## 1.4 DEVELOPMENT OF THE ALL-WEATHER PRECIPITATION ACCUMULATION GAUGE TRANSFER FUNCTION FOR ASOS

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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 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) awarded a contract for design and development of an All-Weather Precipitation Accumulation Gauge (AWPAG) in 2001 to C.C.Lynch and Associates of Pass Christian, Mississippi, in partnership with Ott Hydrometry of Kempten, Germany.

The AWPAG specification requires comparability with a standard NWS 8-inch non-recording precipitation gauge with a single metal Alter shield. However, wind can significantly reduce precipitation catch, particularly when the precipitation is in the form of snow. This has resulted in the World Meteorological Organization (WMO) developing 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.

To assure that ASOS provides representative measurements of precipitation in all conditions, the NWS has undertaken a program to compare measurements of an ASOS production AWPAG with a production AWPAG installed inside a DFIR. In addition to testing production AWPAGs, an additional AWPAG with a Tretyakov shield inside an 8-foot diameter Alter shield was tested. Based on results from Dover (2002), this configuration should catch significantly more precipitation that the Alter shields alone in wind-driven, snow conditions. However, as shown by Wade (2001), Larsen (2005), and Myers et al. (2005), all the tested configurations would be expected to catch less than the reference DFIR. Following an approach developed by the WMO, the measurements of an ASOS production AWPAG can be corrected to be in close agreement with the measurement inside the DFIR. The approach was to use wind speed, temperature, and knowledge of the precipitation type (information that is available from ASOS sensors) to derive the ratio of the two measurements. The equation so derived, referred to as the transfer function, can then be implemented on ASOS to provide more accurate real-time measurements of precipitation, even in wind-driven snow conditions.

## 2. TEST APPROACH

### 2.1 Test Location

Testing took place at the Johnstown, Pennsylvania test site operated by the NWS Sterling Test Facility. 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.

### 2.2 Sensors

#### 2.2.1 Production AWPAG with Tretyakov shield

The production AWPAG with a Tretyakov shield (Production AWPAG) was the test sensor for this effort. It is a weighing gauge that collects precipitation as it falls through a 6.25 inch diameter orifice into a plastic storage container with a capacity of 56 inches of accumulation that includes antifreeze, which in some cases, can account for up to half of the liquid in the gauge. The storage container is continuously weighed and the weight is proportional to the catch amount. Three AWPAGs were installed with a Tretyakov shield at the test site as shown in Figure 1.

**Figure 1 Production AWPAG**

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### 2.2.2 Production AWPAG with Tretyakov shield inside a DFIR

A DFIR containing an AWPAG with a Tretyakov shield (AWPAG DFIR) was the reference sensor for this test. The DFIR (Figure 2) consists of two vertical, concentric octagonal fences, with the outer fence measuring approximately 40 feet from apex to apex (diameter), and the inner fence measuring 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 with a Tretyakov shield was installed inside a DFIR at the test site.

**Figure 2 DFIR**

### 2.2.3 Production AWPAG with 8-foot diameter Alter shield

In addition to testing AWPAGs with a Tretyakov shield, an additional AWPAG with a Tretyakov shield inside an 8-foot diameter Alter shield (AWPAG Alter), as shown in Figure 3 (Lexan) was tested at Johnstown, Pennsylvania. As winter progressed, the Lexan shield was changed to a stainless steel version (Figure 4) manufactured by OTT Hydrometry of Kempten, Germany.

**Figure 3 Outer Alter – Lexan Slats**

**Figure 4 Outer Alter – Steel Slats**

## 3.0 TEST METHODOLOGY AND DATA ANALYSIS

The purpose of this test was to develop and validate a transfer function that provided a correlation between the reported precipitation of the production AWPAG and the AWPAG DFIR. This was accomplished by applying a transfer function to the initial accumulation. This transfer function was developed by the World Meteorological Organization (WMO). Additionally, the catch from an AWPAG Alter was compared to catch from the other gauges to determine if the 8-foot diameter Alter shields improved catch. The goal was to improve catch in wind-driven snow conditions using a shield which could be installed around the production AWPAG on ASOS.

### 3.1 WMO Transfer Function

The following Catch Ratio (CR) was used to adjust the precipitation in the AWPAG so that it is more representative of the actual precipitation 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) meters per second, which is a two-minute average updated every minute. Tmax = Maximum temperature, but for this test, Tmax was the five-minute average updated each minute in °C. The WMO transfer function was developed using a coarser resolution, or daily temperature data set. This test used a finer resolution, or minute-by-minute temperature data set. The CR was applied as the inverse of the ratio. The modified transfer function was only applied to the initial data if there was an accumulation in that minute and it was snowing, otherwise no adjustment was made. The data used was the temperature and wind speed that occurred in that minute when the modified transfer function was applied.

### 3.2 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 orifice 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

### 3.3 Data Analysis

Accumulation data from the AWPAG is reported in 0.01 inch increments. Internal algorithms filter out fluctuations in data due to wind pumping and temperature gradients that can lead to false positive reports and measurement inaccuracies.

## 4.0 RESULTS

The test results shown in table 1 are based on the AWPAG Alter made from Lexan lamellas. As winter progressed, the Lexan shield was changed to a stainless steel version designed by the Atmospheric Turbulence and Diffusion Division (ATDD) and eventually a version manufactured by OTT Hydrometry of Kempten, Germany. Results were very similar when comparing the Lexan shield and the steel shields. This is to be expected, as the shields are geometrically and mechanically similar.

Table 1 shows the differences between the tests and reference sensor for both uncorrected data (modified transfer function not applied) and corrected data (modified transfer function applied) as well as the catch for the 0.01 data. The column, “Catch Before”, refers to the catch before any transfer function was applied to it. The column, “Catch After”, refers to the catch after the modified transfer function was applied to it. The columns labeled “% of DFIR” refers to the percent of catch each configuration reported when compared to the DFIR. The following table incorporates five pure snow events (12/8/05 – 1/14/06).

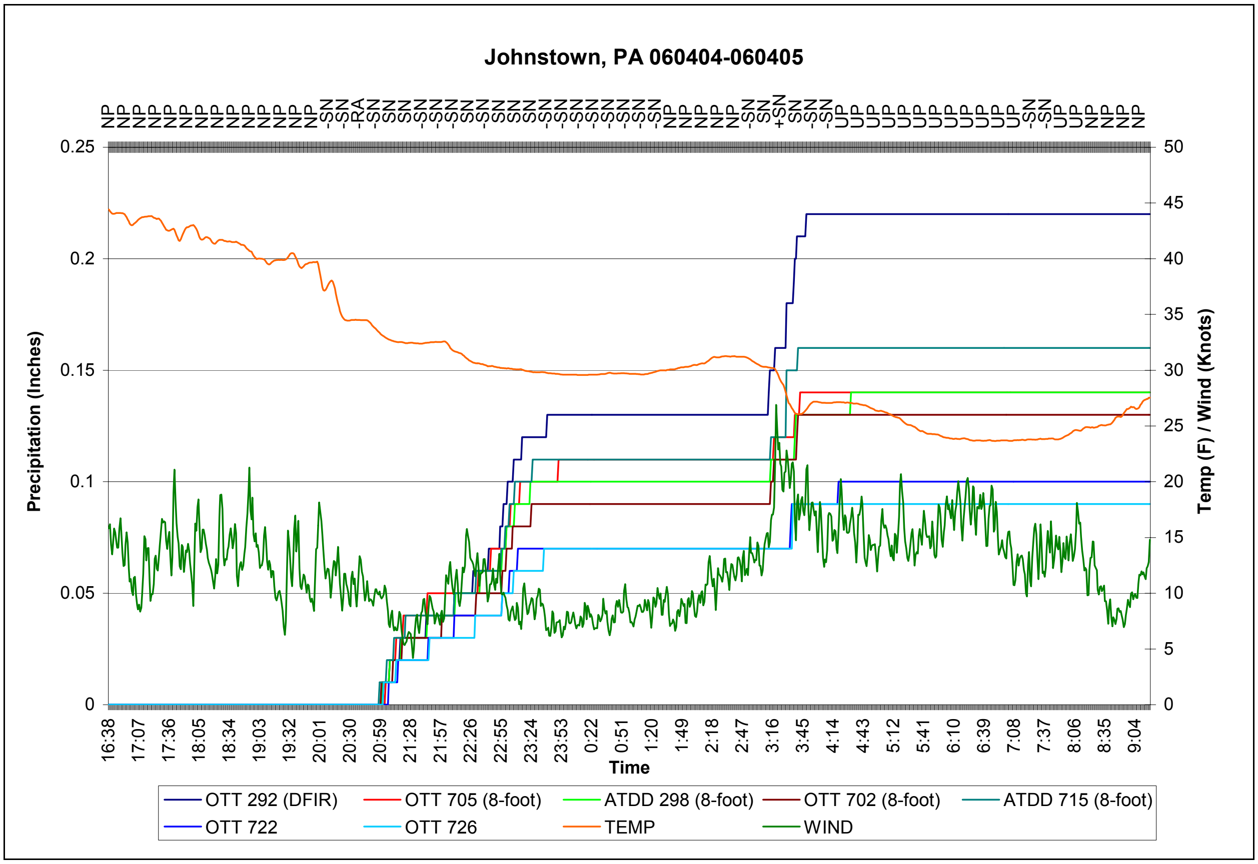
It is important to note that the AWPAG Alter (Sensor #705) showed significant improvement (0.38 inches) over the production AWPAGs. A transfer function was not applied to the AWPAG Alter since the modified transfer function is only valid for a precipitation gauge with a Tretyakov shield. A new transfer function is being developed that will be applied to the AWPAG Alter to increase the catch to that of the reference (DFIR). All production AWPAGs were most comparable to the DFIR once the modified transfer function was applied to it.

## 5.0 CASE STUDIES

During the 2005-2006 winter season, one 8-foot diameter Alter shield manufactured by ATDD and one manufactured by OTT were installed on production AWPAGs. The case study below highlights the similar performance of the shields manufactured by ATDD and the shields manufactured by OTT.

| Sensor Number | Sensor Function | Configuration | Catch Before | % of DFIR | Uncorrected - DFIR | Catch After | % of DFIR | Corrected - DFIR |
|---|---|---|---|---|---|---|---|---|
| 705 | Test | Tretyakov with outer Alter (Lexan) | **1.37** | **87** | **-0.21** | -- | -- | -- |
| 715 | Test | Tretyakov | 0.96 | 61 | -0.62 | 1.41 | 89 | -0.17 |
| 722 | Test | Tretyakov | 0.98 | 62 | -0.60 | 1.50 | 95 | -0.08 |
| 726 | Test | Tretyakov | 1.01 | 64 | -0.57 | **1.53** | **97** | **-0.05** |
| 292 | Reference | Tretyakov inside a Large DFIR | 1.58 | -- | -- | -- | -- | -- |

**Table 1 Sensor Differences of Liquid Water Equivalent**
**Note: The bold numbers indicate the best performers in each category – not including the DFIR gauge**




This case study shows that the AWPAG Alters perform significantly better than the production AWPAGs. The AWPAG Alters still report less than the AWPAG DFIR, but they do report additional precipitation that the production AWPAGs do not. The future transfer function will attempt to correct the precipitation in an AWPAG Alter to that of the reference (DFIR).

## 6.0 CONCLUSIONS

It is important to note that by adding the outer 8-foot diameter Alter shield, the total catch for the test period was increased by 0.38 inches over the production AWPAG, prior to any application of a modified transfer function. The precipitation catch in the AWPAG Alter was 0.21 inches less than the DFIR. A new transfer function will be developed that will be applied to the AWPAG Alter to make it more representative of the reference DFIR. The modified transfer function was not applied to that shield configuration since the transfer function is only valid for a Tretyakov shield. In future testing, the Alter shield used will be the 8-foot diameter Alter manufactured by OTT.

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