

## PendoTECH® Turbidity System

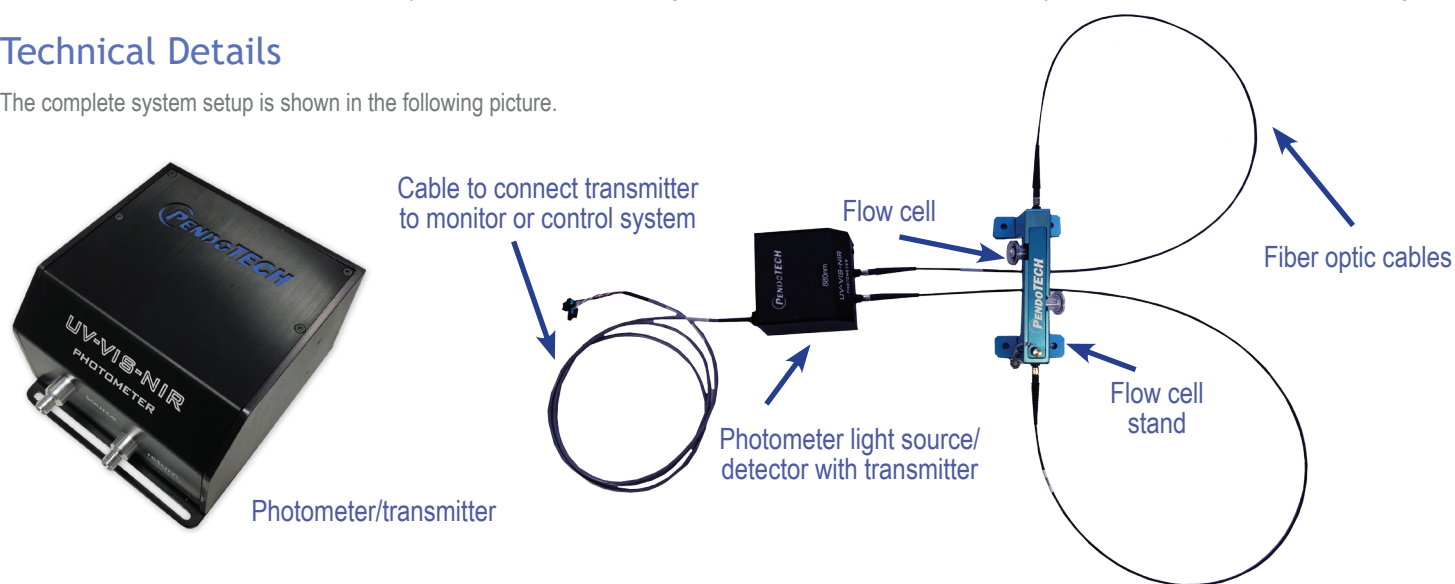
### Background

Turbidity can be defined as an optical property of a liquid that causes light passing through it to be scattered rather than transmitted. Simply stated, it is the relative clarity of the liquid and is the result of solids suspended in the liquid. Turbidity measurements are affected by not only the number of particles in the liquid, but also by the size and shape of the particles. Turbidity measurement detects the presence of particles by determining the difference between the amount of light that is emitted from the light source and received by the detector. The difference is a measure of solids in the light path that have scattered the incoming light. Most turbidity measurements utilize light in the near infrared (IR) region of the spectrum, especially at a wavelength of 880nm. The standard unit of measure of turbidity is the Nephelometric Turbidity Unit (NTU).

In bioprocess operations, the turbidity of the liquid, post filtration, is often measured as an indication of filter performance. It can also be used to measure unclarified material such as directly from a bioreactor or fermentation vessel. The measurement may indicate that undesired components are “breaking through” the filter meaning the filter is losing its retention capacity. The turbidity measurement at 880nm can be used in conjunction with pressure measurements in constant flow filtration processes to give an overall assessment of filter performance. To make a turbidity measurement, a sample may be drawn and measured off-line, or by an on-line measurement unit such as the PendoTECH Turbidity System consisting of the photometer light source/detector, flow cells, fiber optic cables, flow cell stand and cables to connect to monitor or control system. The PendoTECH Single Use Flow Cell can be used with the system to eliminate the need for cleaning.

### Technical Details

The complete system setup is shown in the following picture.



The PendoTECH Turbidity System is a compact photometer light source/detector equipped with an 880nm light source and fiber optic cables that connect to either the flow cell stand in which the single use turbidity flow cell is placed, or if a stainless steel flow cell, the fiber optics connect directly to the flow cell. The photometer houses a light source and detector that measures the difference in light transmitted that is a result of the turbidity of the liquid. There is no display or readout on the photometer/transmitter because it is designed to be integrated to a monitor with data acquisition capability or a control system via its transmitter function. The raw output of the transmitter is a milliamp (mA) signal that is scaled from 0 to 3Absorption Units (AU). In order to convert from AU to NTU, users must develop a correlation equation by taking samples of their stream and measuring its turbidity in NTU using an off-line instrument to develop the correlation. This step can be carried out only once to create the correlation for each unique stream. PendoTECH can provide estimations for a correlation based on NTU standards, but for best results one should be developed for each unique stream.

Conversion to units such as NTUs can be made by the monitor or control system by scaling the analog inputs on the monitor or control system using the previously determined correlation. For filter evaluation studies and filter screening with the PendoTECH Filter Screening System, one to four transmitters may be plugged directly into the system and the turbidity data can be collected with all the other process data. The single use flow cells must be placed into a flow cell stand to block ambient light; reducing any interference with the measurement. Stainless steel cells do not require use of the flow cell stand.

### Single Use Flow Cells

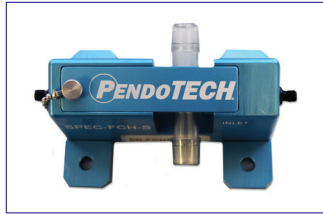
The PendoTECH Single Use Flow Cells enable the measurement to be made non-invasively. This flow cell contains a special silica glass lens installed within the optical path. The difference between the intensity of the light source and the detector is measured without any physical product contact. The stream to be measured flows between the lenses by way of tubing attached to the ports of the flow cell. For proper precision and repeatability, turbidity measurements below approximately 400NTUs, the 6.5cm flow cell is typically used. For greater than 400NTUs, the 1cm flow cell is typically used. Low cost of the flow cell makes it ideal for single-use applications, however the cell may be cleaned and re-used repeatedly. All polymeric materials in fluid path meet USP Class VI standards and flow cells are assembled in an ISO 13485 facility. The flow cell may be autoclaved once to 121°C or gamma irradiated up to 50kGy.



6.5cm Single Use Turbidity Flow Cell



6.5cm flow cell installed in stand



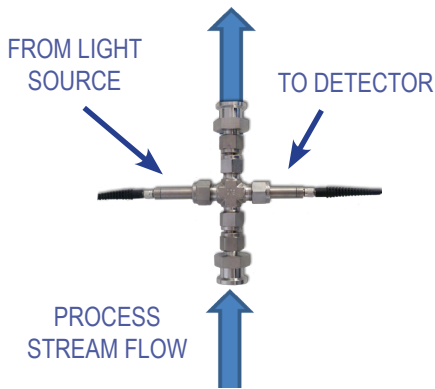
1cm flow cell installed in stand



1cm flow cell with tubing installed

## Stainless Steel Flow Cell Options

**1cm path length flow cell with TC fitting**  
(other inlet/outlet options available)

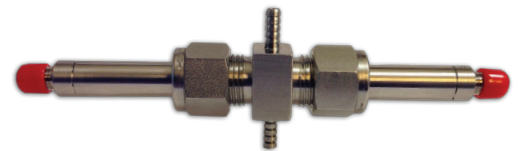


(Available inlet/outlet options)

**6.5cm path length flow cell**



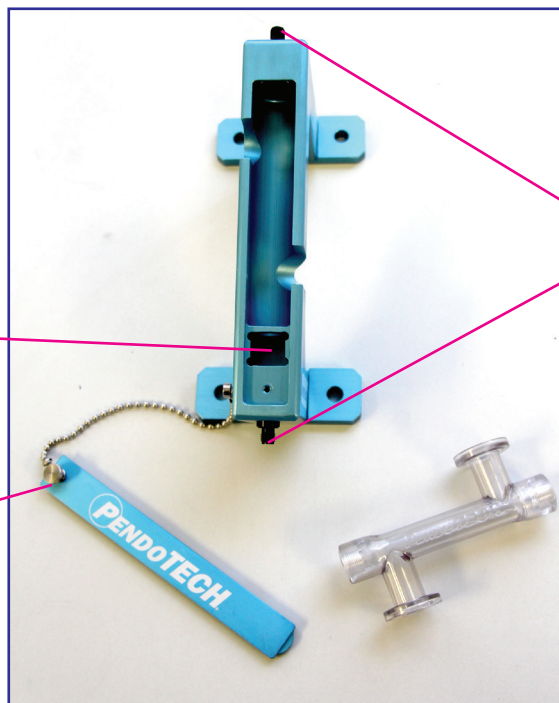
**Low hold-up flow cell**



## Flow Cell Stand Details

Stand features a compartment to place light filters for photometer calibration verification

Removable cover with thumbwheel to secure to stand



SMA905 connectors for connection of fiber optics



Flow cell stand for 1cm flow cell  
PART#: SPEC-FCH-S

Flow cell stand for 6.5cm flow cell  
PART#: SPEC-FCH-L

## Measuring Turbidity

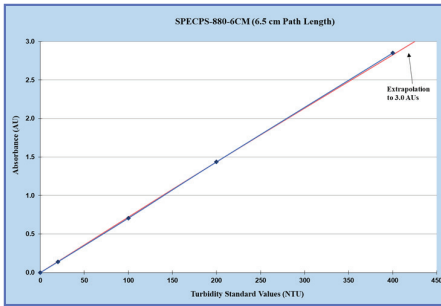
The PendoTECH Turbidity System operates on the principal of light scattering of particles at a wavelength of 880nm, which is the traditional wavelength for turbidity measurements. The raw reading of the instrument is AUs. This can be directly correlated to NTUs that are the typical units of measurement for turbidity. The correlation of AUs to turbidity is based on the path length. Some measurement units can detect the scattering of light that passes either straight through the sample (forward light scattering), scattering at 90 degrees, scattering back toward the light source, or some combination of all scattering modes. The PendoTECH Turbidity System exclusively uses forward light scattering. Because of its in line nature, and its ability to only measure forward light scattering, the precision/repeatability is noted below, and may not be comparable to a benchtop unit.

NTU Standard Measurement, Dynamic Range and Repeatability		
Flow Cell Optical Path Length (OPL)	Approximate Maximum Dynamic Range (NTUs)	Precision/Repeatability ( $\pm 0.5\%FS$ )
6.5cm	425	$\pm 2NTUs$
1cm	2750	$\pm 14NTUs$
0.5cm	6000	$\pm 30NTUs$

However, the correlation may vary between samples from different processes. For best results a product specific correlation from AUs to NTUs may be determined with multiple offline measurements to develop an AU to NTU correlation equation.

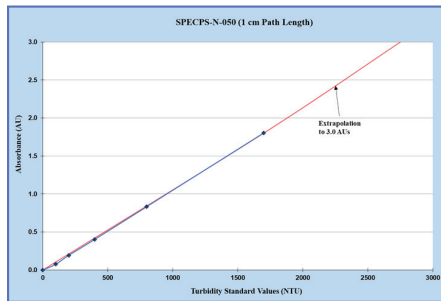
## Application Detail, Flow Cell Comparison with NTU Standards

Commercially available Formazin NTU turbidity standards from Hach® were used to analyze the performance of a PendoTECH Turbidity photometer/transmitter when used with flow cells of varying path lengths.



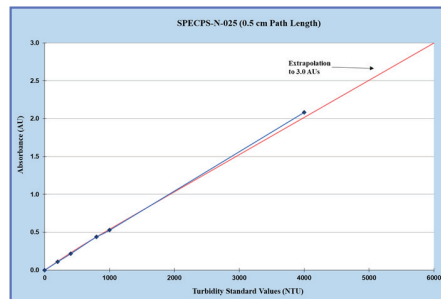
### 6.5cm Path Length Flow Cell:

NTU standards of 20, 100, 200, and 400NTUs 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. An extrapolation to 3.0AUs correlated to turbidity value of approximately 425NTUs.



### 1cm Path Length Flow Cell:

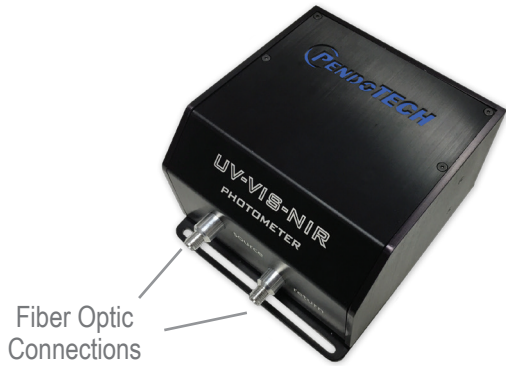
NTU standards of 100, 200, 400, 800, and 1700NTUs were circulated through a 1cm flow cell and the corresponding absorbance values measured from the PendoTECH unit were recorded. The results demonstrate the linear correlation between the turbidity values and absorbance readings. An extrapolation to 3.0AUs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



### 0.5cm Path Length Flow Cell:

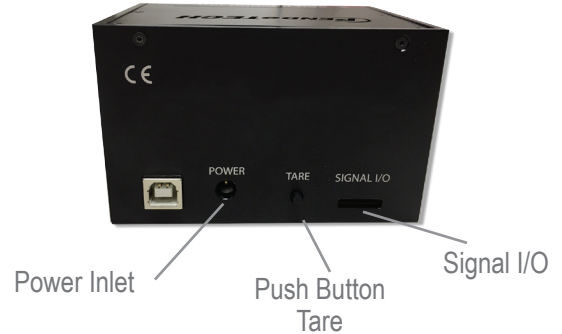
NTU standards of 200, 400, 800, 1000, and 4000NTUs were circulated through a 0.5cm flow cell and the corresponding absorbance values measured from the PendoTECH unit were recorded. The results demonstrate the linear correlation between the turbidity values and absorbance readings. An extrapolation to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

## Photometer/Transmitter Details



### Compact Photometer and Transmitter - Benchtop Version

Back panel view



Models Available:

#### Benchtop Version



Different cabling options available for integration to other equipment

#### Panel Mount Version

Screw Terminal Connector for:

- Power
- Baseline Tare
- mA Output



### Also Available - Dual Wavelength Photometer/Transmitter!

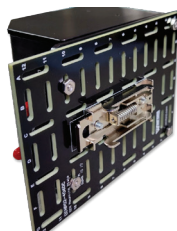
In addition to measuring turbidity at 880nm, with the dual wavelength photometer/transmitter, a second measurement can take place at a different wavelength. Measuring two wavelengths in the same sample simultaneously has many advantages in biopharmaceutical development and manufacturing. PendoTECH is proud to offer its popular UV/VIS/NIR unit in a two wavelength model. The PendoTECH Dual Wavelength UV/VIS/NIR unit can be equipped with 2 LED light sources from 255 to 1000nm with a reading from each wavelength every second using one flow cell.

### DIN Rail Adapter Mounting Plate

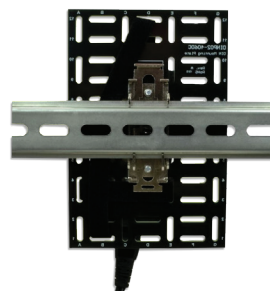
PART #: PHOTO-DR

The PendoTECH Photometer is available as a standalone bench top unit or in a panel mount model. When integrating the PendoTECH Photometer into an electrical cabinet there are several mounting options available (See Technical Note: PendoTECH Dual Wavelength Photometer Monitor/Transmitter Mounting Instructions). For mounting on a DIN rail installed in a cabinet there is a customized accessory available to streamline this process. It comes with the required hardware to mount the photometer:

- 4x #6 - 32 x 3/8inch Philips pan head machine screws
- 4x #6 - 32 Hex nuts



Spring loaded latch for easy removal

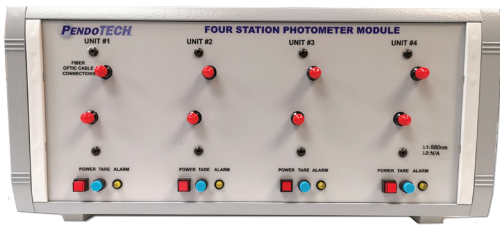


## Photometer/transmitter output enables simple integration to other systems

The unit is designed to be integrated to a monitor with data acquisition capability. PendoTECH offers solutions for using the photometer/transmitter with data acquisition devices such as PressureMAT® PLUS models (which can in turn be used with a PC for datalogging) and PendoTECH Process Control Systems. Other data acquisition devices with analog inputs may be used, as well as higher level control systems like PLCs and HMI's.



## Four Station Photometer Module



For streamlined multi-unit integration to a PendoTECH Filter Screening System, the Four Station Photometer Module can be used to measure turbidity on all four filter trains. It can also be easily integrated to 3rd party control system and data loggers.

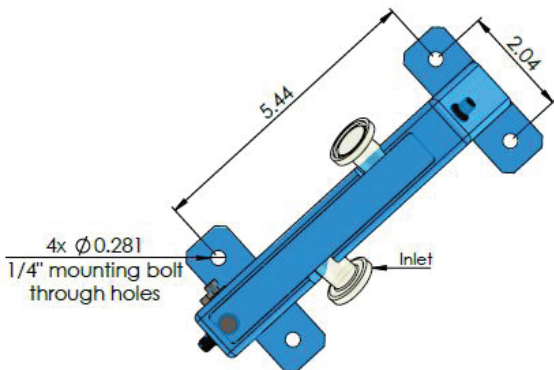
### Hardware Features:

- Front Panel: Fiber optic connections, tare button and power switch
- Back Panel: output signals on D25 connector
- Power inlet and power switch



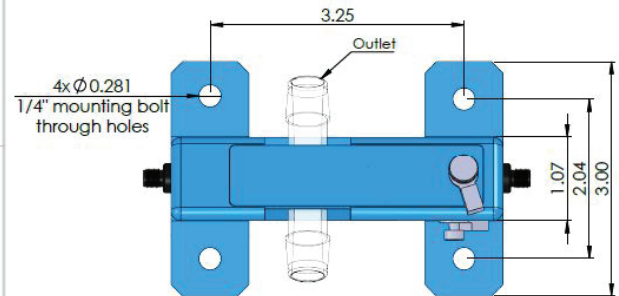
## Flow Cell Stand Mounting Information:

### SPEC-FCH-L Panel Mounting (all dimensions in inches)



**Proper Orientation of Panel/Wall mount, 45 degree angle, outlet higher than inlet**

### SPEC-FCH-S Panel Mounting (all dimensions in inches)



**Proper Orientation of Panel/Wall mount, vertical liquid travel, outlet above inlet**

## Photometer/Transmitter Specifications:

Optical Configuration	880nm LED light source
Optical Connectivity	SMA-905
Mechanical	4inch (10.2cm) W x 4 inch (10.2cm) L x 2.5inch (6.4cm) H Weight: ~1.5lbs.
Power Requirement	24VDC nominal, 2.7W max power
Output	4-20mA (Active/sourcing) spanned 0-3AU
Analog Loop Resistance	500ohms at 24VDC
Operating Temperature	41 to 122°F (5 to 50°C)
Storage Temperature	-4 to 122°F (-20 to 50°C)

Measurement Range	0.00 - 3.00AU
Maximum Zero Shift	±0.1% full scale (±0.002AU)
Response Time	1 second
Accuracy*	0-2AU ±1%FS (±0.03AU) ; 2-3AU ±2%FS (±0.06AU)
Long Term Output Drift	±0.1% full scale (±0.002AU)
Precision/Repeatability	±0.5% full scale (±0.015AU)
LED Lifetime	> 2 years
Available Wavelengths	206-1100nm
Diagnostic Output Signal	The UV/VIS/NIR photometer's indicator LED will glow <b>RED</b> , indicating an alarm condition. For panel mounted units, 2 dedicated alarm contact pins will close during the alarm. The alarm will go off if: 1 - The measurement detector is saturated at 100% 2 - The reference detector is saturated at 100% 3 - The reference light and dark signals are too close together

\* Accuracy is dependent on system arrangement and proper tare

## Single Use Flow Cell Specifications:

Material	Polysulfone and fused silica with silicone O-ring
Pressure range	Rated for pressure up to 75psi (5bar)
Biocompatibility	All materials in contact with product fluid path meet USP Class VI requirements
Manufacturing Environment	FDA Registered, ISO 13485 certified facility; ISO 7 clean room
Gamma Irradiation	Up to 50kiloGrays
Operating temperature	2°C to 50°C (other ranges with process qualification)
Storage temperature	-25°C to 65°C

## Stainless Steel Flow Cells Properties:

Stainless Steel Flow Cell Properties	316 Stainless Steel with Teflon ferrules for easy removal of optical couplers for cleaning, autoclavable
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## Hardware

Complete Turbidity Systems	
SPEC-L-1-SU1-880	Benchtop turbidity system w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, flow cell stand for up to 1cm single use flow cell with integral optical couplers, 24VDC power supply
SPEC-L-1-SU2-880	Benchtop turbidity system w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, flow cell stand for 6.5cm single use flow cell with integral optical couplers, 24VDC power supply
SPEC-P-1-SU1-880	Panel mount turbidity system w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, flow cell stand for up to 1cm single use flow cell with integral optical couplers
SPEC-P-1-SU2-880	Panel mount turbidity system w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, flow cell stand for 6.5cm single use flow cell with integral optical couplers
SPEC-L-1-RU-880	Benchtop turbidity system w/ 880nm light source, 4-20 mAoutput, 2 one meter fiber optic cables, 2 optical couplers for reusable flow cells, 24VDC power supply
SPEC-P-1-RU-880	Panel mount turbidity system w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, 2 optical couplers for reusable flow cells
SPEC-880-4	Four station turbidity system w/880nm light source, 4-20mA Outputs, (8) fiber optic cables, (8) optical couplers with (4) 6.5cm stainless steel flow cells
Photometer/Transmitter	
SPEC-L-1-880-PHOTO	Benchtop unit w/880nm light source, 4-20mA output, benchtop model, with 24VDC supply.
SPEC-P-1-880-PHOTO	Panel mount w/880nm light source, 4-20mA output, panel model.
Couplers, Fiber Optic Cables & Stands	
SPEC-OC-FIBER	One replacement fiber optics cable (3ft / 1M)
SPEC-OC-FIBER-2M	One replacement fiber optics cable (6ft / 2M)
SPEC-OC-FIBER-3M	One replacement fiber optics cable (9ft / 3M)
SPEC-OC-MICRO	One replacement micro optical coupler for stainless flow cell
SPEC-OC-PANEL	Panel mount SMA-905 connector (for pass through)
SPEC-FCH-L	Stand for PendoTECH Single Use Flow Cell with 6.5cm path length
SPEC-FCH-S	Stand for PendoTECH Single Use Flow Cells, up to 1cm path length

## Complete Turbidity System Ordering Information

Generic PendoTECH Part #: SPEC-(L,P,N)-(1,2)-(SU1, SU2, RU)-XXX-YYY	
Specify L, P or N	L = Lab P = Panel with flange on box base N = Panel with no flange on box base
Specify 1 or 2	1 = Single wavelength unit 2 = Dual wavelength unit
Specify SU1, SU2 or RU	SU1 = Flow cell stand with integral couplers for up to 1cm single use flow cell SU2 = Flow cell stand with integral couplers for use with 6.5cm single use flow cell RU = Optical couplers for use with reusable flow cell
Specify XXX and YYY (if applicable)	XXX = Wavelength # 1, i.e. 880nm YYY = Wavelength # 2, i.e. 280nm
For example, a panel mount, turbidity unit, which measures at 880nm with 6.5cm single use flow cell would be ordered with the following part number: SPEC-P-1-SU2-880	

## Flow Cells

Single Use Flow Cells	
SPECPS-N-012	Single use UV flow cell, 2mm path length, non-sterile, polysulfone, 1/8inch hose-barb
SPECPS-N-025	Single use UV flow cell, 0.5cm path length, non-sterile, polysulfone, 1/4inch hose-barb
SPECPS-N-050	Single use UV flow cell, 1cm path length, non-sterile, polysulfone, 1/2inch hose-barb
SPECPS-880-6CM	Single use turbidity flow cell, 6.5cm path length, non-sterile, polysulfone, 3/4inch sanitary flange inlet/outlet
Stainless Steel Flow Cells	
SPEC-880-1CM	Absorbance flow cell, stainless steel with 1cm path length (with path length adjustable down to 0.5cm)- inlet/outlets must be specified (3/4inch sanitary flange, hose barb in sizes: 1/8, 1/4, 3/8, 1/2inch)
SPEC-880-1CMLH	Low hold-up absorbance flow cell, stainless steel with 1cm path length, 0.75ml hold up. 1/8inch barb inlet/outlets
SPEC-880-5MMLH	Low hold-up absorbance flow cell, stainless steel with 0.5cm path length, 0.75ml hold up, 1/8inch barb inlet/outlets
SPECSS-N-ADJ-M	Stainless steel UV flow cell, with nano couplers 0.05 to 2mm path length; inlet outlet fittings to be specified by user (3/4inch sanitary flange, hose-barb in sizes: 1/8, 1/4, 3/8, 1/2inch); fibers ordered separate
SPEC-880-6CM	Turbidity flow cell, stainless steel with 6.5cm path length - inlet/outlets must be specified
SPEC-880-6CM-L	Turbidity flow cell, stainless steel with 6.5cm path length - inlet/outlets luer
Accessories	
SPEC-280-TRS	Test rig for UV-VIS-NIR photometer
PMAT-DAQ	Analog display with 4 inputs with alarm inputs and serial port for data collection
PMAT-DAQ-A	Analog display with 4 inputs, 4 analog outputs, alarms, and serial port for data collection
PHOTO-DR	PendoTECH Photometer DIN Rail mounting kit, includes mounting plate and mounting hardware
Interface Cables	
PDKT-UV1-PMAT	Cable from channel 1 of a single or dual channel photometer to PMAT analog input, 6ft
PDKT-UV1-PCS	Cable from channel 1 of a single or dual channel photometer to PendoTECH PCS Control System (DAQ/TFF), mA, 6ft
PDKT-UV2-1-NFFSS	Cable from channel 1 of a single or dual channel photometer to Filter Screening System train 1, analog 1 via 25 pin analog input connector
PDKT-UV2-1-NFFSSB	Cable from channel 1 of a single or dual channel photometer to PDKT-BOX-NFFSS breakout box, M8 male, mA signal, 2m
PDKT-UV2-FL	Cable from dual channel/turbidity photometer to flying leads, 6ft