SFSC DOCUMENT CONTROL SHEET

TITLE: Test Report for AWPAG Orifice Heater Controller Firmware Change | **DATE: 06/17/08**

ORIGINATOR: Paul Oosterhout

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COMMENTS:

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Y Yes; Comments were made, changes were recommended at this time.
N No; no comments were made, no recommended changes at this time.

TEST REPORT
ON
AWPAG ORIFICE HEATER CONTROLLER
FIRMWARE CHANGES

VERSION 1

June 2008

Prepared for

National Weather Service W/OPS22

by

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1.0 BACKGROUND

The orifice heaters on the production version of the OTT AWPAG are activated and deactivated in response to changes in air temperature. These heaters are programmed to turn on when temperatures fall bellow 41 °F (5 °C). Additionally, the heaters are programmed to be disabled when temperatures fall below 18 ºF (-8 °C). Both of these temperature values are hard-coded inside the current version of the AWPAG's LogoSense controller firmware (version 3.58). The reason that heating is applied to the orifice is to melt freezing rain or wet snow that will stick to the unheated surfaces and not be measured until the temperature rises above freezing. So heat is applied to the orifice to prevent this. The rationale for the cut-off is that freezing rain and wet snow generally do not occur below 18ºF so it is preferable to not heat the orifice at temperatures lower than around 18ºF. An additional rationale is that heat will tend melt snow or ice pellets falling at lower temperatures. This leads to evaporation or sublimation and results in lower catch than would occur if the orifice is left cold and the snow or ice pellets fall into the gauge naturally.

While this is in general a satisfactory approach, a problem can arise when precipitation is falling while the temperature is dropping below 18ºF. In this case, snow that has been melted will freeze to the orifice. It has been observed at Johnstown and other ASOS locations that the melt water can form an icicle that comes in contact with the bucket and then refreezes. In one scenario, the icicle will reduce the force on the weighing mechanism in such a way that when the temperature rises above 18 ºF the sudden increase in force on the weighing mechanism can sometimes lead to a substantial false measurement of precipitation. In a worst case scenario, it has been observed that if the temperature hovers around 18 ºF, a sequence of melting and refreezing of the icicle can lead to multiple false precipitation increases that are completely erroneous.

In response to these problems, OTT began development on a new version of their sensor controller firmware that would allow the operator to set the low temperature cut-off value to any desired value (below 30 °F). This change was incorporated in firmware version 3.59 which was then delivered to the Sterling, Virginia test site in June of 2005. Version 3.59 made provision for using a simple command line entry to change the low temperature cut-off value (defined by OTT as the "PHTEMP" setting). Unfortunately, subsequent testing of v3.59 revealed that the orifice heaters did not work as expected. Environmental chamber tests performed by Michael Salyards in July of 2005 demonstrated that version 3.59 properly disabled the orifice heater controller whenever the ambient temperature dropped below the PHTEMP setting, and the heater controller was re-enabled when the ambient temperature rose above the PHTEMP setting. However, Salyards' testing also revealed two problems:

- Under steady state temperature conditions in the chamber (typically, any temperature around 0 °F (-17.8 °C) and below, but still above the PHTEMP of -20 °F (-28.9 °C)), the heater controller would inexplicably turn off the orifice heater periodically. A typical cycle would be about 120 minutes with the heater on, followed by an unexpected 30 minute period where the heaters was deactivated when they should have remained on. Measurements made with a surface-mounted temperature probe confirmed that the orifice heater status reported (in the "PX" data string) was correct during this cyclic on/off operation of the orifice heater.

- The contact temperature probe inside the orifice revealed that the orifice heaters did not maintain orifice temperatures above freezing when operating at the lower end of the heater control range. This was confirmed by running a series of tests at different combinations of chamber temperatures and PHTEMP settings. These tests indicated that lowering the PHTEMP to any value below 18 °F would provide little additional benefit because the orifice heaters would not keep the orifice above freezing.

AWPAG sensor firmware version 3.59 was never fielded because of these problems. Later analysis by OTT indicated that the temperature cycling problem was caused by a flaw in version 1.9 of their rim heater controller subsystem firmware. In December of 2007 OTT delivered a new version (v2.1) of their rim heater controller firmware. The new heater controller firmware (which is hard coded on a CMOS chip) is designed to prevent the heaters from cycling on and off during steady state heater operation.

This report presents the results of a series of tests that were conducted between January 17th and January 23rd, 2008. These tests were designed to confirm that the version 2.1 of the rim heater controller firmware (along with sensor controller firmware version 3.59) is working properly and determine if this firmware combination can prevent orifice freezing at temperatures below 18 °F.

2.0 PURPOSE

The three purposes of this test were:

1) Confirm that the PHTEMP could be set to any desired temperature below 30 °F.
2) Determine if the new rim heater controller firmware (version 2.1) has solved the problem of the heaters cycling on and off.
3) Determine what is the lowest effective PHTEMP setting is (the lowest practical heater cut-off temperature setting that still allows the rim heaters to maintain an orifice temperature above freezing).

3.0 TEST APPROACH

An ASOS production model AWPAG was installed inside one of the Tenney environmental chambers located at the Sterling Field Support Center. This gauge was be configured with rim heater controller firmware version 2.1 and LogoSense controller firmware version 3.59. Also, the gauge was outfitted with a surface mounted PRT thermometer to measure the orifice temperature directly. To determine if the new rim heater controller firmware is working correctly, the gauge was subjected to several of PHTEMP settings and steady state chamber temperatures. Testing began with the temperature inside the environmental set to several degrees above the current PHTEMP. Then the chamber temperature was programmed to slowly drop down below the PHTEMP and then slowly return back above the PHTEMP. During this procedure the gauge's heater status flags, the gauge's ambient temperature reading (defined by OTT as the "PX temperature"), the ambient chamber temperature, and the orifice surface temperature data were monitored to determine at what temperature the rim heaters cut out and when they began working again.

To determine the lowest effective PHTEMP, the gauge was subjected to a slowly decreasing chamber temperature setting. The orifice temperature was continuously monitored during this period. Later the temperature data was analyzed to determine the chamber temperature at which the rim heaters could no longer maintain an orifice temperature above freezing. This temperature equates to the lowest practical PHTEMP setting.

3.1 Test Methodology – Hardware Setup

This test was conducted using ASOS production model AWPAG serial number 198157 and pipe house serial number 00008. This gauge was reconfigured to run with rim heater controller firmware version 2.1 and LogoSense controller firmware version 3.59. The gauge was then installed on a test stand inside the new Tenney environmental chamber.

To measure the orifice surface temperature, a pair of OMEGA model OSK5091/3/TFD/48” PRT thermometers were used. These thermometers are well suited for making surface temperature measurements because they are small and flat (the sensor body is only 0.125 inch wide by 0.400 inch long by 0.020 thick). Two PRT’s were attached to the inside surface of the orifice using a small dab of OMEGATHERM #201 thermal conducting paste and a small strip of aluminum foil adhesive tape. One of the PRT’s was also covered with a small piece of polystyrene foam which was held in place with a second strip of tape. This was done to insulate the top surface of the PRT from the surrounding air. A separate pair of OSK5091 thermometers was installed to measure the ambient chamber temperature. One PRT was located in the air about six inches away from the orifice and the other PRT was located beneath the gauge’s base plate.

Figure 1. Surface mount PRT thermometers on gauge orifice.

Figure 2. AWPAG orifice heater test set up.

All four of PRT's were connected to a Keithley model 2001 digital multimeter. This entire setup (the digital multimeter and all four PRT's) was run through a two point calibration check in Hart precision temperature bath. This procedure confirmed that all the PRT's were operating in specifications and he calculated accuracy of the PRT's and multimeter measuring system was within ±0.1°F.

The AWPAG and the temperature sensors were connected to a PC computer configured to act as a data acquisition computer (DAS). The DAS program was set up to record (and time stamp) the gauge's detailed data output string (the "PX" data string) and the temperatures measured by the four PRT thermometers.

3.2 Test Methodology – Part 1. Rim Heater Function Evaluation

To determine if the new rim heater controller firmware is working correctly, the gauge was subjected to several of PHTEMP settings and steady state chamber temperatures. All tests began with the temperature inside the environmental chamber set at 5 °F above the current PHTEMP value. The temperature was the allowed to stabilize for 30 minutes. The chamber was programmed to slowly drop down (at a rate of 0.05 °F per minute) until the chamber temperature reached 5 °F below the PHTEMP. This temperature change would take 200 minutes. Then the chamber temperature would

then return back to 5 °F above the PHTEMP. This change would take an additional 200 minutes. This test was repeated for the four different PHTEMP values shown below in table 1. During this procedure, the computer DAS recorded the gauge's heater status flags, the gauge's internal temperature (the "PX" temperature), the chamber's ambient temperature, and the orifice temperature measurements.

Table 1. Selected PHTEMP values for rim heater function evaluation.

PHTEMP Setting (°F)	Chamber Starting Temperature (°F)	Ramp Down Temperature (°F)	Ramp Up Temperature (°F)	Elapsed Time (minutes)
18	23	13	23	400
10	15	5	15	400
0	5	-5	5	400

This data was downloaded from the DAS at the end of the test and evaluated using an Excel spreadsheet program to determine at what temperature the rim heaters cut out and when they start working again.

3.3 Test Methodology – Part 2. Effective Minimum PHTEMP Setting

This test used the same AWPAG and a similar test setup as used in part 1. For this test only one insulated PRT was mounted on the orifice and one PRT was used to measure the ambient chamber temperature. First the PHTEMP was set to -10 °F and the environmental chamber was set to +35 °F. Then the chamber temperature would be programmed to slowly drop down (at a rate of 0.05 °F per minute) until the chamber temperature reaches 0 °F. This temperature change would take 700 minutes (11 hours 40 minutes). Then the chamber temperature would return back to +35 °F. This change took an additional 700 minutes. During this procedure, the computer DAS recorded the gauge's heater status flags, the PX temperature, the chamber temperature, and the orifice temperature measurements.

The data was downloaded from the DAS at the end of the test and evaluated using an Excel spreadsheet program to determine the lowest ambient temperature at which the rim heaters were able to maintain the orifice surface temperature above freezing.

4.0 RESULTS

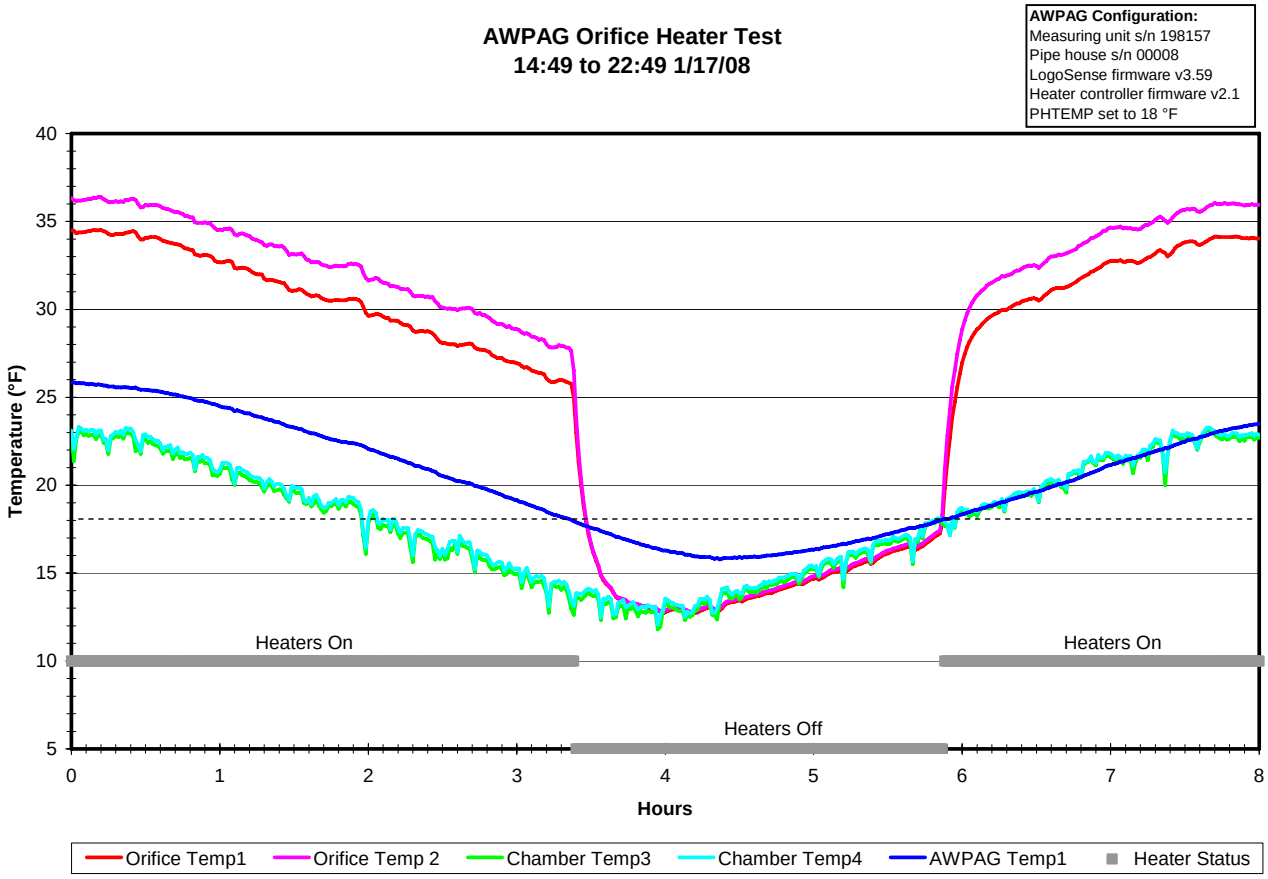
4.1 Results – Part 1. Rim Heater Function Evaluation

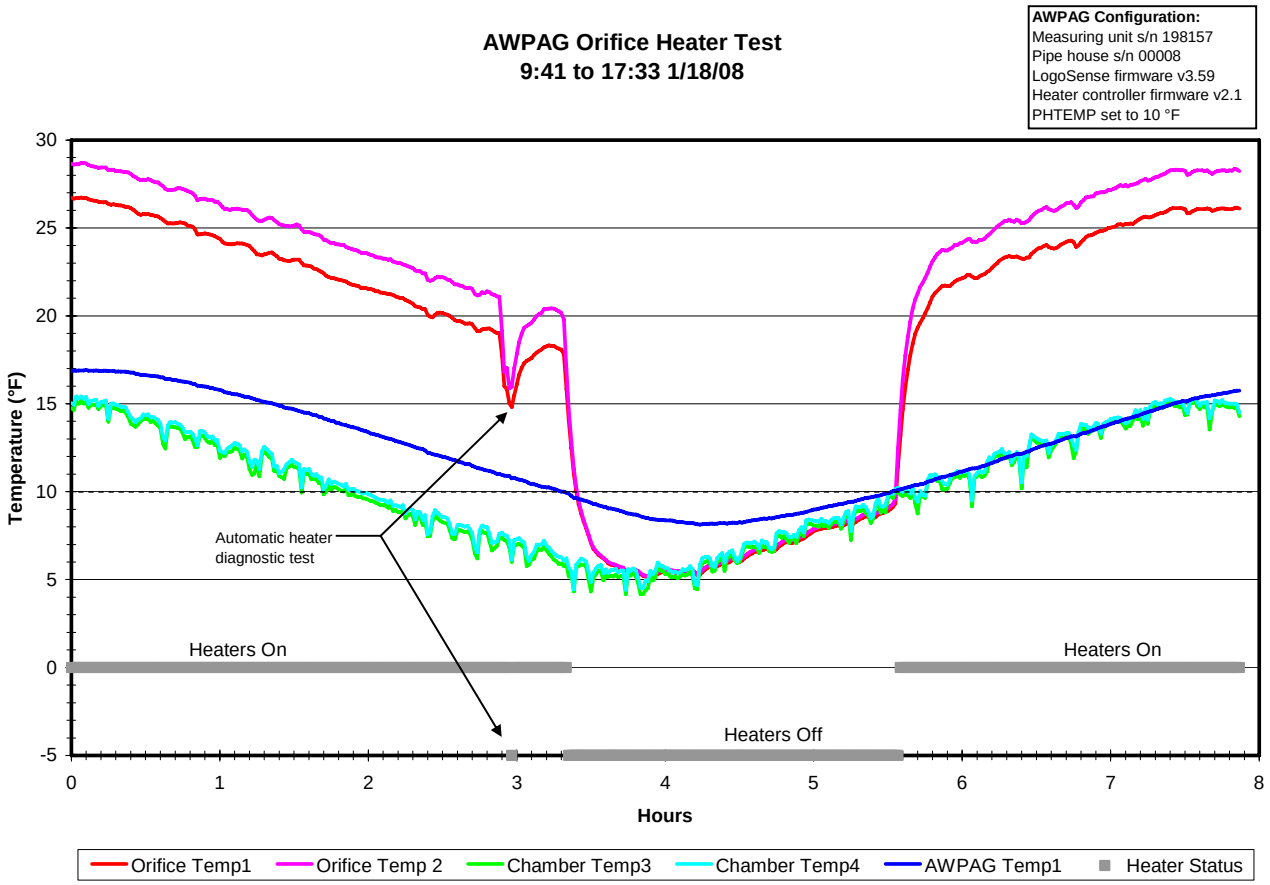
The first rim heater evaluation test took place on January 17th, 2008 with follow on tests on January 18th and 19th. The procedure evaluated the gauge's performance while the PHTEMP was set at 18, 10, and 0 °F. The following three graphs show the elapsed time; the ambient chamber temperature (lines labeled "Chamber Temp3" and "Chamber Temp4"; the orifice surface temperature with the non-insulated PRT ("Orifice Temp1"); the orifice surface temperature with the insulated PRT

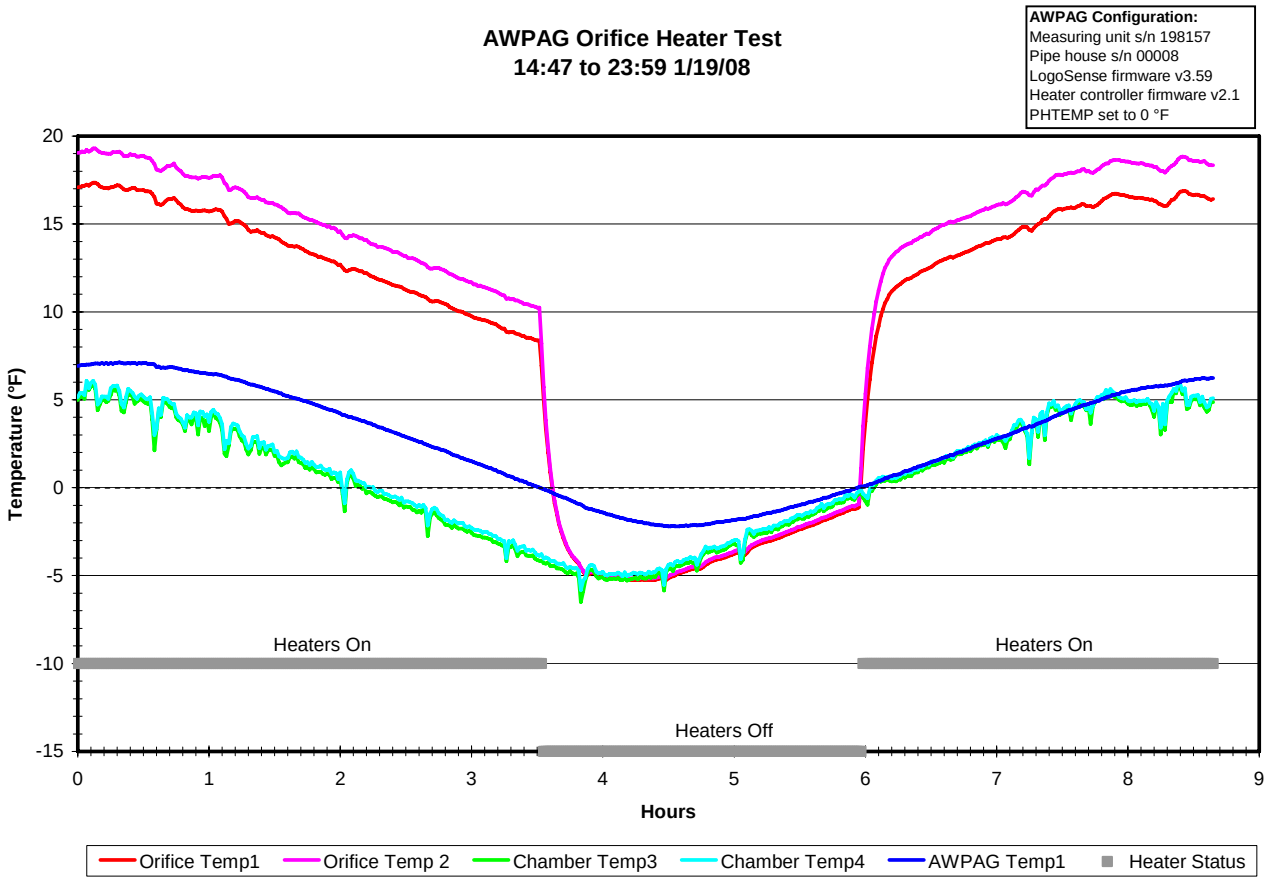
("Orifice Temp2"); the gauge's internal temperature ("AWPAG Temp1"); and the orifice heater status flags for each test run.

By examining the heater status flags indicated on the graphs it can be seen that the orifice heaters would turn off the moment the gauge's internal temperature sensor fell below the PHTEMP and the heaters turned back on when the internal temperature rose back above the PHTEMP. The deactivation (and reactivation) of the heaters could also be confirmed by examining the orifice temperature which would begin to drop immediately after the heaters turned off. It is also clear that the orifice surface temperature is fairly steady. The heaters did not unexpectedly turn off for long periods of time (while the temperature is above the PHTEMP) and the orifice temperature not exhibit the large swings evident with the old heater controller software. However, the second and third test runs do show that the gauge's heaters could not maintain the orifice surface temperature above freezing when the ambient temperature fell below 17 °F.

Note that on the second test (run on January 18th) the orifice heaters were briefly turned off (at 2.97 hours into the test) while the temperature was still above the PHTEMP. This was simply a routine internal diagnostic heater check that the AWPAG automatically runs once every twelve hours. Also note that gauge's internal temperature reading always lags behind the ambient temperature reading. This is because the AWPAG's ambient temperature probe is located inside the gauge near the base plate and therefore it is somewhat insulated from the outside air.



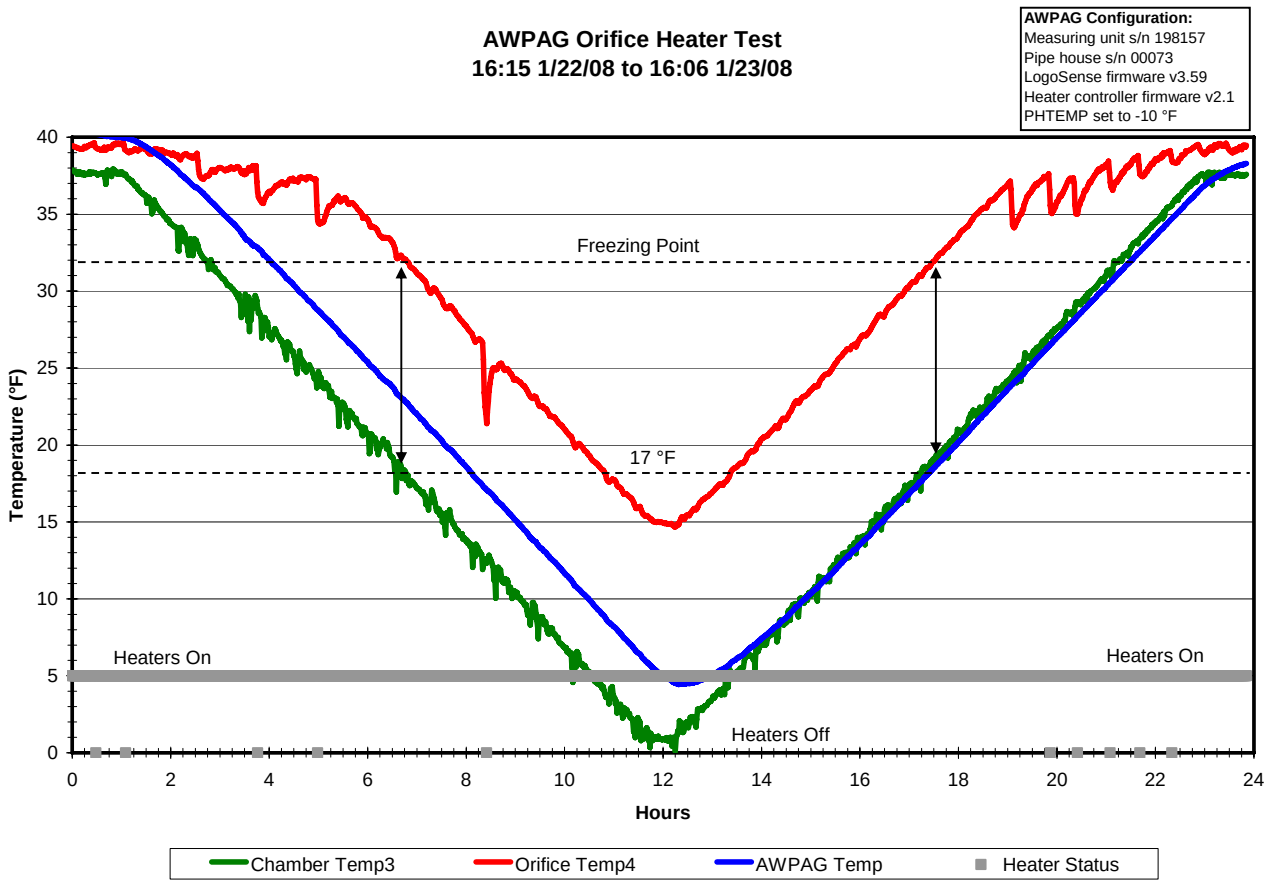

AWPAG Orifice Heater Test
9:41 to 17:33 1/18/08
AWPAG Configuration:
Measuring unit s/n 198157
Pipe house s/n 00008
LogoSense firmware v3.59
Heater controller firmware v2.1
PHTEMP set to 10 °F
Temperature (°F)
30
25
20
15
10
5
0
-5
Automatic heater diagnostic test
Heaters On
Heaters Off
Heaters On
0
1
2
3
4
5
6
7
8
Hours
Orifice Temp1
Orifice Temp 2
Chamber Temp3
Chamber Temp4
AWPAG Temp1
Heater Status


AWPAG Orifice Heater Test
14:47 to 23:59 1/19/08
AWPAG Configuration:
Measuring unit s/n 198157
Pipe house s/n 00008
LogoSense firmware v3.59
Heater controller firmware v2.1
PHTEMP set to 0 °F
Temperature (°F)
20
15
10
5
0
-5
-10
-15
Heaters On
Heaters On
Heaters Off
0
1
2
3
4
5
6
7
8
9
Hours
Orifice Temp1
Orifice Temp 2
Chamber Temp3
Chamber Temp4
AWPAG Temp1
Heater Status

4.2 Results – Part 2. Effective Minimum PHTEMP Setting

The minimum effective PHTEMP test took place on January 22nd and 23rd, 2008. The procedure evaluated the gauge during a long slow temperature ramp beginning at 40 °F, falling to 0 °F, and then returning to 40 °F while the PHTEMP was set at -10 °F. The following graph shows the elapsed time; the ambient chamber temperature ("Chamber Temp3"); the orifice surface temperature the insulated PRT ("Orifice Temp4"); the gauge's internal temperature ("AWPAG Temp"); and the orifice heater status flags.

The graph shows (that with the heaters running continuously) the orifice surface temperature fell below freezing when the ambient chamber temperature fell below approximately 17 °F. And, the orifice temperature did not go above freezing until the ambient temperature rose back above 17 °F.



5.0 CONCLUSION

Operation of the gauge during these tests has shown that LogoSense firmware version 3.59 will allow the operator to set the PHTEMP desired temperature below 30 °F. Furthermore, it appears that OTT's new heater controller firmware (version 2.1) has solved the problem of the heaters cycling on and off when the ambient temperature is below freezing (but still above the PHTEMP). However, these tests also show that the orifice heaters cannot maintain the orifice surfaces above freezing when the ambient temperature falls below approximately 17 °F.

LogoSense firmware version 3.59 was originally developed so that the NWS could have the option of setting the PHTEMP value to a lower value in those locations where icing at temperatures below the default PHTEMP value (18 °F) were common. Unfortunately, it appears that this change would not be of any use because the orifice heaters would not be able to keep the orifice from freezing whenever the temperatures fell below 17 °F. This will be particularly true in strong winds at low temperatures where heat dissipation will exacerbate the problem. Similarly the latent heat of condensation and sublimation will further cool the orifice, tending to prevent it from reaching freezing.

If the NWS wishes to lower the PHTEMP, then OTT will need to find a way to increase the heaters' power and/or segment heat distribution so that the heat is concentrated in places where the temperature is lowest, generally the downwind edge of the orifice. Additionally, it may be possible to improve the heat management algorithm to prevent heaters from being turned off while precipitation is falling. This is the main cause of false precipitation accumulation "spikes" that have been observed. Thus if no "recent" accumulations have been measured the heater can be safely turned off without risk of creating an icicle. Then the heaters will not have to be turned on until the temperature rises above the cut-off setting. The choice of the cut-off setting will have to be based on the regional climatology and from experienced gained by observing the gauge performance with particular attention to anomalous sudden increases in precipitation that are seen to occur when the temperature is near the PHTEMP temperature.

That said, it is recommended that the NWS consider upgrading the heater controller firmware in all AWPAG's to version 2.1. The current heater controller version frequently cycles the heaters on and off. Testing by Michael Salyards showed this control cycling often turns the heaters off for as long as 30 minutes at a time. This condition could allow the orifice to accumulate ice during moderate freezing rain events, even when ambient temperatures are well above 18 °F.

6.0 POSTSCRIPT

These results of these tests were informally presented to OTT's engineers and discussed at a teleconference that was held on March 19th, 2008. OTT claimed that they had run their own tests in 2004 which showed that the orifice heaters could maintain the surface temperature above freezing at ambient temperatures down to -5 °F. It was OTT's contention that the Sterling Field Support Center's (SFSC) temperature measurement technique was flawed. SFSC does not concur with this assessment.

The central issue is whether or not the orifice heaters will prevent ice from accumulating on the orifice when ambient temperatures are below 17 °F. The best approach to make a final determination on this issue would be to subject an AWPAG to a freezing rain test inside one of the environmental chambers. SFSC is prepared to conduct this test if directed to do so.