SWAN
ANALYTICAL INSTRUMENTS

DEVIATION IN TURBIDITY READINGS AT A LOW RANGE

WHITE PAPER

Irene Rüegg, Technical Support

SWAN Analytische Instrumente AG

Studbachstrasse 13

8340 Hinwil

Switzerland

Table of Content

1 Introduction

The turbidity readings of different turbidity analyzing instruments may deviate up to 0.020NTU/FNU in the low range. The Standard Methods ISO 7027 and the EPA 180.1 define the formazine stock standard of 4000 NTU/FNU, but the zero point of the turbidity scale, as well as the turbidity values above 4000 NTU/FNU, are not defined explicitly. The turbidity of Particle Free Water (PFW) is expected to be zero, as the term PFW states, but in practice many users assign a turbidity value to PFW that is in the range of 0 – 0.020 NTU. This may lead to deviations of values in a low range, if different instruments are compared.

This “white paper” will illuminate this topic, to be able to interpret the different influences that interfere with the “zero” measurement.

2 Basics

2.1 Contributions to the instrument baseline

The measured value of the scattered light of Particle Free Water, is considered the baseline of a turbidimeter. There are different contributions that add to the electric signal of the photo detector:

- molecular scattering: media used for zero baseline, Particle Free Water (PFW), scatters the light depending on the wavelength to a certain extent
- background contribution: reflection on measuring cell walls, characteristics of optical system
- electric contribution

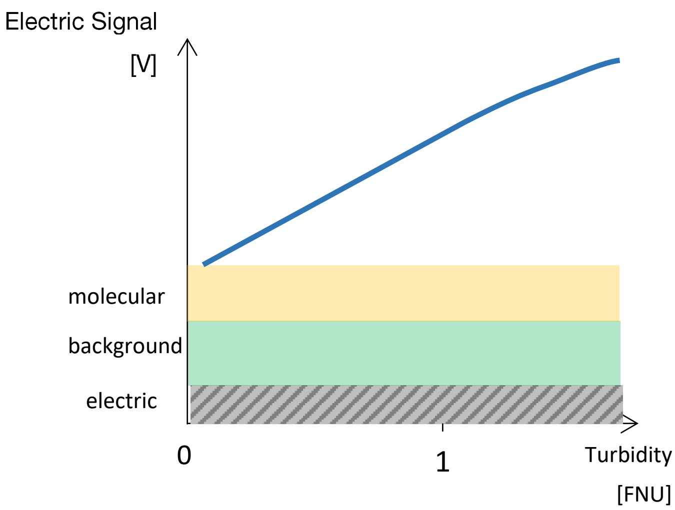

Figure 1 Contributions to the electric signal of the of the photo detector

Through calibration the electrical signal and all the different influences are correlated to a turbidity value (FNU/NTU).

2.2 Molecular scattering

In Particle Free Water (PFW), even though there are no particles present, a slight scattering of the light beam is measured. This type of scattering by the water molecules is called Rayleigh scattering. The intensity of the Rayleigh scattered light is related to the wavelength of the light. Blue light (λ = 400 nm) is scattered ten times more efficiently than red light (λ = 710 nm) and so the intensity of the scattered light depends on the spectrum of the illuminating light source. That is why the “turbidity value of PFW” is not constant, it depends on the type and the operating conditions of the light source.

The typical range for the “turbidity of PFW” for white light instruments is 0.01 - 0.02 NTU (cf. M.J. Sadar, Turbidity Science, Hach company, p.11, 1998). ISO 7027 type instruments measure turbidity with near infrared light (λ = 860 nm); Rayleigh scattering with 860 nm light is approximately 20 times less intense than with blue 400 nm light. The typical range for the “turbidity of PFW” for ISO 7027 type instruments is 0.003 - 0.007 FNU.

2.3 Background contributions

Depending the instrument setup, the influence of the reflected light from the walls of the measuring cell could add to the electric signal. Even though, with a clever design of the instrument, this influence can be kept very low, it is not possible to avoid it completely.

2.4 Electric contributions

The electric signal of the photo detector is evaluated for the measurement. The electric offset of the signal amplifier can be easily determined by turning off the light source. This effect can be compensated with the corresponding offset.

3 Calibration process

3.1 General background information

Turbidity and the method for determining the turbidity in water samples is defined by the standards ISO 7027, EN 27027 and EPA 180.1 respectively.

The intensity of the scattered radiation depends on:

- type of scattering particles (shape, color, etc.)
- their concentration
- their size distribution
- the wavelength of the measuring light
- and the angle between the illuminating beam and the measured scattered beam

The method for determining the turbidity by means of the scattered radiation requires the angle between the incident radiation and the scattered radiation to be 90° (± 2.5° ISO 7027; ± 30° EPA 180.1). This measuring arrangement is called nephelometry.

The wavelength of the incident radiation must be 860 ± 30 nm according to ISO 7027. In contrast, EPA 180.1 requires a tungsten halogen lamp ("white light source") operated at a color temperature of 2200 - 3000°K (white light LED is accepted), for nephelometric measurements. The detector and any filter system must have a spectral peak response between 400nm and 600 nm.

The philosophy of a brand and the hardware setup of an instrument are important for the interpretation of a turbidity reading in the low range of 0-1NTU. The disadvantage of including the Rayleigh scattered light of PFW in the "formazine turbidity scale" is a variable zero mark and hence a varying graduation for different methods and instrument brands. SWAN Turbidity meters compensate all the influences, including electric amplifier offset, background stray light and molecular scattering of deionized PFW with the factory zero calibration.

Drinking Water Inspectorate (DWI) WRc Ref: UC9882/15891-0 March 2014 "A critical appraisal of existing guidance on online monitor performance data" WRc Ref: UC9882/15891, states:

… It is a known fact and since it is likely that the majority of laboratories will use Hach bench instruments and it may simply be that there is an instrument-dependent factor which tends to give higher readings on water samples associated with the optical arrangements of these instruments…

To satisfy the customer needs, who wants to compare readings of turbidity analyzers of different brands, SWAN implemented a parameter, which allows to adjust the offset of the zero baseline.

3.2 Calibration with Formazine

Turbidity is not a substance-specific property. Since the above parameters and their influence on the scattering intensity are generally unknown, no absolute value for the turbidity can be calculated.

Therefore, the turbidity is measured as a reference to a reference standard, formazine. Its preparation and handling are described exactly as in the standards. Formazine is chosen for its characteristics of uniform particles in shape and size. The stable stock solution of Formazine with a value of 4000NTU/FNU is diluted to calibration standards of various turbidity.

3.3 Zero - Calibration

A Zero-calibration is necessary to correct all the previously mentioned factors, that are related mostly to instrument specific setup and design (light source, background stray light,…) , the electric signal and the molecular scattering.

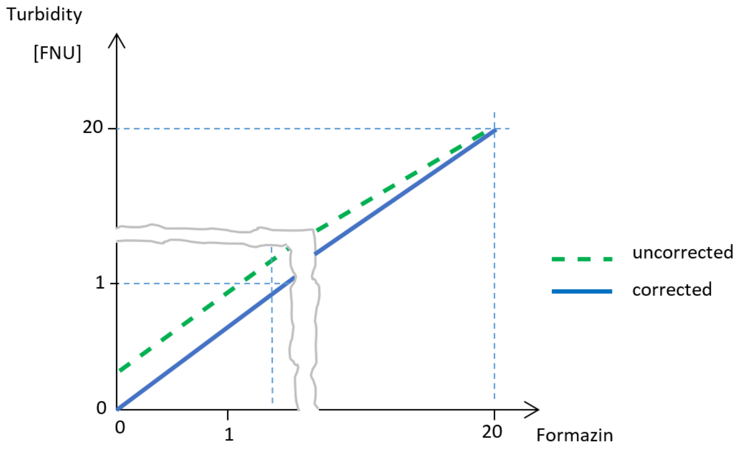

Figure 2 Example of a calibration with a 20 FNU Formazin Standard solution and without (uncorrected) /with (corrected) zero calibration with PFW

Whether or how a zero-calibration is performed is a matter of the philosophy of the turbidity analyzer manufacturers.

With the zero-calibration performed with PFW, the baseline-value is set equal to the PFW value determined for this specific instrument. The blank reading done with PFW includes the scattering of PFW and the background stray light, which can only be measured in combination. The electric signal offset of the instrument is also eliminated with this calibration.

The measured readings of an instrument calibrated with this method will be the “particle - turbidity” of the sample.

4 SWAN Turbidity Instruments

4.1 Optical Setup

SWAN's turbidity instrument "AMI Turbiwell" is designed in a way, that many sources of side effects that can add to imprecision of the turbidity readings, are eliminated.

- contact free optical system to avoid coating by adherent substances and/or fouling
- heated glass lenses to avoid condensation
- wide beam diameter of 5mm (signal more stable)
- electrical offset correction performed daily
- zero calibration performed with PFW

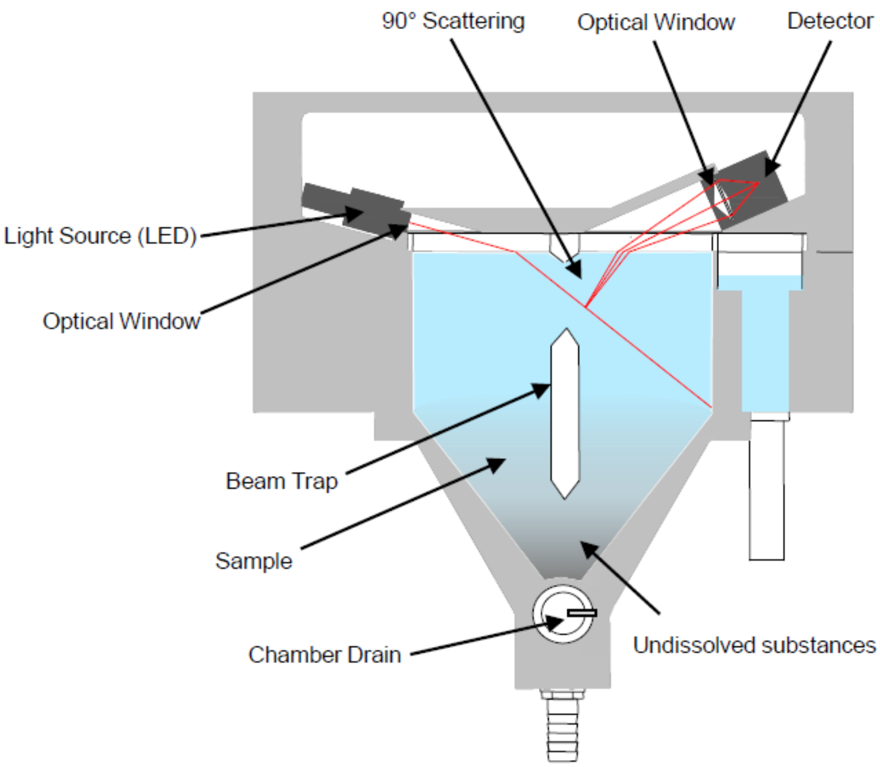

Figure 3 Optical setup of AMI Turbiwell

4.2 Zero-Calibration at SWANs Wet-Bench

The zero-calibration at SWAN's wet bench is performed with properly filtered particle free water. The PFW for the blank is prepared from the deionized water loop. The water is recirculated through a submicron-filter, that removes particles. The turbidity of this blank sample is measured with a reference turbidimeter equipped with another submicron-filter that can be switched into the line. If this additional filter does not reduce the turbidity further, the sample is accepted as a blank for the calibration.

With this calibration method, all influences, background stray light and molecular scattering of PFW, are eliminated.

4.3 Dark measurement

To correct the electric offset, the measurement with light source turned off, is applied. This “dark-measurement" is performed daily and therefore any possible drift is corrected on a regular basis.

4.4 Zero Baseline Offset

To be able to compare different turbidity analyzers, the method of calibration for the zero baseline must be considered. Our SWAN Turbidity meters compensate all influences, electric amplifier offset, background stray light and molecular scattering of PFW, with the factory zero-calibration. To satisfy the customer needs, who wants to compare readings of turbidity analyzers of different brands, SWAN implemented a parameter, which allows to adjust the offset of the zero baseline.

4.4.1 Example of applying "Zero Baseline Offset"

- Calibration of a Swan turbidity meter (including zero baseline of PFW) and a reference instrument with a Formazine standard solution of 1 FNU.
- Zero baseline of 0.020 FNU added to the Swan values to meet the values of the reference instrument in the low range.

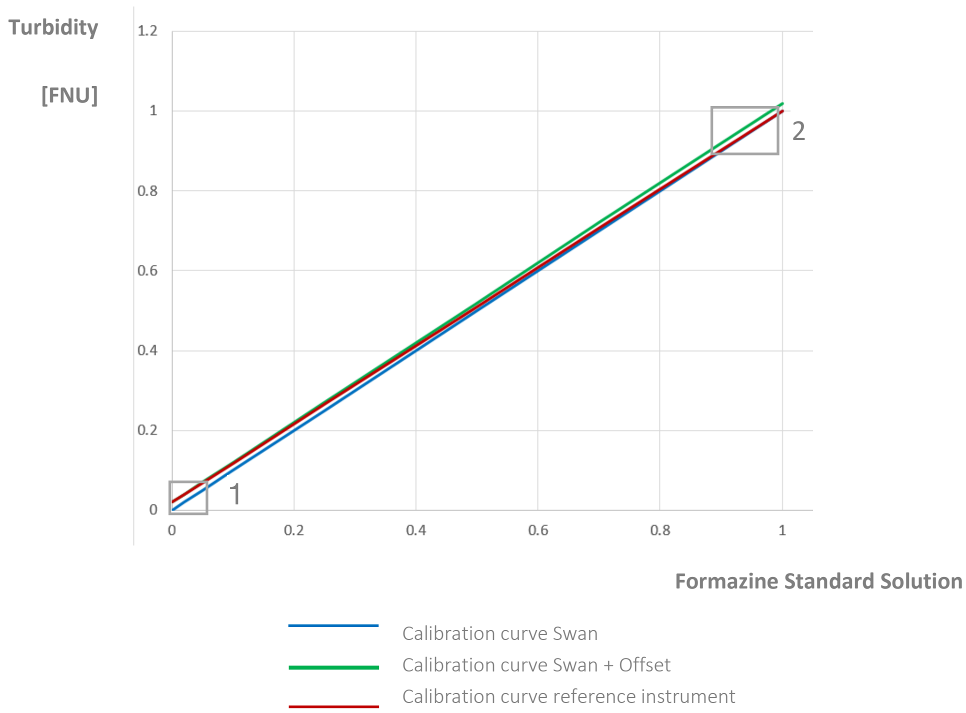

Figure 4 Calibration curves turbidity range: 0 – 1 FNU

The "Zero Baseline Offset" of 0.020 FNU, which is introduced to the calibration curve of the Swan instrument to match the value to the reference instrument, minimizes the difference between the two instruments in the low range.

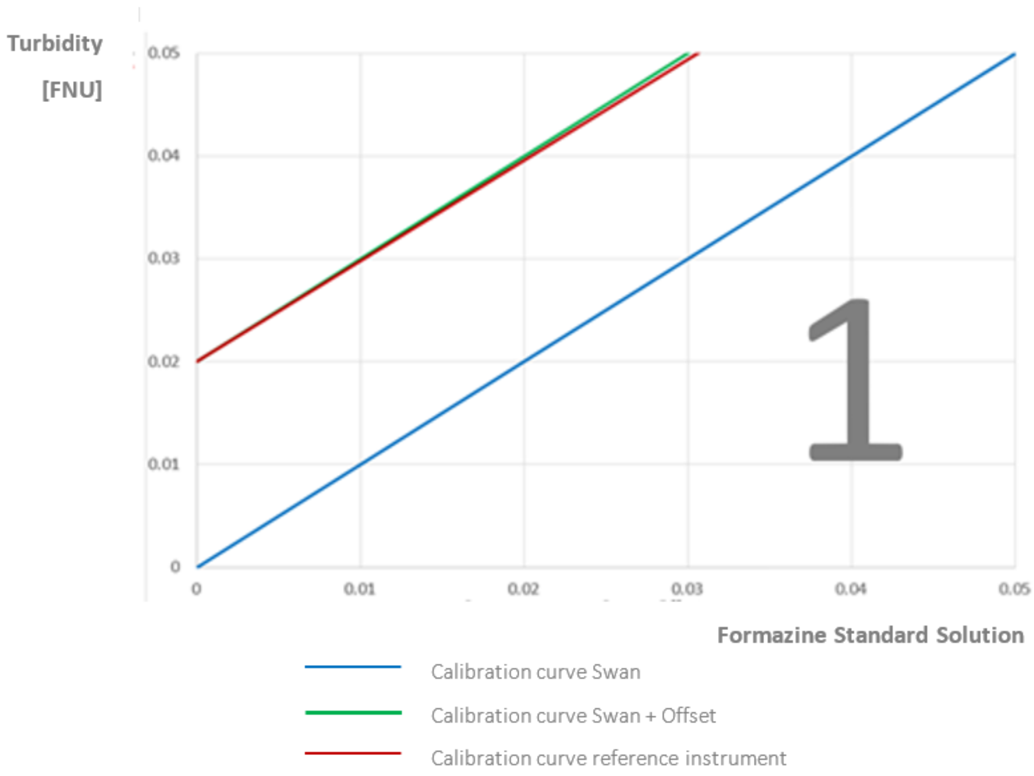

Figure 5 Calibration curves turbidity range: 0.00 – 0.05 FNU

In figure 5 it is visible that the two calibration curves, of Swan with a "Zero Baseline Offset" and of the reference instrument", match very well in this low range.

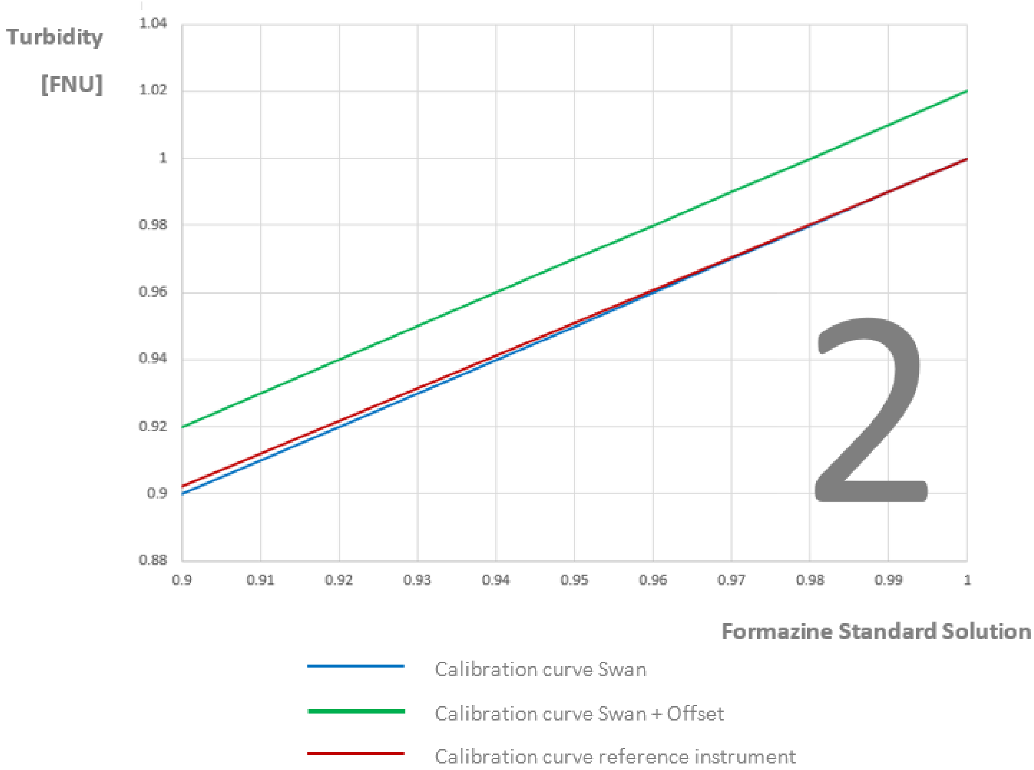

Figure 6 Calibration curves turbidity range: 0.9 – 1.0 FNU

In the higher range, around the calibration point 1 FNU, the values diverge from each other, up to the value of the offset, in this example 0.020 FNU (figure 6).

This effect depends on the calibration points. The impact of the "Zero Baseline Offset" is less relevant as higher the calibration value is chosen.