johnstown.

Tables 1-4 summarize winter event and hourly results at Johnstown showing an improvement of the production AWPAGs with the 8-foot diameter ATDD Alter shield (AWPAG #715, #298). This is compared to the standard production AWPAG with Tretyakov shield (AWPAG #722, #726), and the standard production AWPAG located within the small and large DFIR (AWPAG #729, #292). The AWPAGs in the small and large DFIR were used only for comparison purposes, not qualification.

Tables 1-4 disregard the upper specification requirement (+0.02 inches, or +4% if greater than 0.5 inches), as the AWPAG with the 8-foot diameter Alter shield had exceeded the upper limit specification multiple times. In practical terms, ignoring the upper limit specification means that an AWPAG with the 8-foot diameter Alter is exceeding the allowed catch when compared to the 8-inch manual reference gauges, but in all cases the catch was less than the DFIR shielded gauges. The 8-foot diameter Alter AWPAGs technically failed the specification requirement by over reporting compared to this standard NWS manual reference gauge, but actually was closer to the ground truth measurements of the DFIR. For this reason, the 8-foot diameter Alter AWPAGs were not penalized for exceeding the upper limit requirements.

| **Johnstown Event Comparisons** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | | **Liquid** | | **Freezing** | | **Frozen** | | **Mixed** | |
| Test Gauge | # of Events | # in Spec. | # of Events | # in Spec. | # of Events | # in Spec. | # of Events | # in Spec. | # of Events | # in Spec. |
| AWPAG #715 (8' Alter) | 19 | 17 | 8 | 8 | - | - | 4 | 4 | 7 | 5 |
| AWPAG #298 (8'Alter) | 19 | 18 | 8 | 8 | - | - | 4 | 3 | 7 | 7 |
| **Totals:** | 38 | 35 | 16 | 16 | - | - | 8 | 7 | 14 | 12 |
| AWPAG #722 | 19 | 12 | 8 | 8 | - | - | 4 | 0 | 7 | 4 |
| AWPAG #726 | 19 | 13 | 8 | 8 | - | - | 4 | 1 | 7 | 4 |
| **Totals:** | 38 | 25 | 16 | 16 | - | - | 8 | 1 | 14 | 8 |

**Table 1 – Johnstown Winter Event Summary**

The number of events that passed the specification improved from **25** to **35** events when comparing the production AWPAG to the AWPAG within the 8-foot diameter Alter shields. The most notable results are in frozen precipitation which resulted in a **6** event improvement between the AWPAGs within the 8-foot diameter Alter shields and the standard production AWPAGs. Mixed precipitation events resulted in a **4** event improvement under the same test comparison.

The 8-foot diameter Alter style AWPAGs still report less than the AWPAGs installed in the international reference wind shields in wind-driven, dry snow events. This is to be expected without an application of a transfer function. The event precipitation catch results with the AWPAG in the 8-foot diameter Alter shields averaged **3.32** inches compared to the standard production AWPAGs averaged **2.98** inches. The AWPAGs with the 8-foot diameter Alter shields come closer to the results of the DFIR AWPAGs. The goal is getting as close to the truth as possible.

**Johnstown Event Precipitation Catch Comparisons**

| | **Total** | | **Liquid** | | **Freezing** | | **Frozen** | | **Mixed** | |
|---|---|---|---|---|---|---|---|---|---|---|
| Test Gauge | # of Events | Total Catch (inches) | # of Events | Total Catch (inches) | # of Events | Total Catch (inches) | # of Events | Total Catch (inches) | # of Events | Total Catch (inches) |
| AWPAG #715 (8' Alter) | 19 | 3.35 | 8 | 1.22 | -- | -- | 4 | 0.49 | 7 | 1.64 |
| AWPAG #298 (8' Alter) | 19 | 3.29 | 8 | 1.23 | -- | -- | 4 | 0.42 | 7 | 1.64 |
| AWPAG #722 | 19 | 2.99 | 8 | 1.22 | -- | -- | 4 | 0.27 | 7 | 1.5 |
| AWPAG #726 | 19 | 2.96 | 8 | 1.19 | -- | -- | 4 | 0.28 | 7 | 1.49 |
| 8" Manual North | 19 | 3.34 | 8 | 1.23 | -- | -- | 4 | 0.45 | 7 | 1.66 |
| 8" Manual South | 19 | 3.36 | 8 | 1.24 | -- | -- | 4 | 0.46 | 7 | 1.66 |
| AWPAG #292 Large DFIR | 19 | 3.69 | 8 | 1.2 | -- | -- | 4 | 0.61 | 7 | 1.88 |
| AWPAG #729 Small DFIR | 19 | 3.55 | 8 | 1.22 | -- | -- | 4 | 0.54 | 7 | 1.79 |

**Table 2 – Johnstown Winter Precipitation Summary**

| Johnstown Hourly Precipitation Catch Comparisons | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | | **Liquid** | | **Freezing** | | **Frozen** | | **Mixed** | |
| Test Gauge | # of Hours | # in Spec. | # of Hours | # in Spec. | # of Hours | # in Spec. | # of Hours | # in Spec. | # of Hours | # in Spec. |
| AWPAG #715 (8' Alter) | 58 | 56 | 20 | 20 | 9 | 9 | 21 | 20 | 8 | 7 |
| AWPAG #298 (8' Alter) | 58 | 57 | 20 | 20 | 9 | 9 | 21 | 20 | 8 | 8 |
| **Totals:** | 116 | 113 | 40 | 40 | 18 | 18 | 42 | 40 | 16 | 15 |
| AWPAG #722 | 58 | 54 | 20 | 19 | 9 | 9 | 21 | 18 | 8 | 8 |
| AWPAG #726 | 58 | 52 | 20 | 19 | 9 | 9 | 21 | 17 | 8 | 7 |
| **Totals:** | 116 | 106 | 40 | 38 | 18 | 18 | 42 | 35 | 16 | 15 |

**Table 3 – Johnstown Winter Hourly Summary**

The 8-foot diameter Alter style AWPAGs technically failed the specification requirement by over reporting compared to this standard NWS manual reference gauge, but actually was closer to the ground truth measurements of the DFIR in wind driven, dry snow events. This is to be expected without an application of a transfer function. There is an overall improvement of **7** hourlies within specification between the AWPAGs within the 8-foot diameter Alter shields and the standard production AWPAGs. The most notable results are in frozen precipitation events which resulted in a **5** hourly improvement between the AWPAGs within the 8-foot diameter Alter shields and the standard production AWPAGs.

| Johnstown Hourly Precipitation Catch Comparisons | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Total** | | **Liquid** | | **Freezing** | | **Frozen** | | **Mixed** | |
| Test Gauge | # of Hours | Total Catch (inches) | # of Hours | Total Catch (inches) | # of Hours | Total Catch (inches) | # of Hours | Total Catch (inches) | # of Hours | Total Catch (inches) |
| AWPAG #715 (8' Alter) | 58 | 3.37 | 20 | 1.54 | 9 | 0.7 | 21 | 0.61 | 8 | 0.52 |
| AWPAG #298 (8' Alter) | 58 | 3.23 | 20 | 1.53 | 9 | 0.64 | 21 | 0.52 | 8 | 0.54 |
| AWPAG #722 | 58 | 2.81 | 20 | 1.47 | 9 | 0.55 | 21 | 0.3 | 8 | 0.49 |
| AWPAG #726 | 58 | 2.83 | 20 | 1.41 | 9 | 0.58 | 21 | 0.35 | 8 | 0.49 |
| 8" Manual North | 58 | 3.22 | 20 | 1.54 | 9 | 0.63 | 21 | 0.49 | 8 | 0.56 |
| 8" Manual South | 58 | 3.24 | 20 | 1.54 | 9 | 0.62 | 21 | 0.53 | 8 | 0.55 |
| AWPAG #292 Large DFIR | 58 | 3.55 | 20 | 1.58 | 9 | 0.57 | 21 | 0.85 | 8 | 0.55 |
| AWPAG #729 Small DFIR | 58 | 3.35 | 20 | 1.56 | 9 | 0.56 | 21 | 0.68 | 8 | 0.55 |

**Table 4 – Johnstown Hourly Precipitation Catch Totals**

The AWPAG gauges with the 8-foot diameter Alter shields still report less than the AWPAGs installed in the international reference wind shields in wind-driven, dry snow events. This is to be expected without an application of a transfer function. The hourly comparison results between AWPAGs in the 8-foot diameter Alter averaging **3.30** inches compared to the standard production AWPAGs averaging **2.82** inches. The AWPAGs with the 8-foot diameter Alter shields come closer to the results of the DFIR AWPAGs averaging **3.45** inches. The AWPAGs located in the large and small DFIR were used only for comparison and not qualification. The overall goal is getting as close to the truth as possible.

## 5. CASE STUDIES

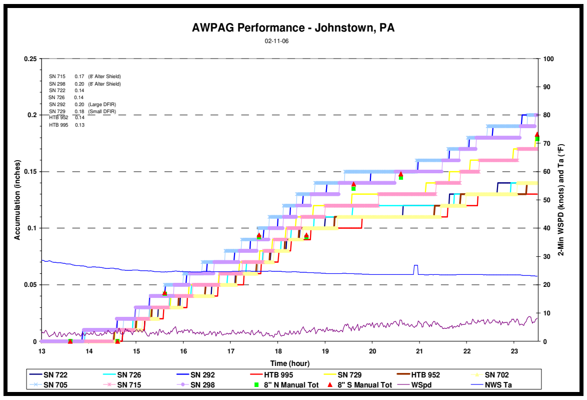


**Chart 1 – Johnstown, Pennsylvania – Frozen Precipitation Event (Calm to Light Winds)**

This frozen precipitation event occurred on February 11, 2006 under winds less than 10 knots and the NWS ambient temperature dropping from 24°F to 22°F over the entire period. Wind speed had steadily increased over this event from 2 to 10 knots. AWPAGs SN #722 and #726 (with standard Tretyakov shield) both caught a total amount of 0.14 inches. AWPAGs SN #715 and #298 (with 8-foot diameter Alter shield) caught a total amount of 0.17 and 0.20 inches, respectively. Manual observations caught a total amount of 0.17 and 0.18 inches.

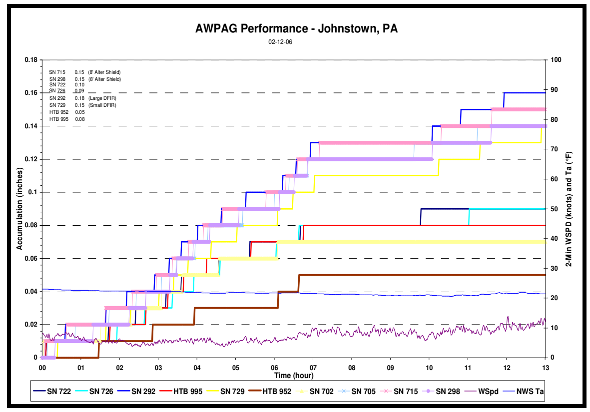


**Chart 2 – Johnstown, Pennsylvania – Frozen Precipitation Event (Sustained Light Winds)**

This frozen precipitation event occurred on February 12, 2006 under winds ranging from 5 to 14 knots and the NWS ambient temperature averaging 20°F during the entire period. AWPAG #722 and #726 (with standard Tretyakov shield) caught 0.10 and 0.09 inches. AWPAGs SN #715 and #298 (with 8-foot diameter Alter shield) both caught a total amount of 0.15 inches. Manual observations caught a total amount of 0.15 and 0.14 inches.

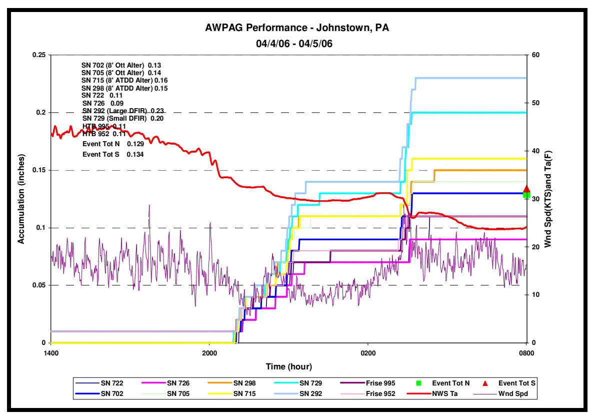


**Chart 3 – Johnstown, Pennsylvania – Mixed Precipitation Event (Moderate Winds)**

During the 2005-2006 winter season, the stainless steel 8-foot diameter Alter wind shields designed by ATDD were changed to a version manufactured by Ott Hydrometry. Results, as shown in the case above, display similar catch efficiency between the Ott and the ATDD shields. This is to be expected as the shields are geometrically and mechanically similar. This was the first (and only) significant winter event late in the testing period with the installation of the 8-foot diameter Ott Alter style shields on AWPAGs #702 and #705. This mixed precipitation event occurred over a two day period from April 4, 2006 to April 5, 2006 with winds ranging from 10 to 20 knots over the entire period and the NWS ambient temperature dropping steadily from

43°F to 24°F. The AWPAGs inside the Ott and ATDD style Alter shields caught a range of 0.13 to 0.16 inches over the event. The production AWPAGs (#722, #726) caught a total of 0.11 and 0.09 inches. The AWPAGs located within the small and large DFIR (#729, #292) caught a total of 0.20 and 0.23 inches. Manual observations both caught a total amount of 0.13 inches.

These case studies show that the AWPAGs located in the 8-foot diameter Alter style shields come closer to the actual catch of the manual observations compared to the production AWPAGs with the Tretyakov. This shows that the 8-foot diameter Alter shield can significantly increase catch in wind-driven light snow.

## 6. CONCLUSIONS

Testing during 2005-2006 at Johnstown has shown that production AWPAGs, with the addition of an outer 8-foot diameter Alter shield met the event requirements in **35** out of **38** events, while the AWPAG with Tretyakov shield met the event requirements **25** out of **38** events.

The Johnstown hourly accumulation requirements for the 8-foot diameter Alter shields were **113** out of **116** hourlies and **106** out of **116** hourlies for the AWPAG with a Tretyakov shield.

This is promising because the results show that the outer 8-foot diameter Alter shield can significantly improve catch in wind-driven, light snow. The overall event improvement between the production AWPAG with the additional 8-foot diameter Alter over the production AWPAG with a Tretyakov shield was **7** events that passed specification. The most notable difference is in frozen precipitation events, where there was a **6** event improvement between the AWPAGs within the 8-foot diameter Alter shields and the production AWPAGs.

An important result of this test was that while the AWPAGs located in the 8-foot diameter Alter shield did not technically pass the event requirements (±0.02 inches, or ±4% if greater than 0.5 inches) primarily due to over-reporting, the performance far exceeded that of the AWPAG with Tretyakov shield.

While the results of the AWPAG with the 8-foot diameter Alter shield are better than the AWPAG with Tretyakov shield, the AWPAG gauges with the 8-foot diameter Alter shields still report less than the AWPAGs installed in the international reference wind shields in wind-driven, dry snow events. The overall goal is getting as close to the truth as possible.

The 8-foot diameter Alter shields were installed late in the season and additional wind-driven, dry snow events are needed during the 2006-2007 winter test to assess AWPAG performance. While the results of this winter test were from the ATDD style Alter shield, the Ott and ATDD style Alter shields are mechanically and geometrically similar. The Ott style Alter shield will be used as the standard testing Alter shield as it can be attached to the current AWPAG frame. In conjunction with this effort, development of a transfer function is in progress to provide corrections to the AWPAG accumulations that would result in accumulations comparable to those achieved with the large DFIR wind shields.

## 7. ACKNOWLEDGMENT

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

This work was sponsored by the National Weather Service ASOS Program under Contract No. 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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