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Validation of PendoTECH's Next-Generation Single Use Turbidity System

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Abstract

This poster summarizes upgrades made to PendoTECH®'s turbidity system, as well as the validation of this product update. A new advanced photometer with an enhanced response, improved accuracy, and the ability to read up to 3.00 AU is reported. The system includes the addition of a flow cell stand, which not only blocks ambient light, but also makes the system much more convenient for use as flow cells are essentially "dropped" into place. In order to analyze the extent of these upgrades, extensive validation testing was performed. NIST traceable Formazin NTU turbidity standards were circulated through PendoTECH single use flow cells with optical path lengths of 6.5cm, 1cm, and 0.5cm. Flow cells with each path length were tested to evaluate the relationship between absorbance (AUs) and Turbidity (NTUs). The results demonstrated a linear correlation between the turbidity values and absorbance readings ($R^2 > 0.99$ for each path length), as well as minimal variance from flow cell to flow cell. Therefore, these changes have significantly upgraded the performance, dynamic range, and overall usability of PendoTECH's Single Use Turbidity System.

Background

Turbidity is the relative clarity of a liquid as the result of suspended solids in the liquid. Turbidity measurements typically use a beam of light to detect the presence of particles by measuring the difference between the amount of light that is emitted from a light source and the amount that is received by a detector. PendoTECH's system utilizes "forward light scattering" to measure turbidity, which means it detects the scattering of light that passes straight through the sample. (Figure 1)

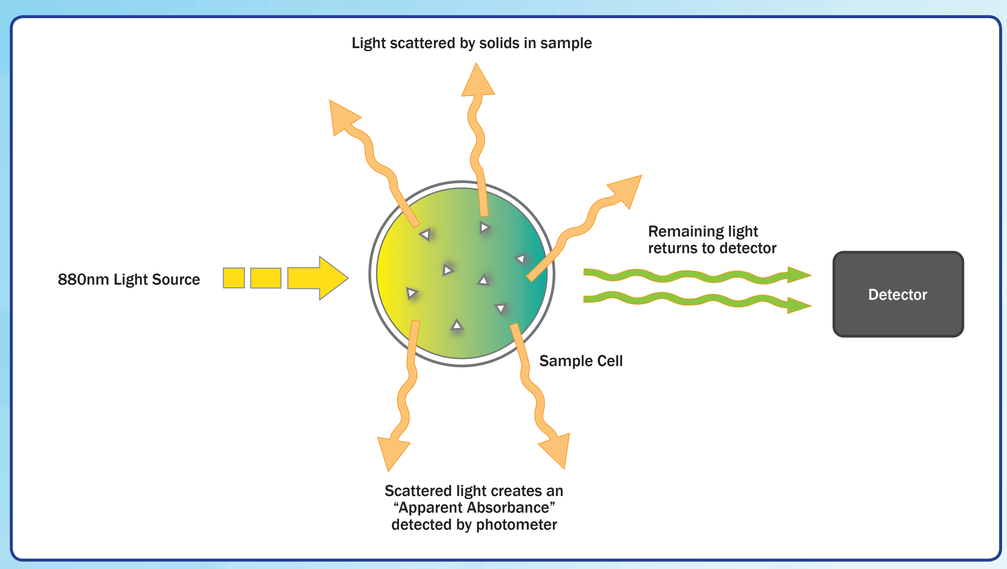

Figure 1: Example of a forward light scatting turbidity measurement system

In bioprocess operations, the turbidity of the liquid is often measured to monitor unclarified material leaving a bioreactor or fermentation vessel. Turbidity is also often measured post-filtration to detect "break through," or undesired materials coming from a filter, which can provide an overall assessment of filter performance.

Presently, turbidity measurements are generally made through off-line sampling. However, this is inefficient and often disruptive to the bioprocess. Conversely, PendoTECH's system takes inline measurements, allowing users to monitor turbidity in real time. Additionally, the system utilizes a single use flow cells, which enables measurements to be made non-invasively (no physical product contact) and eliminates typical maintenance requirements, such as calibration or cleaning.

Overview of Turbidity System

The PendoTECH Turbidity System is a compact photometer equipped with an 880nm light source and fiber optic cables that connect to a flow cell stand which houses the single use turbidity flow cell (Figure 2). Recently, PendoTECH has made significant upgrades to this system with the inclusion of an advanced, high-performance photometer, and the addition of a new flow cell stand.

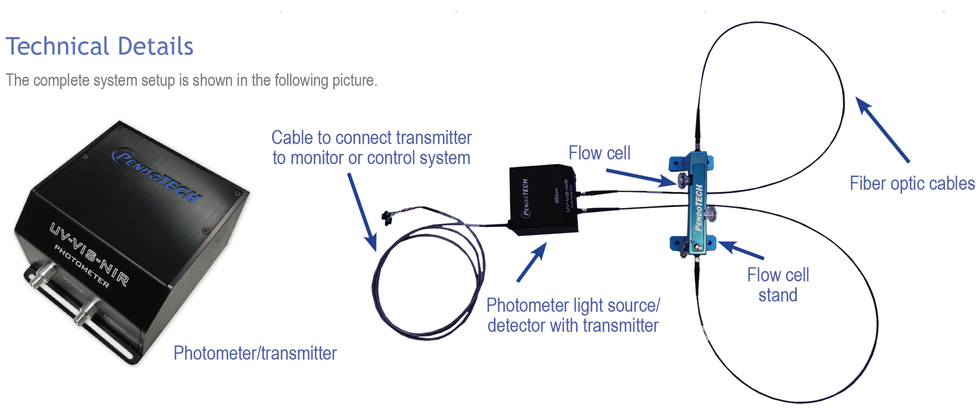

Figure 2: PendoTECH Turbidity System setup

The advanced photometer, which is the same hardware as PendoTECH's dual-channel photometer, has an enhanced response and improved accuracy, an illuminated indicator that indicates the status of the device, and the ability to read up to 3.00AU. The photometer is also available in either a benchtop or panel mounted version. The addition of a flow cell stand (Figure 3) is also a crucial aspect to this upgrade. The stand makes PendoTECH's turbidity system much more convenient for use as flow cells are essentially "dropped" into place, thus enabling them to be swapped in and out of the system with ease. The stand also acts as a barrier to ambient light and is designed to minimize air bubbles, both of which can negatively impact the readings.

Figure 3: The large flow cell stand (left) accommodates 6.5cm path length flow cells, while the small flow cell stand (right) can hold all other flow cell sizes.

Validation Testing and Results

Extensive validation testing was performed in order to evaluate the accuracy, repeatability, and true dynamic range of PendoTECH upgraded turbidity system. NIST traceable Formazin NTU turbidity standards were used analyze the correlation between turbidity (in NTU) and absorbance (as measured by the system in AU). The standards were circulated through PendoTECH single use flow cells with optical path lengths of 6.5cm, 1cm, and 0.5cm. The average and standard deviation of the readings were calculated across 3 or more flow cells of each type to characterize the performance.

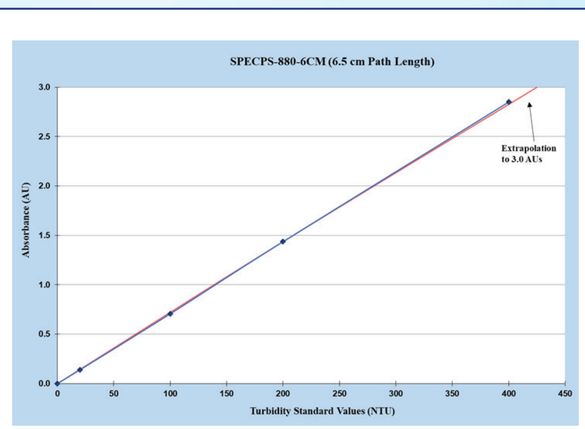

Figure 4: 6.5cm flow cell performance

NTU standards of 20, 100, 200, and 400 NTUs were circulated through a 6.5cm flow cell and the corresponding absorbance values measured from the PendoTECH unit were recorded. The results demonstrate the linear correlation between the turbidity values and absorbance readings ($R^2 > 0.9999$) . An extrapolation to 3.0 AUs correlated to turbidity value of approximately 425 NTUs.

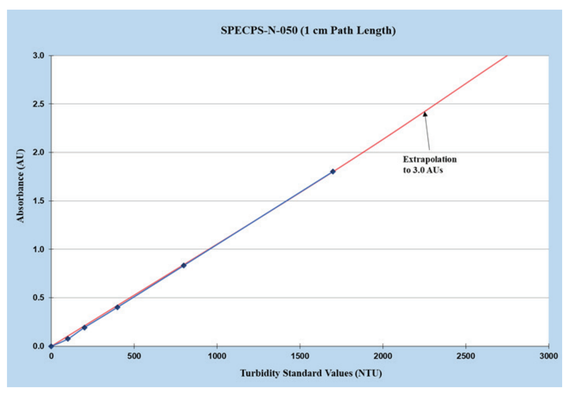

Figure 5: 1cm flow cell performance

NTU standards of 100, 200, 400, 800, and 1700 NTUs were circulated through a 1cm flow cell and the corresponding absorbance values measured from the PendoTECH unit were recorded. The results demonstrate the linear correlation between the turbidity values and absorbance readings ($R^2 = 0.9998$). An extrapolation to 3.0 AUs correlated to turbidity value of approximately 2750 NTUs.

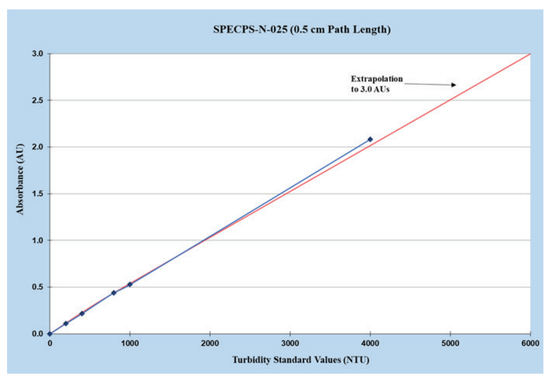

Figure 6: 0.5cm flow cell performance

NTU standards of 200, 400, 800, 1000, and 4000 NTUs were circulated through a 0.5 cm flow cell and the corresponding absorbance values measured from the PendoTECH unit were recorded. The results demonstrate the linear correlation between the turbidity values and absorbance readings ($R^2 = 0.9999$). An extrapolation to 3.0 AUs correlated to turbidity value of approximately 6000 NTUs.

Flow Cell Optical Path Length (OPL)	Approximate Dynamic Range (NTUs)	Approximate Accuracy*	Precision/Repeatability
6.5cm	0 to 425	± 10 NTUs	± 2 NTUs
1cm	0 to 2750	± 55 NTUs	± 14 NTUs
0.5cm	0 to 6000	± 120 NTUs	± 30 NTUs

*Exact accuracy in NTUs depends on an NTU to AU correlation curve, which can be developed via offline sampling.

Figure 7: Summary of performance for different optical path lengths

In conclusion, there is a highly linear correlation between the turbidity of the sample and the absorbance as measured by PendoTECH's Single Use Turbidity system. This data supports an overall accuracy specification of ±1% (±0.03AU) from 0-2AU and of ±2% (±0.06AU) from 2-3AU. An approximate conversion of this specification to NTUs is listed in Figure 7. The system does not have an exact NTU accuracy specification as this is dependent on an NTU to AU correlation curve, which can be developed with offline sampling and is specific to the sample. There was also very little variance from flow cell to flow cell, which resulted in an overall repeatability of ±0.5% full scale (±0.015AU) for the system