# Case Study of Swan Turbiwell Quarterly Calibrated Unit versus Quarterly Verified Unit

Authored by

Shaun Sharrett
Support Manager, Chemist
Swan Analytical USA

and

Randy Turner
Technical Director, Chemist
Swan Analytical USA

## Table of Contents



**Abstract**

This paper presents the field data collected over a twelve month period at a municipal surface water treatment plant employing traditional clarification and filtration. The final effluent turbidity was monitored by the third party compliance turbidimeter, a Swan Turbiwell (Protocol Turbiwell) was calibrated quarterly just as the compliance turbidimeter, and a second Swan Turbiwell (Non-protocol Turbiwell) that was not calibrated. The performance of each Turbiwell was verified weekly using a Swan secondary standard, Verification kit. The data proves the Turbiwell does not need quarterly calibration which provides significant benefit and value to the end user by reducing operating and maintenance costs while providing accurate and reliable results.

## Glossary and Terms

**Primary Calibration**- a process by which a Formazine solution is used to *adjust* the slope of the instrument

**Primary Verification**- a process by which a Formazine solution is used to *check* the calibration curve in which no slope adjustment occurs

**Secondary Standard** (proprietary) - a device consisting of a glass prism with a known Turbidity value that is inserted in the instrument that checks the calibration curve

**Normalization-** a process that uses the ratio of the scattered light to the emitted beam intensity. Normalization of Turbidity Signals (NTS) $=I_{90}/I^{o}$ where $I_{90}$ is the scattered light intensity and $I^{o}$ is the emitting light intensity

**Purpose:** In accordance of 30 TAC 290.39(l), On behalf of Swan Analytical USA and Hurst Creek MUD, we are formally requesting an exception for our turbidity analyzer, SWAN AMI Turbiwell WLED, regarding the ***primary calibration*** of once every 90 days[30 TAC 290.46(s)(2)(B)(iii)].

*Request #1*: Swan Analytical wishes to request that a *calibration (slope adjustment)* with primary standards (Formazine) only be required if a *verification* with primary standards is outside of the instruments error range.

Request#2: Swan Analytical wishes to request that a *verification* with primary standards (Formazine) only be required if a verification with secondary standards is outside of the instruments error range.

**Background:** Swan Analytical Instruments and the TCEQ agreed on a pilot study to obtain data that would show the performance of the Swan AMI Turbiwell over a period of time. Throughout this time period, the AMI Turbiwell was subject to various calibrations and verifications. The pilot study that was approved stated that Swan was to perform the below:

*Initial 12 months*

-Primary Calibration once every 90 days

*Subsequent 6 months*

-Verification with primary standard of known turbidity every 90 days

*Weekly*

-Verification with proprietary standards provided by Swan or other method in 30 TAC

This pilot study was to be performed for 18 months. At the request of the TCEQ, the exception was requested to be submitted early due to the data the pilot study showed. The data obtained during the course of the pilot study as well as the overall operation of the Swan AMI Turbiwell is analyzed and discussed in this request.

**Operation**

*Instrument:* The Swan AMI Turbiwell WLED is a non-contact, white LED turbidity analyzer. The optical windows are not in direct contact with the sample. This placement of the optics eliminates fouling that can be caused by the sample (Fig. 1). The optical widows are also heated to prevent condensation on the lenses. This condensation could cause inaccurate readings due to covering of the lenses. Furthermore, unlike a tungsten light source, the light source of the AMI Turbiwell is a white LED which does not degrade and is rated at 100,000 hours.

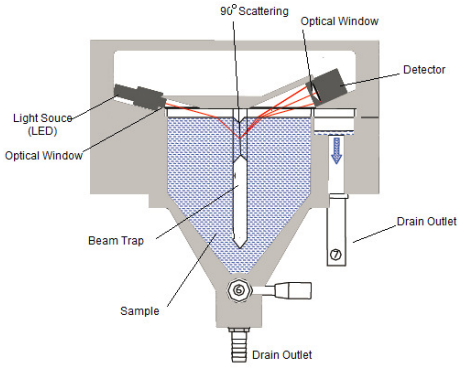
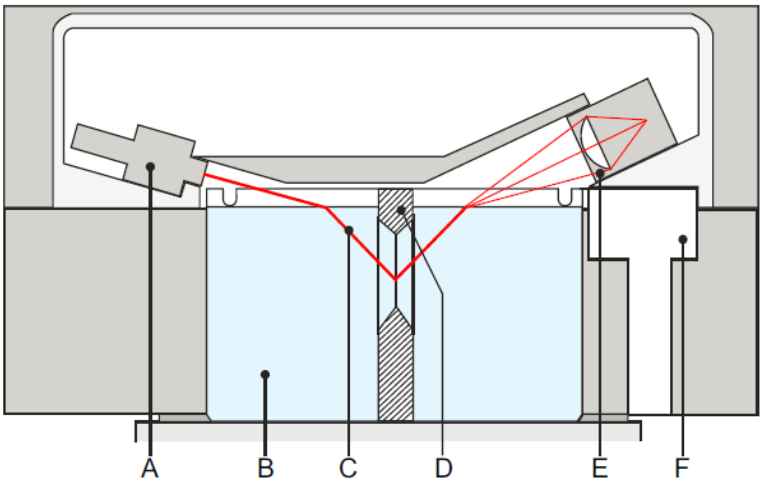



**Fig. 1**

*Measuring Principal:* The light beam of the LED impinges the water surface and is refracted. The refracted light is detected at an angle of 90°. A special design of the sample chamber, consisting of a barrier, eliminates interferences due to reflected light (Fig 2.) Furthermore, compensation is achieved by normalization. Normalization is achieved by the beam splitter which is a semi-transparent mirror within the light source that directs a portion of emitted light to a photodiode which records the emitted beam intensity. By using the ratio of the scattered light to the emitted beam intensity, fluctuations in the light source can be compensated and therefore eliminated.




***A*** *LED*
***B*** *Sample*
***C*** *Light beam*
***D*** *Barrier*
***E*** *Detector*
***F*** *Drain*

**Fig. 2**

**Calibration**: Calibration of a turbidity analyzer is necessary when variables like lens or light source integrity are not adjusted for or taken into account in normal operation. If you have sample covering the optics or a dimming light source, than an adjustment of the analyzers slope must be performed. With the Swan AMI Turbiwell, these variables have been eliminated. An onsite, field calibration with primary standards is not necessary. The semi-transparent mirror sends a portion of the LED light source to a photodiode sensor. This sensor monitors the intensity of the light source and automatically compensates for it at the detector. If any degrading is encountered, it is adjusted for at the detector portion.

*Factory Calibration*

The AMI Turbiwell is factory calibrated with Formazine. This standard is a 20NTU concentration. The zero point is determined using turbidity free water passed through a 0.45µ filter. An electro optical zero point is also determined which consists of powering off the LED and monitoring any source of light or background noise. This is completed automatically every night at midnight.

**Verification**

An onsite calibration where the slope is adjusted is not necessary with the Swan AMI Turbiwell. There are, however, means of verifying the calibration curve. This check will determine if the instrument is holding at its established calibrated values.

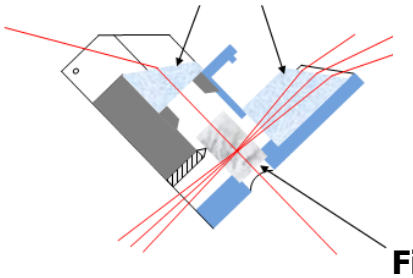


**Fig. 3**

*Secondary Standard (proprietary):* SWAN has developed a verification kit (Swan Veri-Kit™) which consists of a glass prism (Fig. 3). This prism is measured in the factory and determined to have a known turbidity value. The Swan Veri-Kit is mounted in the flow

cell in such a way that it simulates a sample (Fig. 4). An automatic procedure is carried out in the controller to calculate a percent deviation which takes into account the actual value vs. expected (set point) value. If this percent deviation is greater than +/-10%, the verification fails. If the verification is less than +/-10% then it passes. All verifications are stored in the controller and retrievable up to 64 points. Verifications with secondary standards can be done as frequent as required by each state.

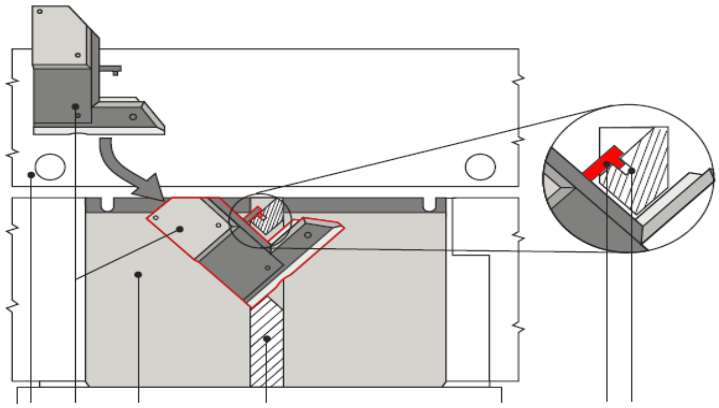


**Fig. 4**

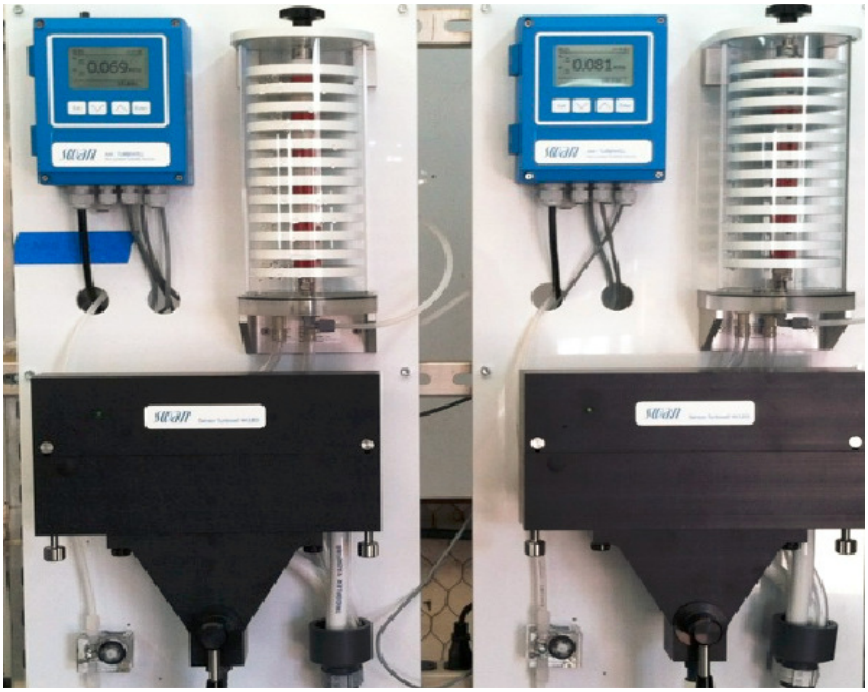
*Primary Standard*: Verifications with prepared primary standards are also possible. The user programs the set point or standard concentration that is prepared and introduces it in the Turbiwell flow cell. This simulates a sample ran at a known turbidity. A percent deviation is calculated and is stored in the controller.

*Alarm Function:* Swan has equipped the AMI Turbiwell with numerous alarm capabilities to ensure that the in-process reading is an accurate representation of the sample. To name them all would be time consuming but pertinent ones would be failure of the LED or the reference photodiode. These both are monitored at all times and if failure occurs, the transmitter will see it and issue an alarm. This alarm would need to be addressed by the user.

Pilot Study

Location: Hurst Creek MUD, 101 Trophy Drive, Lake Way, TX

Start Date: 3/2012



**Installation**

As part of the protocol, Swan was instructed to install one AMI Turbiwell at a point in process where it can be monitored as well as easily accessed. The application point for this unit was finished water in the high service pump room at Hurst Creek MUD. In addition to installing one AMI Turbiwell per the proposed protocol, Swan installed a second identical AMI Turbiwell on the same sampling point as the Protocol analyzer. The purpose of this second unit was to not be calibrated but only verified using secondary standards monthly. These two units were labeled according to their serial numbers.

*Instrument information:*

Protocol Instrument

AMI Turbiwell WLED

Product Number: A-25.411.700.1

Serial Number: 1154

Non-Protocol Instrument

AMI Turbiwell WLED

Product Number: A-25.411.700.1

Serial Number: 1153

As part of quality monitoring, as well as to rule out any anomalies, flow meters and degassers were installed on both instruments. Both units were equipped with Modbus RS485 cards to output all data to a SCADA system.

The sampling point was *finished water* in which both Turbiwell units were sharing the same sample. A third party instrument was also monitoring this point, for compliance, so that the data can be compared. The Swan Turbiwell's were mounted on strut which was stretched along a grated floor (Fig. 5). The instability of this foundation leads to a few anomalies in the readings. Vibration and movement from walking on the grated floor caused the units to shake. This shaking can lead to a slight elevation of values over a period of a few seconds. This will not be seen in normal operation where the unit would be permanently mounted.

**Fig. 5 Picture of Installation**

**Data Overview**

As per the protocol, Swan Analytical USA along with Hurst Creek MUD was to calibrate the Protocol Instrument (SN1154) using a 20NTU Formazine standard. These calibrations were performed once every 90 days. The NTU value before calibration, the value after calibration, and the calibration factor were recorded. This was to be performed for an initial period of 12 months. For a subsequent period of six months, Swan was to perform a verification of the Turbiwell's value using a primary standard of known Turbidity. These verifications were to not affect the slope of the calibration curve of the Turbiwell. These verifications were to be performed once every 90 days. In addition to the quarterly calibration and verifications, Swan Analytical was to perform weekly verifications using secondary standards. All data from verifications and calibrations were to be logged in a workbook provided by Swan. A copy of that book will be submitted along with this paper.

*Primary Standard Value:* 20NTU

The 20 NTU standard is prepared by diluting a 4000NTU stock standard.

*Veri-Kit Value* (Secondary Standard): 0.490NTU, 0.510NTU, and 17.7NTU.
These values were chosen to check the curve up to 20NTU. In normal operating condition, one kit, either low NTU or high NTU, is necessary to verify the calibration curve.

## Data Analysis

The AMI Turbiwell's used Modbus RS485 (digital) to transmit data to a SCADA system. All values such as NTU, flow, raw signal, case temperature, etc were programmable to be transmitted to archive. The Swan AMI Turbiwell's had a filter time constant (signal averaging) of 30 seconds whereas the 3rd party 180.1 compliant turbidimeter had a 90 second averaged signal. This will be noticed with the standard deviation as well as just overall sensitivity of the data. Each calibration factor was logged in a workbook and also noted in this paper (Fig. 6). Each verification value and percent deviation were recorded in a log book but not placed in this paper due to size of data. See separate file labeled "TCEQ Secondary Verifications".

*Primary Calibration Data*

| | Value Before Calibration (NTU) | Value After Calibration (NTU) | Calibration Factor |
|---|---|---|---|
| | | | |
| 3/23/2012 | 0.070 | 0.065 | 0.93 |
| 6/13/2012 | 0.058 | 0.050* | 0.92 |
| 8/22/2012 | 0.020 | 0.037 | 0.92 |
| 11/8/2012 | 0.035 | 0.033 | 0.92 |
| 2/6/2013 | 0.030 | 0.051 | 0.88 |

**Fig. 6** Calibration factors before and after as well as process readings.*Value in log book notes 0.117NTU. Proper rinse time wasn't allowed but the data shows the value did decrease from 0.117 down to 0.05 with proper rinse time observed.

*Secondary Verification Data*

As stated above, the secondary verification were performed using three Swan Verification Kits each consisting of a known turbidity value. These kits were valued at 0.490NTU, 0.510NTU and 17.7NTU. The data received differed in some fashion as one would expect given the known error associated with this method. Typical errors can be explained with fogging of the standard from humidity, high ΔT between standard and flow cell environment, and operator error (smudges, fingerprints, etc). The value range of secondary verifications, while majority passing +/- 10%, can be explained by the above reasoning. However, according to the data of the Protocol Turbiwell, the changes in the verification percent deviation were more pronounced immediately following a primary calibration with Formazine. For the majority, it was still within the 10% acceptance criteria of the instrument but in a few cases, it was outside of the acceptable limit.

*Process Data*

The raw data was analyzed at 10 minute intervals and shown to be stable throughout the pilot study timeframe. The trend lines of the three instruments tracked identically with a visible offset to the 3$^{rd}$ party compliant turbidimeter. This offset is most likely due to the design of the Swan AMI Turbiwell. The non contact, WLED design allows for a very stable, low zero point calibration to be determined. The difference can be attributed to the zero point calibration. The average values off the three analyzers sharing the same process sample were calculated (Fig. 7).

| Month | Non Protocol Turbiwell SSN1153 | Protocol Turbiwell SN1154 | 3rd Party EPA 180.1 Compliant Turbidimeter |
|---|---|---|---|
| Mar-12 | 0.07981 | 0.0843 | 0.1242 |
| Apr-12 | 0.0971 | 0.099 | 0.1482 |
| May-12 | 0.0764 | 0.0722 | 0.1302 |
| Jun-12 | 0.0482 | 0.0475 | 0.1016 |
| Jul-12 | 0.0403 | 0.0406 | 0.0945 |
| Aug-12 | 0.0327 | 0.0334 | 0.0847 |
| Sep-12 | 0.0283 | 0.0292 | 0.0756 |
| Oct-12 | 0.0334 | 0.0324 | 0.0776 |
| Nov-12 | 0.0378 | 0.0339 | 0.0821 |
| Dec-12 | 0.0395 | 0.0327 | 0.0799 |
| Jan-13 | 0.0388 | 0.0353 | 0.0774 |
| Feb-13 | 0.0347 | 0.0368 | 0.0697 |
| Mar-13 | 0.0377 | 0.0378 | 0.0667 |

**Fig. 7** Average NTU values of three Turbidimeters with data collected every 10 minutes. Turbidimeter A remained non-calibrated with only monthly verification with secondary standards while Turbidmeter's B and C were calibrated quarterly per the requirements

The values show the offset between the Swan AMI Turbiwell and the 3rd party turbidimeter, however, the trend of such data tracks well for all three instruments as seen in Fig 8.

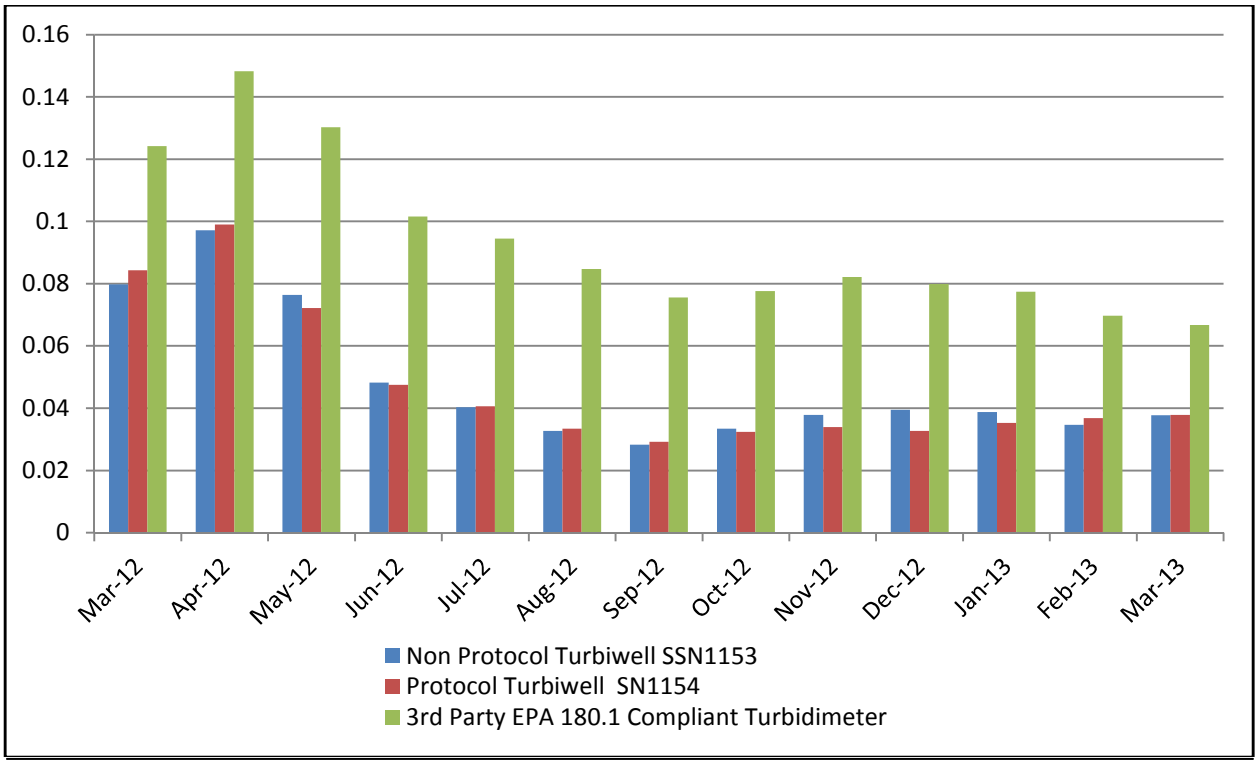



**Fig. 8** Average values are plotted. The difference between the three instruments are visible, however, the overall trend is consistent.

As discussed above, this offset can be contributed to the zero point calibration.

*Monthly Data Representation*

After graphing the monthly raw data (see excel sheet for data) for SN1153, SN1154, and 3rd Party instruments, numerous spikes are visible. Further analysis shows that the spikes were contributed to the weekly verifications or quarterly primary calibrations denoted by (V) or (C) respectively. Time stamps were started by the operator months in so for the first few months' time stamps are not available. These time stamps are helpful in determining when verification is done, however, this can also be seen since we had flow being archived in SCADA. We can see in the raw data that flow was off due to the verification or calibration process. We can differentiate it from an in process high reading. In normal process this will not be a problem since one verification kit will be used. In this study, we were using three kits and since the instrument only stores the

last 64 verifications, the oldest data will not be saved. Also, note that a few graphs these spikes will not be seen since you can hold the data transmission by going into the verification or calibration process before altering and condition (i.e. shutting flow off, opening flow cell, etc).

## Conclusion

Swan has determined that a primary, on-site/field calibration is not necessary due to the method and design of the AMI Turbiwell. The values that are expressed are taken from a calibration curve established with Formazine. This is done during the initial factory calibration at Swan and the calibrated slope is stored in the instrument. The most common causes of 'drift' in turbidity analyzers are the fouling of the optics and degradation of the light source. These two variables are eliminated due to the design of the AMI Turbiwell. Throughout the pilot study at Hurst Creek MUD, the Swan AMI Turbiwell's showed their stability and consistency. The Protocol Turbiwell (SN1154), even though calibrated, trended well with a non-calibrated Turbiwell measuring the same sampling point. The non contact, WLED Turbiwell design showed that process conditions did not alter the calibration curve. The non-calibrated Turbiwell (SN1153) remained in calibration for the pilot study period and showed a lower % deviation during secondary verification. The calibration of the Swan AMI Turbiwell didn't show a substantial effect on the low NTU reading but it did introduce error at the high NTU range >0.5NTU. The data shows that an onsite, field calibration is not necessary in order for the Swan AMI Turbiwell to monitor process conditions. For these reasons, Swan Analytical Instruments requested an exception regarding ***primary calibration*** of once every 90 days [30 TAC 290.46(s) (2) (B) (iii)]. The exception was granted for region 11.