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TEST PLAN FOR

AWPAG TRANSFER FUNCTION TEST
November 2008 – April 2009

Version 2

AUGUST 2008

PREPARED BY

SAIC
From Science to Solutions

FOR

ASOS Product Improvement Program

National Weather Service W/OST/1

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ACRONYMS AND ABBREVIATIONS

TERMS	DEFINITION
ASOS	Automated Surface Observing System
NWS	National Weather Service
SFSC	Sterling Field Support Center
NCAR	National Center for Atmospheric Research
COTS	Commercial-Off-The-Shelf
PI	Product Improvement
DAS	Data Acquisition System
CCLA	C.C Lynch and Associates
AWPAG	All-Weather Precipitation Accumulation Gauge
DFIR	Double Fence Intercomparison Reference
WMO	World Meteorological Organization
LEDWI	Light Emitting Diode Weather Identifier
CR	Catch Ratio

1.0 BACKGROUND

The heated tipping bucket was the initial precipitation accumulation gauge when the Automated Surface Observing System (ASOS) was deployed. The sensor measures liquid precipitation accumulation, but is not designed to accurately measure freezing and frozen precipitation. The accurate measurement of all types of precipitation is an important part of weather observations; therefore the National Weather Service (NWS) ASOS Product Improvement (PI) team evaluated commercial off-the-shelf (COTS) sensors from October 2000 to March 2001. The NWS down-selected to one vendor and a design and development contract 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.

As a contract requirement, the production All-Weather Precipitation Accumulation Gauge (AWPAG), which comes standard with a Tretyakov shield, was tested against a standard NWS 8-inch non-recording precipitation gauge (NWS specification number D040) with a single metal Alter shield. Results conducted by NWS at the Sterling Field Support Center in Sterling, Virginia, showed that the production AWPAG was not within the NWS specification for precipitation catch when compared to the reference (8-inch manual gauge) (Greeney, 2005). There were some cases that resulted in no catch at all from the production AWPAG with the Tretyakov. These cases that resulted in no catch were typically high wind, light snow events where precipitation persisted for several hours.

The significant influence of wind on overall precipitation gauge performance has resulted in the development of an internationally recognized reference windshield (Goodison, B.E, Louie, P.Y.T, and Yang, D., 1998), the Double Fence Intercomparison Reference (DFIR), which will improve precipitation gauge catch efficiency. The DFIR is prohibitively large for installation on ASOS in airport environments; therefore the NWS has investigated ways to improve catch in the AWPAG with an auxiliary shield. The NWS in cooperation with OTT has developed an outer 8-foot Alter shield that can be mounted around a production AWPAG. This has shown much improvement over the stand alone AWPAG during previous winter testing. The NWS has decided to compare a production AWPAG surrounded by an 8-foot Alter shield (AWPAG 8-foot Alter) to a production AWPAG inside a large-scale DFIR (AWPAG DFIR) to develop a transfer function that will improve precipitation accumulation.

An AWPAG DFIR will be the reference sensor for this test. The AWPAG 8-foot Alter will be compared to the AWPAG DFIR in an attempt to improve catch efficiency in events with wind-driven, dry snow.

The testing will take place during the winter of 2008 - 2009 at test sites in Sterling, Virginia, Johnstown, Pennsylvania and at the Marshall Test Site in Boulder, Colorado, which is a collaborative effort with the National Center for Atmospheric Research.

2.0 PURPOSE

The purpose of this test is to adjust reported precipitation accumulation from an AWPAG 8-foot Alter so that it would closely match precipitation collected by an AWPAG DFIR. The World Meteorological Organization (WMO) transfer function equation and variations of that equation showed promising results during previous years of winter testing. The WMO equation is the basis for conducting the study, with refinements or modifications implemented to gain a better level of correlation.

3.0 TEST APPROACH

3.1 Sensor Description

3.1.1 Production AWPAG with Tretyakov shield inside a DFIR

The production AWPAG, Figure 1, is a weighing gauge that collects precipitation as it falls through a 6.25 inch diameter orifice into a plastic storage container. The gauge has a capacity of 56 inches of accumulation which includes antifreeze. In some cases, this can account for up to half of the liquid in the gauge. The storage container is continuously weighed; the weight is proportional to the catch amount.

An AWPAG DFIR will be the reference sensor for this test. The DFIR, Figure 2, consists of two vertical, concentric octagonal fences. The outer fence measures approximately 40 feet from apex to apex (diameter), and the inner fence measures approximately 13 feet from apex to apex. The top of the outer fence is 108 inches above grade and the top of the inner fence is 88 inches above grade. Both fences use 60-inch long vertical slats configured for 50% porosity. One AWPAG DFIR is installed at Johnstown, Pennsylvania and Sterling, Virginia. The precipitation gauge installed in the DFIR in Colorado will most likely be the Geonor gauge, but that is still undecided.

Figure 1 Production AWPAG

Figure 2 Large DFIR

3.1.2 Production AWPAG with 8-foot diameter Alter shields

The AWPAG 8-foot Alter, Figure 3, is the test sensor being used. The OTT shield, made of stainless steel, is manufactured by OTT Hydrometry of Kempten, Germany. The shield is mounted 2 ¼ inches above the height of the production AWPAG Tretyakov shield. TBD AWPAG 8-foot Alters are installed at Johnstown, Pennsylvania, Sterling, Virginia and one AWPAG 8-foot Alter will be installed in Colorado.

Figure 3 AWPAG Tretyakov with Alter

3.2 Test Location and Sensor Configuration

The test will be conducted at the Sterling Field Support Center in Sterling, Virginia, the ASOS test site in Johnstown, Pennsylvania (See Appendices A & B for maps of the test beds), and the Marshall Field Site in Boulder, Colorado. Testing will occur from November 3, 2008 to April 27, 2009. The AWPAG configuration at the three test sites will be as follows:

Serial No.	Sensor	Shield Configuration	Sensor Function
Johnstown, PA			
TBD	AWPAG	AWPAG 8-foot Alter	Test
TBD	AWPAG	AWPAG 8-foot Alter	Test
TBD	AWPAG	AWPAG DFIR	Reference
Sterling, VA			
TBD	AWPAG	AWPAG 8-foot Alter	Test
TBD	AWPAG	AWPAG 8-foot Alter	Test
TBD	AWPAG	AWPAG DFIR	Reference
Boulder, CO			
TBD	AWPAG	AWPAG 8-foot Alter	Test
TBD	Geonor	Geonor DFIR	Reference

Table 1 AWPAG Configuration

There will also be a number of reference weather sensors that will be used to classify the data into different categories for more detailed and accurate transfer function analysis. These include:

- Vaisala 425AHW Sonic Anemometer installed at a height of 54 inches above ground (orifice height)
- ASOS 425NWS installed at a height of 5 meters
- ASOS Temperature (Model 1088) and Dewpoint Sensors (DTS1)
- ASOS visibility sensor
- Two ASOS precipitation identification sensors (LEDWI - Light Emitting Diode Weather Identifier)

The NCAR effort is not yet clearly defined, but it is expected that we will receive LEDWI, 10 meter and orifice level IFW data, precipitation data from the AWPAG 8-foot Alter and from a Geonor in the DFIR and manual snow measurements (if they are on-site in support of other testing).

3.3 Data Collection

One minute data will be collected from all test and reference weather sensors using a desktop computer based data acquisition system (DAS).

3.4 Weather Observations

Detailed surface observations will be made by SAIC and NOAA/NWS observers at the test sites during covered events. Observers will be deployed to cover events when a significant period of precipitation is forecasted. For this test, event coverage decisions will be made based on snowfall forecasts of two inches or more.

During events, the observers will:

- record precipitation onset/cessation times
- record type and intensity of precipitation to verify the LEDWI
- inspect the test gauges at least once per hour during events and take photographs of unusual occurrences (e.g., snow/ice accretion around the orifice)
- measure event total precipitation in two alter shielded 8” gauges and one unshielded 8” gauge

4.0 TEST METHODOLOGY AND DATA ANALYSIS

The AWPAG data to be used during this test will be the standard 0.01 inch increment accumulation data used by ASOS. Internal AWPAG algorithms filter out fluctuations in data due to wind pumping and temperature gradients that can lead to false positive reports in the absence of precipitation. When precipitation is very light, especially during higher winds or temperature changes, precipitation that falls into the gauge is not always reported, and is sometimes rejected by the algorithms. While OTT has successfully eliminated the false reports (Greeney, 2005), there is concern that the algorithms can hinder reporting of very light precipitation over a long duration. In recent months, Ott Hydrometry made changes to the algorithms that report the amount of precipitation catch. The algorithms, along with shield design changes, will be evaluated

concurrently with this test effort.

The purpose of this test is to adjust reported precipitation accumulation from an AWPAG 8-foot Alter so that it would closely match precipitation collected by an AWPAG DFIR or Geonor DFIR. The WMO transfer function equation and variations of that equation showed promising results during previous years of winter testing. The WMO equation is the basis for conducting the study, with refinements or modifications implemented to gain a better level of correlation. The following sections, 4.1 through 4.3, show various transfer functions that were used in the previous winters. It is expected that the final transfer function will be a variation of one of these equations.

4.1 WMO Transfer Function

The following is the Catch Ratio (CR) developed by the WMO and is the basis for all transfer function development. The transfer function will be used to adjust the precipitation in a precipitation gauge with a Tretyakov shield so that it is more representative of the actual precipitation that is recorded in the DFIR (Goodison, B.E, Louie, P.Y.T, and Yang, D., 1998).

$$CR = 103.10-8.67*Ws+0.30*Tmax$$

Ws = Wind Speed (orifice height) in meters per second, which is the daily wind speed.
Tmax = Maximum temperature in °C, which is the maximum temperature for the day.

The CR will be applied as the inverse of the ratio. The WMO transfer function is only applied to the initial data if there is an accumulation in that minute and it is snowing, otherwise no adjustment is made.

4.2 Modified WMO Transfer Function

The following Catch Ratio (CR), which is a variation of the WMO transfer function, will be used to adjust the precipitation in the AWPAG 8-foot Alter so that it is more representative of the actual precipitation that is recorded in the DFIR.

$$CR = 100-X*Ws+0.30*T$$

Ws = Wind Speed (orifice height) meters per second, which is a two-minute average updated each minute.
T = Temperature in °C, which is a five-minute average updated each minute.
X = Coefficient that is dependent on wind speed, temperature and shield

The WMO transfer function was developed using a coarser resolution of daily temperature and wind speed data. The modified version of the WMO transfer function used a 15-minute average of the two-minute wind speed and five-minute temperature data to reduce the chances that the coefficient (X) would change rapidly.

The CR will be applied as the inverse of the ratio. The modified transfer function is only applied to the initial data if there is an accumulation in that minute and it is snowing, otherwise no adjustment

is made.

4.3 Least Squares Regression Transfer Function

The following Catch Ratio (CR) will be used to adjust the precipitation in the AWPAG 8-foot Alter so that it is more representative of the actual precipitation that is recorded in the DFIR. This equation differs from the Modified WMO Transfer Function in that it was derived using a least squares regression fit.

$$CR = a1*T+(a2*\ln(W))/1.1+a3$$

W = Wind Speed (orifice height) knots, which is a two-minute average updated each minute.
T = Temperature in °F, which is a five-minute average updated each minute.
a1, a2, a3 = Coefficients derived by multiple regression
1.1 = factor used to improve the fit

For the Tretyakov with Ott lamellas, the coefficients are: a1 = 0.0088; a2 = -0.43; a3 = 1.42

The CR will be applied as the inverse of the ratio. The transfer function is only applied to the initial data if there is an accumulation in that minute and it is snowing, otherwise no adjustment is made.

4.4 Wind Speed at Gauge Orifice Height

The wind speed in the CR equation requires that it be measured from orifice level. Since ASOS wind height is measured at 10m, the wind speed must be estimated using the following equation (Goodison, B.E, Louie, P.Y.T, and Yang, D., 1998):

$$Uh = [\log (h/ z_o)/(\log(H/ z_o))] \times UH$$

Uh= Wind speed (knots) at the height of the gauge orifice
h= height(m) of gauge orifice above ground
z_o= roughness length: 0.01m for winter
H= height(m) of the wind speed measuring instrument above ground, normally at 10m
UH= wind speed (knots) measured at the height H above ground

4.5 Metrics

Sensor Difference

This test will develop a transfer function to correct for reported AWPAG accumulations when compared to DFIR accumulation. The following formula will be used to calculate the difference between the test sensor and the reference, before and after the correction:

Sensor Difference = AWPAG test sensor (uncorrected/corrected) - DFIR Reference Sensor

A positive result will indicate that the test sensor is reporting a higher catch than the reference sensor. The converse is true with a negative result. The goal of this test is to reduce the AWPAG bias close to

zero, meaning the two sensors have a nearly identical catch. These data will be shown in tabular and graphical form.

5.0 DATA REPORTING AND TEST SCHEDULE

In addition to the final report, case studies will also be submitted to show the progress of this test throughout the winter test season. A final report will be submitted no later than June 29, 2009. The final report will contain the results from the transfer function evaluation, but a multi-year effort will be required to validate and refine the function over many events.

Table 2 below contains the schedule for the start/end of the test and any deliverables.

EVENT	***START DATE***	***COMPLETION DATE***
Test Operational	November 3, 2008	April 27, 2009
Case Studies	Immediately after each event	≤ 3 days after each event
Draft Final Report	May 25, 2009	June 29, 2009
Final Report	Upon receipt of comments	10 days after receipt of comments

Table 2 Test Schedule

6.0 RESPONSIBILITIES

ASOS PI Manager	J. Monte, W/OST11
Program Manager	J. Vogel, SAIC
Test Director	R. Lewis, W/OST32
Lead Engineer	P. Oosterhout, SAIC
Meteorologist	TBD
Data Acquisition System Software	S. Ranieri, SAIC M. Childs, SAIC
Technician	D. Eckberg, SAIC M. Baldwin, SAIC
Observers	J. Dover, SAIC G. Whitaker, SAIC B. Rice, SAIC A. Poyer, SAIC B. Wnek, SAIC R. Lewis, W/OST32

Table 3 Responsibilities

7.0 REFERENCES

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Greeney, Christopher, Final Report for Production AWPAGs 2005-2006, SAIC/NWS, 2006.

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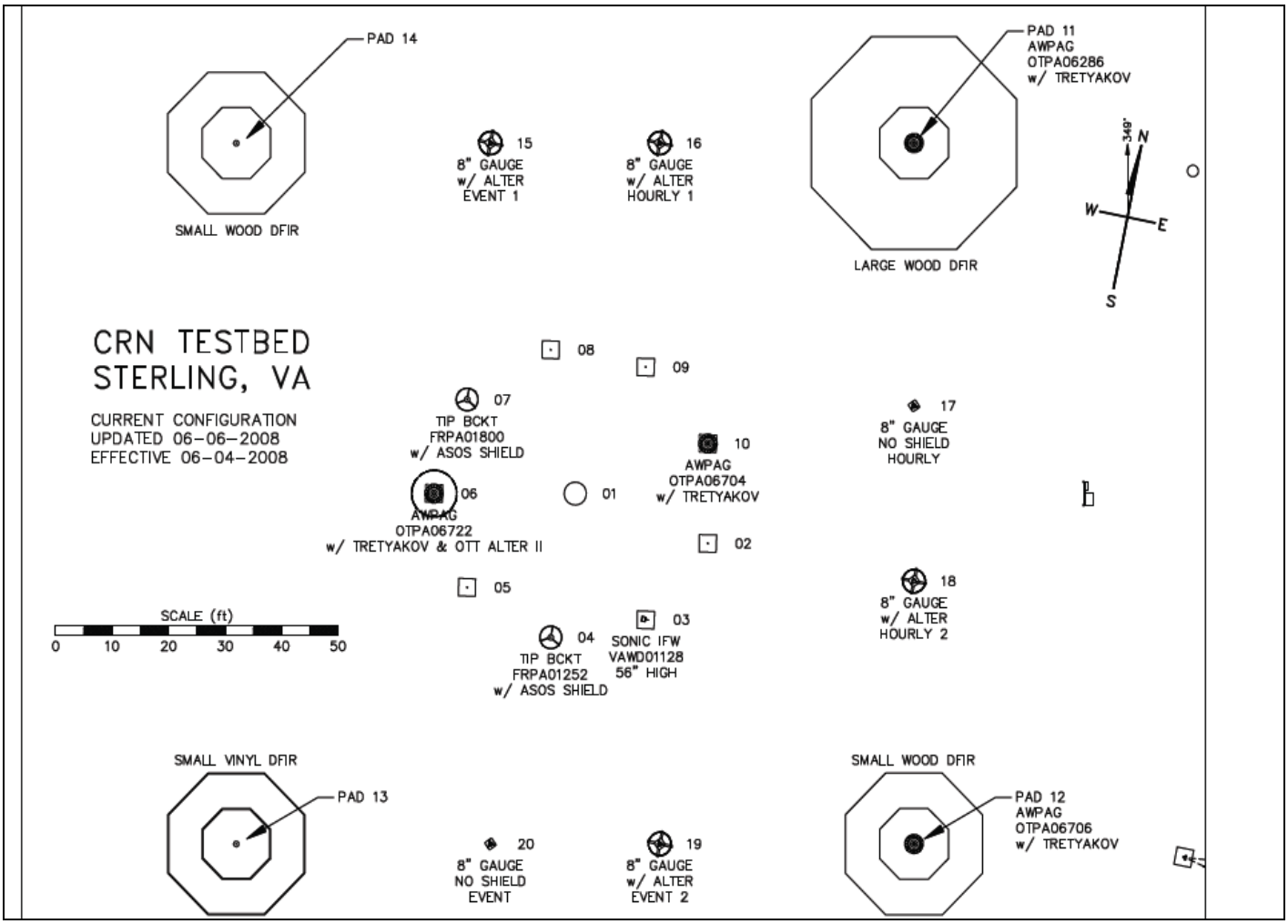
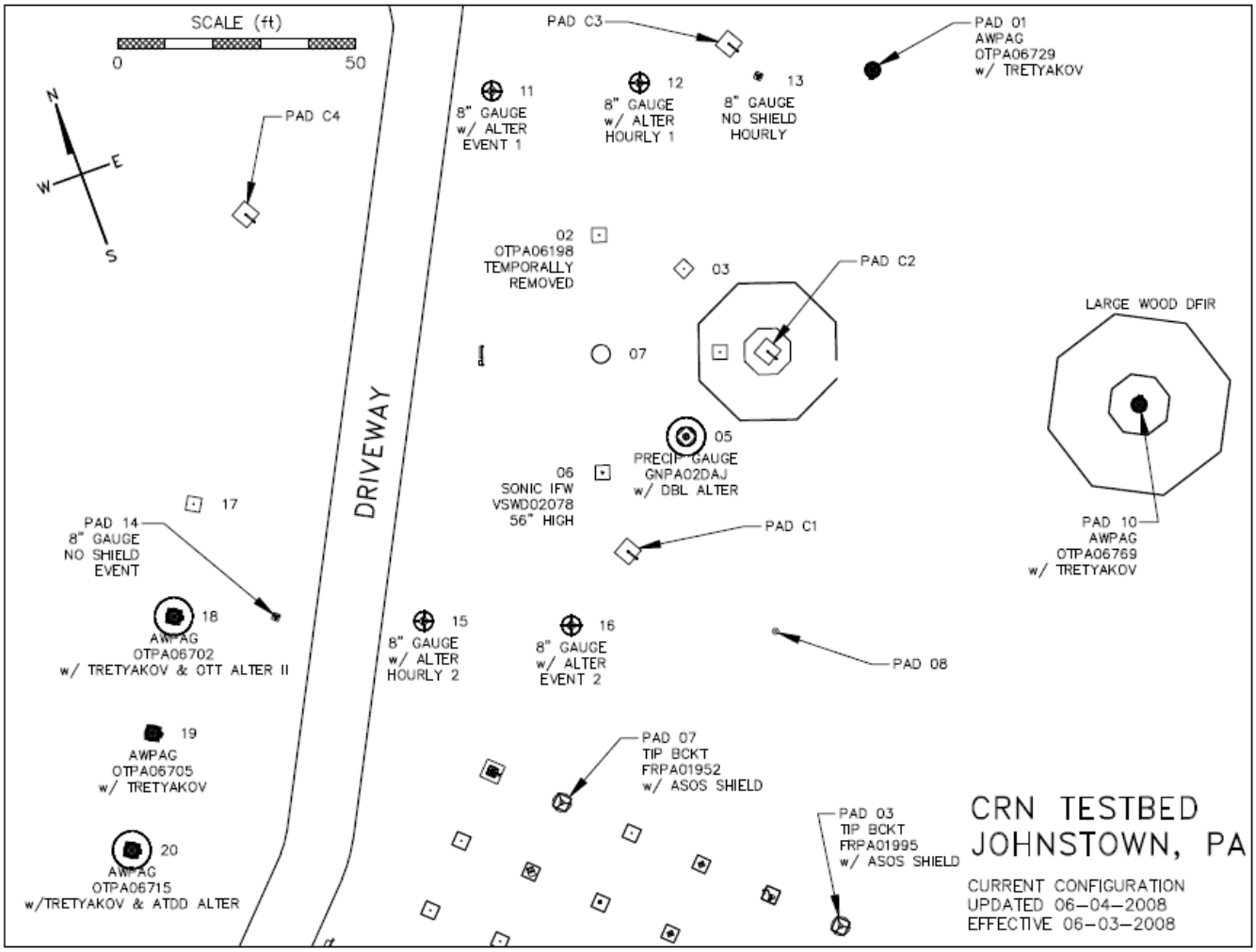
Wade, C., and J. Cole, 2001, Final Report to CRN Management on the Snow Gauge and Windshield Evaluation Studies Conducted at NCAR from January to April 2001, NCAR Research Applications Program (RAP), 17 July 2001.

Larsen, L.W., C.B.Baker, E.L.May, and H.Bogin, Operational Testing of Various Precipitation Sensors in Support of the United States Climate Reference Network, 13th Symposium on Meteorological Observations and Instrumentation, 19-23 June 2005, Savannah, GA, P4.4.

APPENDIX A: Sterling, Virginia Test Site



APPENDIX B: Johnstown, Pennsylvania Test Site