PendoTECH Filter Screening System™

for Normal Flow Filtration Experiments

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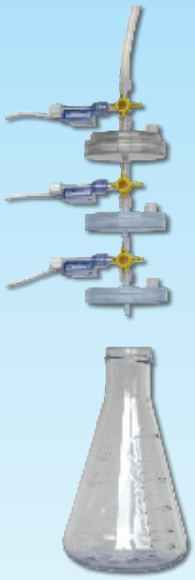
Adding Value To Your Process

DATA SHEET



Product Information

- Conducts volume throughput studies with constant flow or constant pressure
- Four simultaneous filtration optimization studies
- Designed for up to 3 filters per train - perfect tool for Virus-Depth Filtration optimization
- Process interaction via graphical user interface (GUI) with real-time trending feature
- Data acquisition of process data and experiment details
- Four independent filter trains each with their own pump control. Designed for up to 3 filters per train - each train with 3 pressure measurements and weight measurement, plus the option for additional process data such as turbidity and temperature
- Completely automated with total volume or pressure endpoints and alarms

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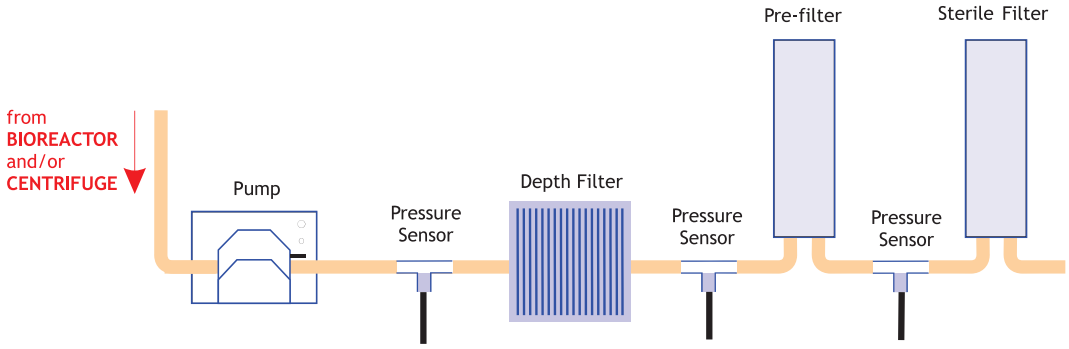
Normal Flow Filtration Processes and Filter Screening

Understanding the performance of filtration unit operations when developing a biotech process for clarification of therapeutic agents is an important consideration. Non-optimal filter selection can significantly affect the cost of goods upon scale-up and also impact efficiency and operation of many other unit operations in the bioprocessing train. Therefore, adequate process characterization is required with methods and tools to screen and size filters in a cost effective, practical and operationally friendly manner. This is central to any development function. Small scale filter test devices that contain the same filter media as the large devices are offered by many of the major filter vendors. These are well suited for screening at the laboratory development scale for sizing and selection to create the optimal scale-up model.

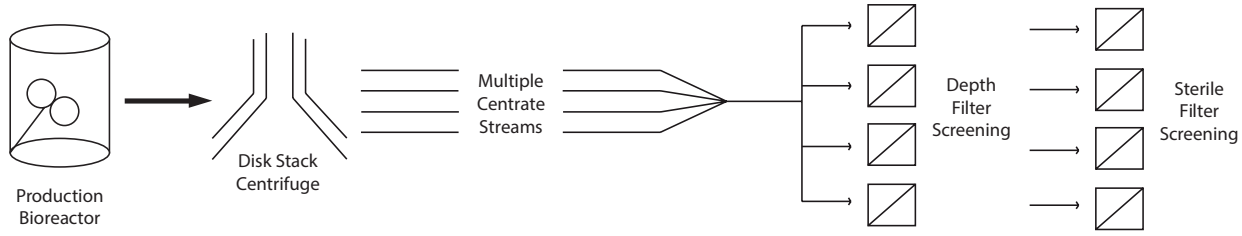
Filter screening can be particularly useful in virus filtration steps where there may be a pre-filter, followed by a virus filter, and centrifugation harvest development. The development of a traditional centrifuge process for the removal of cells and cellular debris varies such parameters as cell concentration or PCV, viability, feed flow rate and bowl speed. However, the input operational parameters of the centrifuge process will directly affect the filterability of the resulting centrate.



Schematic of Clarification Process that can be simulated at laboratory scale

Measuring filter capacity (as a function of volumetric throughput at constant pressure or constant flow) of the depth and sterile filters down stream as a function of centrifuge operating conditions (bowl speed and flow rate) and filter types is important. Pressure is a critical parameter to measure as an indication of filter performance and capacity. Performing such a multiple factor experiment can produce a large number of conditions depending on the experimental design strategy employed.

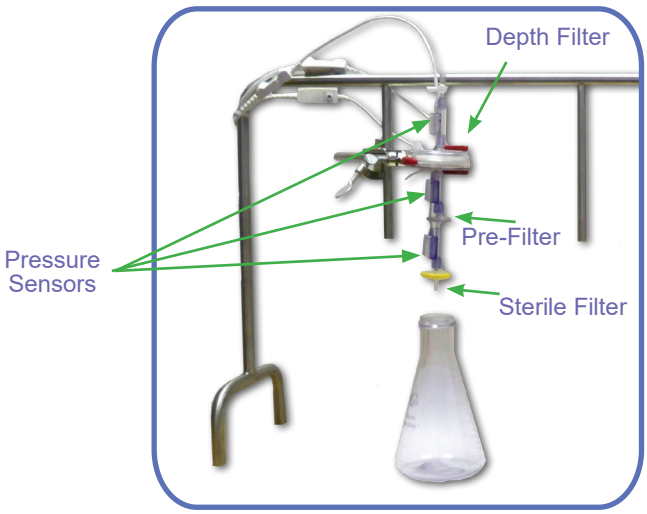
Process Flow Diagram for Centrifuge and Subsequent Filter Development



With pressure being a key dependent variable in the experimentation, pressure data measurement is a key feature of any system design. The integration of a pressure sensor to the vent hole or feed line of a screening filter with calibration not required and integrated to a data collection and retrieval system is advantageous.

Important factors to consider when implementing a system for filtration studies are: ability to conduct parallel experiments, data collection, storage and flexible trend analysis.

The PendoTECH Filter Screening System™ can assist dramatically in the optimization of a normal flow filtration process.



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Core System Comprised of:

CONTROL BOX

The Control Box is the “brains” behind the system. Pressure sensors and scales are read by the control box as well as pumps are controlled. In addition, all settings are stored in the memory and while running, endpoints and alarms are monitored here.

PC WITH SOFTWARE

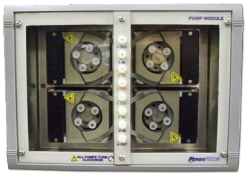
The user interaction with the system is via the PC. The PC with the custom Filter Screening System software communicates with the control system:

1) Receiving all data for viewing and storage

2) Updating the parameters in the control system via the user interaction with the PC software

3) Optionally, the PC running the software can serve the data to OPC clients such as a data historian and PI from OSIsoft®

PUMPS



PendoTECH Peristaltic Pump Module

PendoTECH Diaphragm Pump Module

Pumps are a critical component of any integrated system used for ‘constant flow’ experiments (ie, Pmax). Two specially designed pump modules are available from PendoTECH - one is a Peristaltic Pump Module and the other a Diaphragm Pump Module. They offer different characteristics and are both packaged in a compact form factor to minimize bench space required for a full featured set-up. The Diaphragm Pump Module enables generation of pressure up to 60psi/4bar. In addition, 3rd party pumps can be used such as pumps offered by Masterflex and Watson-Marlow. These may enable a more flexible setup as pumps can be used for other purposes when not in use with the system.

Masterflex L/S Pump

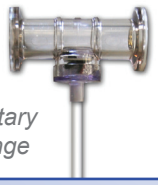
Watson-Marlow 120 Pump

PRESSURE SENSORS

Luer fitting inlet/outlet

1/8inch hosebarb

Sanitary Flange



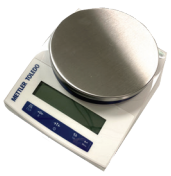
Any size PendoTECH Pressure Sensor can be used but most often, the sensors with the luer fittings are often the best choice. Features of the luer sensors are:

- Low hold-up volume
- Polycarbonate version that comes sterile in its Tyvek pouch
- Polysulfone version for superior chemical resistance

Sanitary flange sensors are available to connect to filters with flanges. Hose barb sensors are also available

SCALES

Ohaus®



Mettler-Toledo

The amount of material that is filtered is measured by the scales integrated to the system. For constant flow applications, the scales function can be disabled and the filtered volume will automatically be measured by pump totalization based on the flow rate setting.

For constant pressure applications, the scales are required to measure the cumulative volume versus time. Also, for ‘constant pressure’ (e.g Vmax) experiments, a pressure vessel is required. PendoTECH offers one option with a low hold-up volume, precise pressure regulation and pressure recording capability.

Key Features

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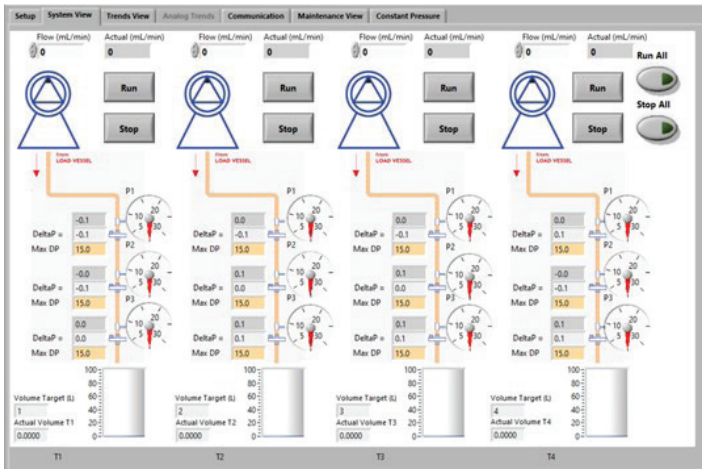
- Operate up to 4 trains in parallel with up to 3 pressure measurements per train
- Graphical User Interface (GUI) to streamline user interaction with the process
- Interfaces with up to 4 pumps for independent control of each pump
- Automation allows the system to be operated unattended - individual pumps will shut off when volume target is reached or alarm occurs
- Total flow by either scales with ability to enter density to convert weight to volume or pump accumulation (eliminates need for scale and filtered volume is estimated)
- Alarms for high pressure for each train and high delta pressures for each filter that will shut the pump off for that train
- Real time calculation of flux and permeability based on entered filter area within GUI
- Ability to view a wide variety of trends real-time with instant export feature of current trend view
- Process data acquisition (including filter, train names and key experiment information and notes) into a CSV data file that is opened with Excel
- Ability to run 4 parallel Constant Pressure experiments by use of scale input functionality
- PendoTECH Pressure Sensors with luer fittings connecting directly to filter test devices or larger sensors with sanitary flange or barb can be used
- Expansion option for input of up to 2 analytical measurements per train such as temperature and turbidity
- Logs individual pump run times for management of pump maintenance and/or tubing change outs
- FLOW-ADJUST Feature where GUI automatically controls a filter deltaP Setpoint
- Option to serve data to OPC clients such as PI from OSIsoft®

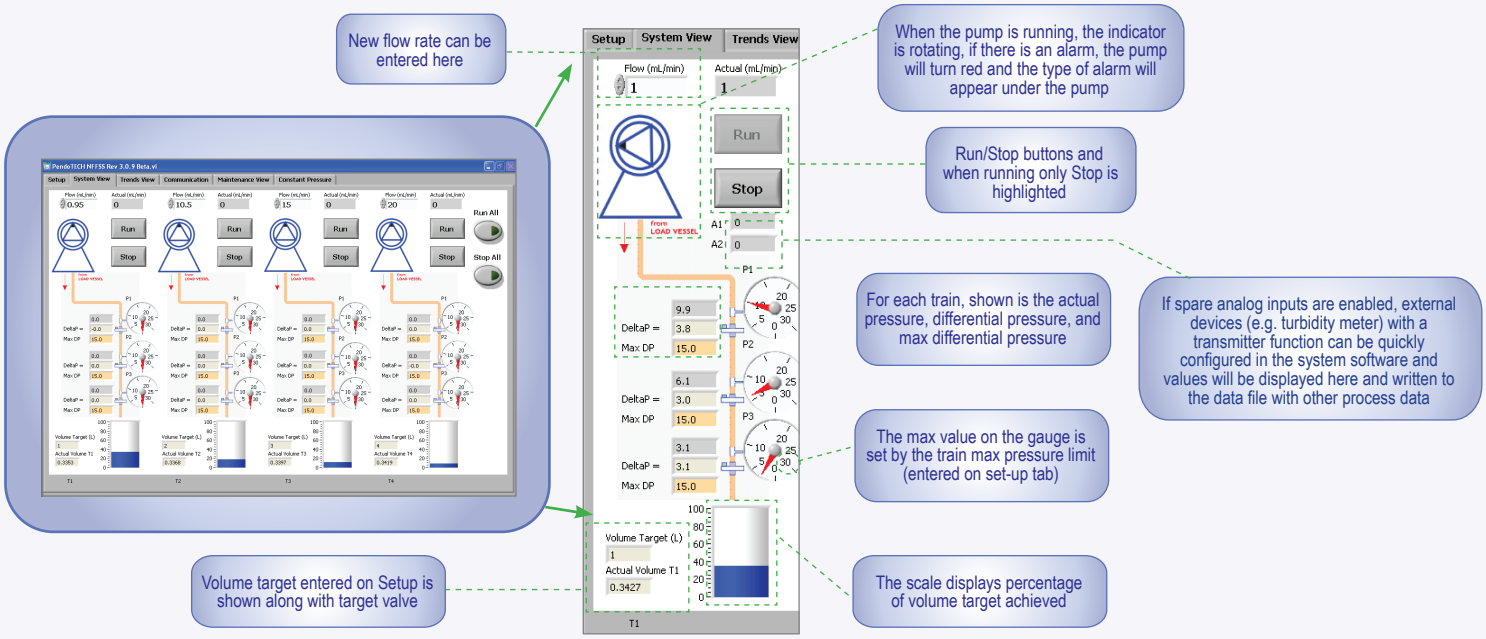


7 Tabs for Fast and Easy Navigation (System View Shown)

1 - Setup - enter filter information, alarm settings and volume endpoint
2 - System View - view process data, change flow rate, start/stop pumps
3 - Trends View - create trends and view process data over time
4 - Analog Trends - for trending of up to 8 analog inputs connected via the expansion module (tab is active only when inputs are enabled)
5 - Communication - start data file and save/recall setup information and setup optional inputs
6 - Maintenance View - zero pressure sensors, zero total volume, setup pumps and reset the run-time counter
7 - Constant Pressure Tab - for viewing data and performing calculations during constant pressure experiments

System View

This is the "dashboard" for constant flow experiments where all process data can be viewed. In addition, pumps can be stopped/started and flow rates adjusted.



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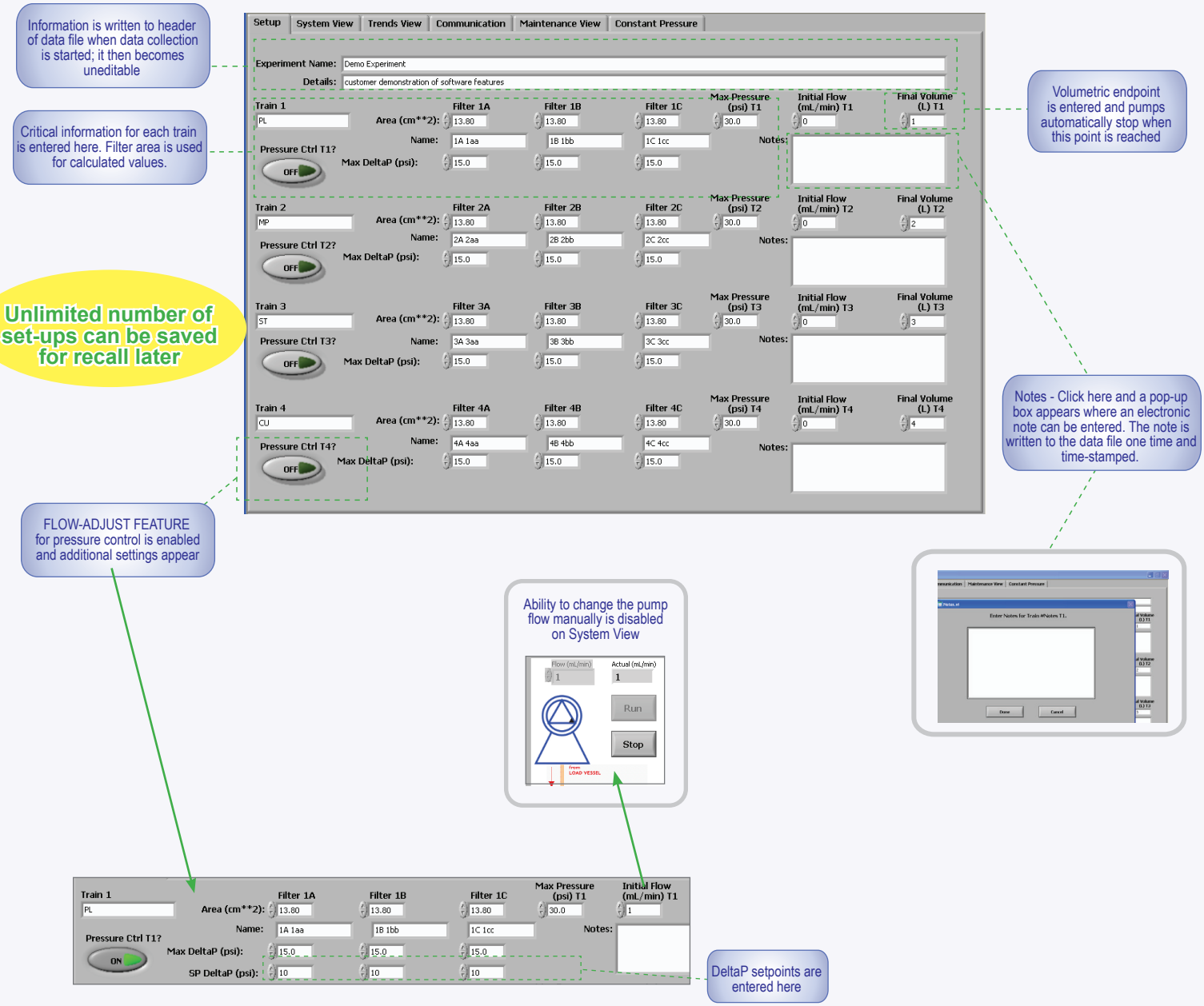
Setup View

The Setup view is where end points and alarm points are entered, along with information critical to an experiment, such as train names, filter names and areas. Train names and filter names are all stored in the data file as a permanent record. In addition, electronic notes can be entered during an experiment that are time-stamped when entered in the file. These notes are excellent for observations or to mark sample points. The FLOW-ADJUST feature can be activated, which allows the pump flow to be automatically reduced to maintain pressure.



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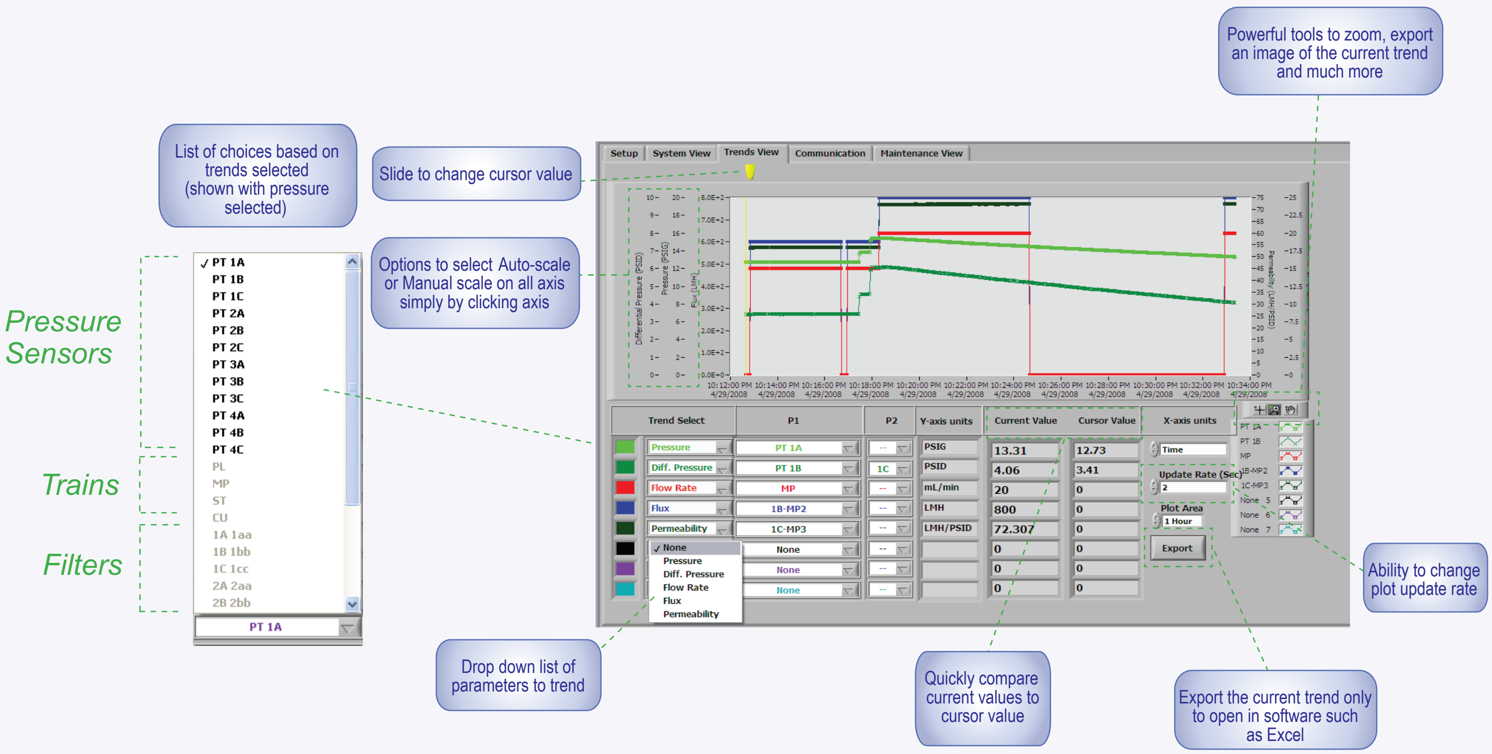
Trends View

After data collection is initiated by the user, real-time trending is active.

- Select up to 8 trends simultaneously (can be changed as needed)
- Export the trended data directly to a file
- Export plot image
- Open selected data directly in Excel for quick-calculations



Data Storage

Separately from the trending, data is written to the file created when the data collection is started. The frequency is set on the communication tab which can be different than the trending frequency. Data is written to the locked file until the user "ends data collection," and the file is released. All data and notes are logged. Train 1 data is shown below and there are additional columns for Trains 2 to 4.

Experiment Name: Demo trial
Details: experiment for equipment qualification
Pressure units psi

Date/Time	1-Notes	1-Train Name	1-FilterA_	1-FilterB_	1-FilterC_N	1-Mode	1-Pressur	1-Pressur	1-Pressur	1-DeltaA	1-DeltaB	1-DeltaC	1-Flow	1-FluxA	1-FluxB	1-FluxC	1-PermA	1-PermB	1-PermC	1-CumVol	1-Target	1-Error
11/30/2016 9:00		Clarification	1A- Depth	1B- Pref	1C- Sterile	STOP	0.02	0	0.01	0.02	-0.01	0.01	0	0	0	0	0	0	0	0	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	STOP	0.04	0	0.02	0.04	-0.02	0.02	0	0	0	0	0	0	0	0	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	0.03	0.01	0.01	0.02	0	0.01	24	1043.478	1043.478	1043.478	52173.92	0	0	0	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.13	0	0.01	7.13	-0.01	0.01	24	1043.478	1043.478	1043.478	146.3504	0	0	0	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.13	0	0.02	6.13	-0.02	0.02	24	1043.478	1043.478	1043.478	170.2248	0	0	0.0015	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.12	-0.01	0.01	7.13	-0.02	0.01	24	1043.478	1043.478	1043.478	146.3504	0	0	0.0033	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.38	0	0.02	6.38	-0.02	0.02	24	1043.478	1043.478	1043.478	163.5546	0	0	0.0050	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.17	0	0.02	7.17	-0.02	0.02	24	1043.478	1043.478	1043.478	145.5339	0	0	0.0050	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.11	0	0.01	6.11	-0.01	0.01	24	1043.478	1043.478	1043.478	170.782	0	0	0.0066	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.11	0	0.01	6.11	-0.01	0.01	24	1043.478	1043.478	1043.478	170.782	0	0	0.0066	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.11	0	0.01	6.11	-0.01	0.01	24	1043.478	1043.478	1043.478	170.782	0	0	0.0066	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.11	0	0.01	6.11	-0.01	0.01	24	1043.478	1043.478	1043.478	170.782	0	0	0.0066	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	5.92	0	0.01	5.92	-0.01	0.01	24	1043.478	1043.478	1043.478	176.2632	0	0	0.0101	0.1	No_Error (0)
11/30/2016 9:01	sample 1	Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.21	0	0.01	7.21	-0.01	0.01	24	1043.478	1043.478	1043.478	144.7265	0	0	0.0132	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.21	0	0.01	7.21	-0.01	0.01	24	1043.478	1043.478	1043.478	144.7265	0	0	0.0132	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.28	0	0.01	6.28	-0.01	0.01	24	1043.478	1043.478	1043.478	166.159	0	0	0.0165	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.04	0.01	0.01	7.03	0	0.01	24	1043.478	1043.478	1043.478	148.4322	0	0	0.0180	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.21	0	0.01	7.21	-0.01	0.01	24	1043.478	1043.478	1043.478	144.7265	0	0	0.0180	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.2	0	0.01	6.2	-0.01	0.01	24	1043.478	1043.478	1043.478	168.3029	0	0	0.0196	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.16	0	0.01	7.16	-0.01	0.01	24	1043.478	1043.478	1043.478	145.7372	0	0	0.0212	0.1	No_Error (0)
11/30/2016 9:01		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.1	0	0	6.1	0	0	24	1043.478	1043.478	1043.478	171.062	0	0	0.0227	0.1	No_Error (0)
11/30/2016 9:02		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	7.07	0	0.01	7.07	-0.01	0.01	24	1043.478	1043.478	1043.478	147.5924	0	0	0.0227	0.1	No_Error (0)
11/30/2016 9:02		Clarification	1A- Depth	1B- Pref	1C- Sterile	RUN	6.39	0	0.01	6.39	-0.01	0.01	24	1043.478	1043.478	1043.478	163.2986	0	0	0.0245	0.1	No_Error (0)

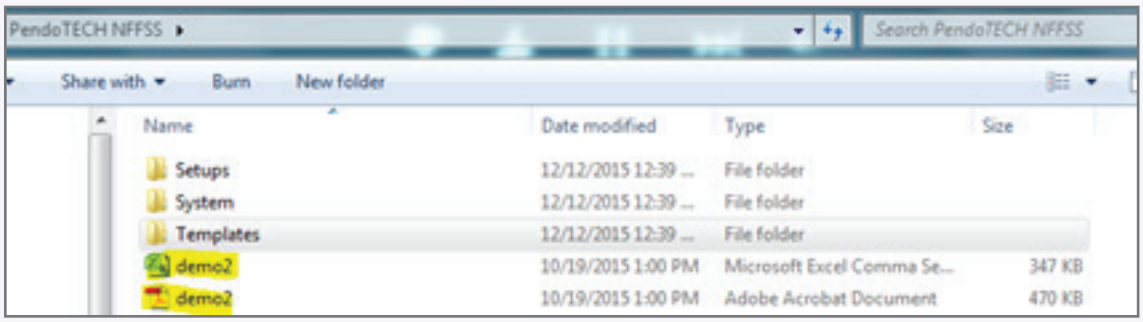
Communications View

Functions Include:

- Set the data file update rate
- Start an experiment (creates data file)
- End an experiment (stops logging of data to file)
- Save and recall Setup information
- Turn on Estimated Flow Calculator
- Configure analog inputs
- Select pressure units (psi or bar)
- Controls to fine tune FLOW-ADJUST mode
- Generate Report
- Exit the program

Automatic Creation of a Locked, Uneditable PDF Data File

When End Experiment is selected to end logging to the file, a PDF file that is locked and password protected is automatically created. The Excel file is locked while data is being logged but will not be locked after End Experiment is selected. This automatic creation of a PDF file provides the user with a locked, un-editable copy of their data. The PDF will have the same name as the CSV as shown below:



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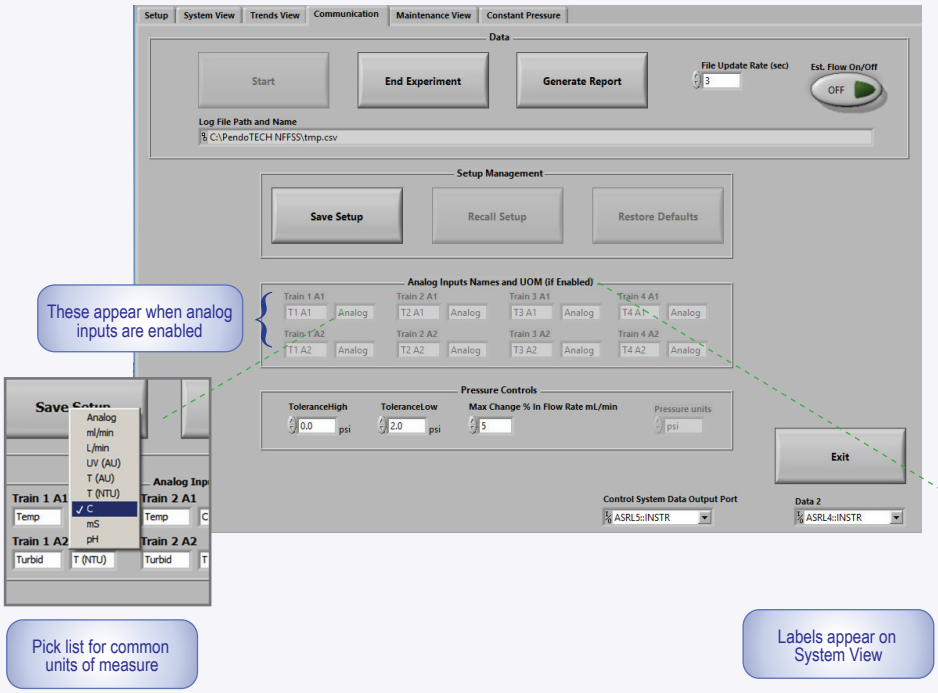
Analog Input Setup & Analog Trends View

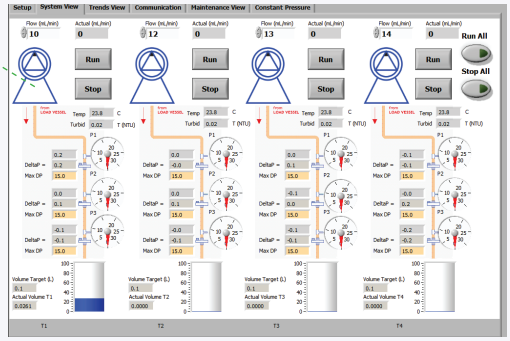


These appear when analog inputs are enabled

Pick list for common units of measure

Setup Details:

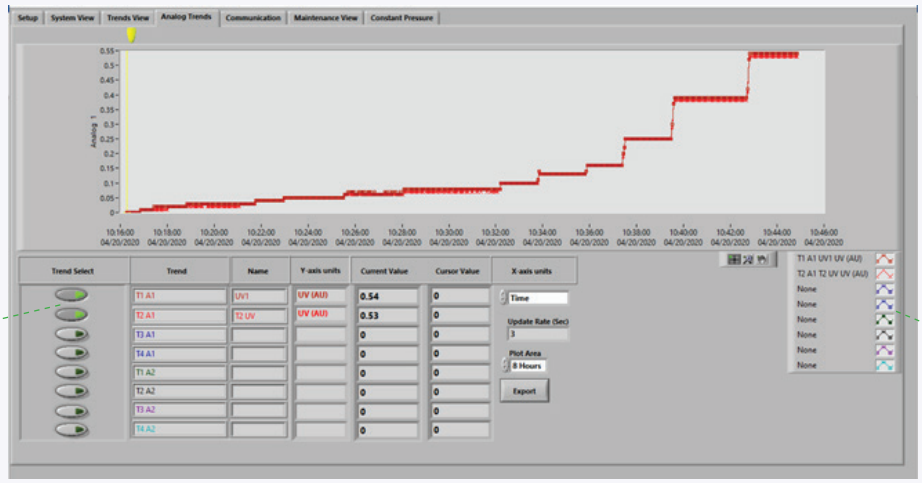
- Name the inputs in use
- Select units of measure from the list
- The actual span of these external inputs is set in the control system menu
- Once enabled, the actual input values appear on both the System View and in the data file
- Analog Trends View allows any of the 8 inputs to be selected and viewed as a trend



Labels appear on System View

Analog Trends Details:

- For viewing of the selected trends
- Has many of the advanced features that are on the Trends View
- Two Y axis appear for analog 1 and analog 2
- The legend identifies the position, parameter and units of measure



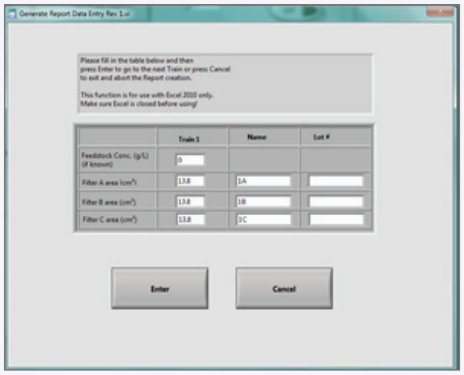
The trends select buttons determine which inputs appear on the graph

The names of the actual trends appear along with the position identifier

Generate Report Function

Once a file has been created, the Generate Report button is enabled to generate an Excel report using the template included with the software. This template can be customized by the user to meet their specific needs.

When the button is pressed, there are a series of dialog boxes (one for each train) with the following prompts:



A concentration may be entered and the areas entered on the Setup tab are pre-populated along with the Filter Name. A filter lot number may be entered if desired.

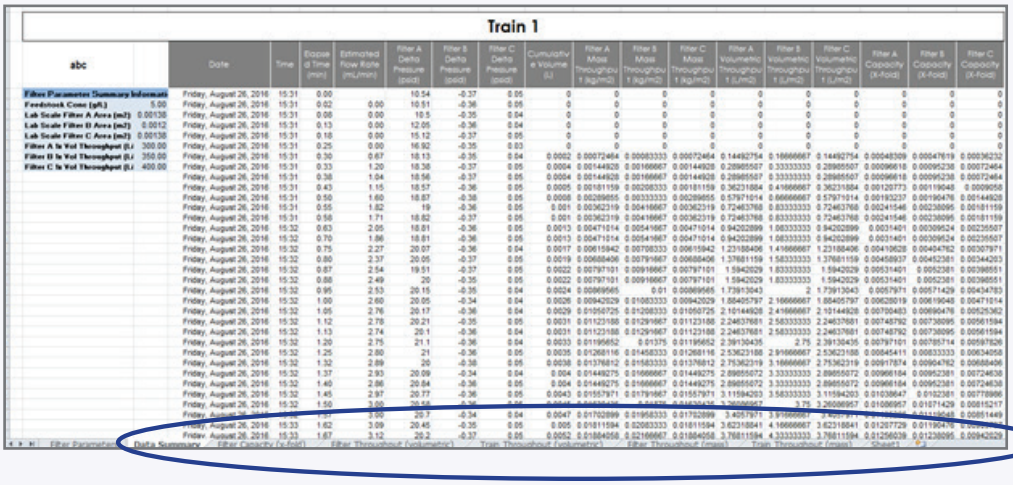
Excel will be used to create an Excel Workbook file (.xlw) with the same name as the CSV.

The spreadsheet created allows the user to input capacity target:

	Train 1			Train 2			Train 3			Train 4		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Parameter	Filter A	Filter B	Filter C	Filter A	Filter B	Filter C	Filter A	Filter B	Filter C	Filter A	Filter B	Filter C
Filter Names	1A PL6	1B PL7	1C PL8	2A mp	2B	2C	3A	3B	3C	4A	4B	4C
Filter Areas (cm²)	13.8	12	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
Filter Lot #s												
Feedstock Concentration (g/L)	5			0			0			0		
1x Volumetric Throughput (L/m²)	300	350	400	222	223	224	333	334	335	444	445	446

*Yellow fields require user input for capacity calculations and graphs

There is a data summary table created as well as a number of graphs within the same spreadsheet.



The NFFSS Analysis Software also uses the same template to generate reports from files generated on previous experiments.

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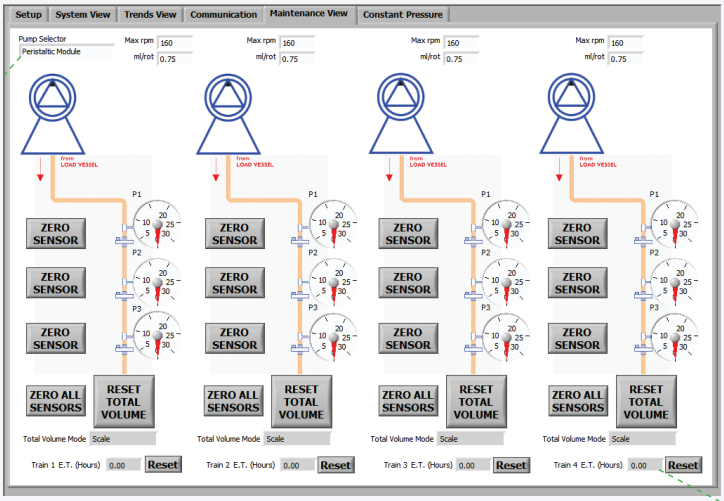
Maintenance View

Pumps are quickly configured here based on the pump used

Quick-picks for common choices or the ability to set each one manually so any pump can be accommodated



- Tare pressure sensors
- Zero flow totalizer or tare scales
- Configure pumps
- Monitor pump run time - may be reset with password

Displays pump run time to monitor tubing life so it can be replaced at set intervals or maintenance cycles on the diaphragm pump. A password is required to reset this to zero

Pump Calibration

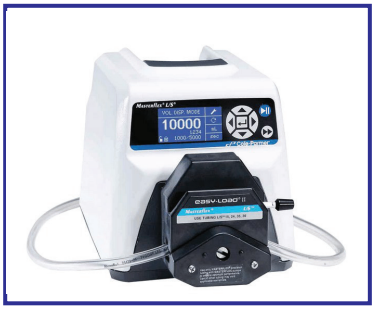
The Pump Selector drop-down box has a range of choices for nominal pump calibrations. There are two factors used to calibrate any pump - its maximum motor speed in RPMs and how much liquid is delivered each time the motor turns. This is quantified in mL/rotation. When these two values are multiplied, you get maximum possible flow rate. In a peristaltic pump, the mL/rotation is based on the tubing inner diameter; and for a diaphragm pump, the mL/rotation is based on the pump chamber. For fine-tuning calibration or for configuration of a pump/tubing combination not in the list, there is an option called Custom Settings where individual values can be entered for Maximum RPMs and mL/rot. For more details on pump calibration, please view the PendoTECH Pump Calibration Tech Note.

Watson-Marlow 120 Pump

Max RPMs = 200

Tubing Size ID (in)	1/32	1/16	1/8	3/16
Tubing Size OD (in)	5/32	3/16	1/4	5/16
Tubing Size ID (mm)	0.8mm	1.6mm	3.2mm	4.8mm
Masterflex L/S reference	13	14	16	25
Max Flow (mL/min)	8.0	28	94	170
mL/rotation	0.04	0.14	0.47	0.85

Masterflex L/S Pump



Max RPMs = 600

Tubing Size ID (in)	1/32	1/16	1/8	3/16
Tubing Size OD (in)	5/32	3/16	1/4	5/16
Masterflex L/S	13	14	16	25
Max Flow (mL/min)	36	130	480	1000
mL/rotation	0.06	0.22	0.8	1.7

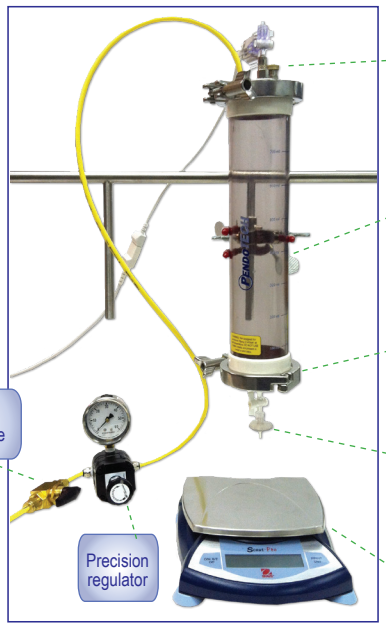
PENDOTECH
Adding Value To Your Process

Constant Pressure/Vmax™

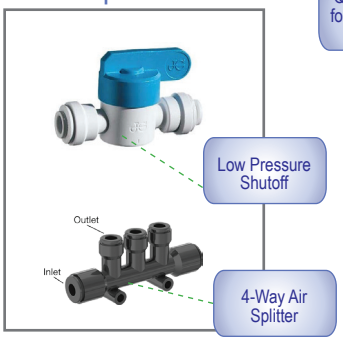
A pressure vessel with a precision regulated pressure source can be used to conduct 4 simultaneous "Vmax" experiments.

The software creates two concurrent trends of volume vs. clock time and elapsed time vs. elapsed time/volume. This allows the view of a direct plot of rate of volume accumulation and the plot of predictive model calculations. Using the calculations associated with this predictive method, the correlation coefficient is calculated real-time to confirm if the prediction model is valid and the predicted max throughput is calculated real-time. This is normalized to L/m^2 using Filter A area.

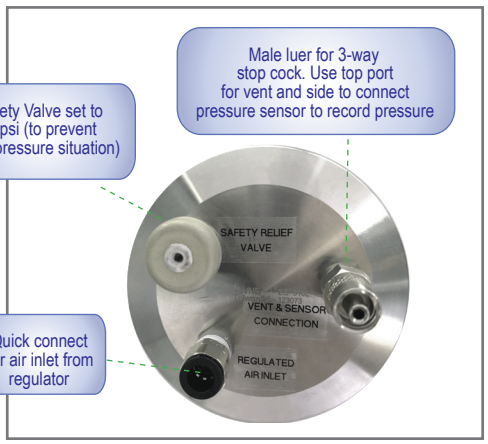
PendoTECH Pressure Vessel with Regulated Pressure Source



Accessories for Using Multiple Vessels



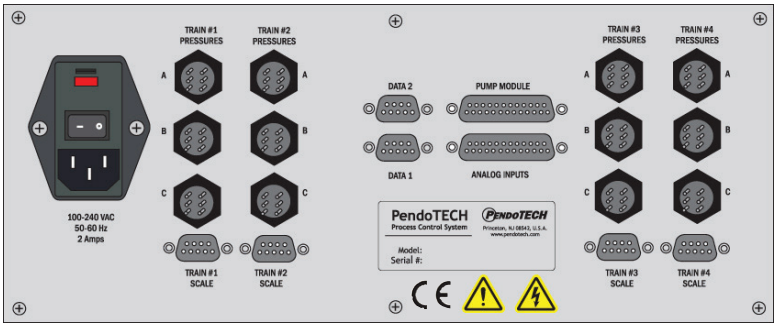
Top Detail



Bottom Detail

Components Interfaced to Control System

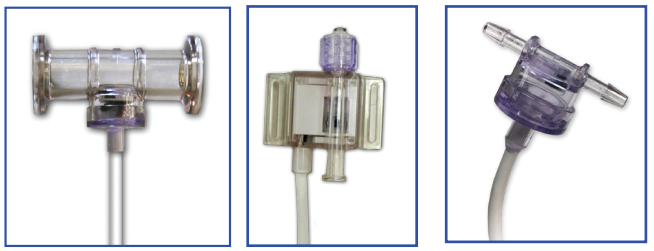
The system comes with the required cables to quickly get the system up and running. All connections are keyed to prevent connection of a cable to the wrong connector. Pumps and scales may be delivered with the system or existing equipment or self-procured equipment may be used. A scale selection menu on the process control system is used to quickly configure the RS232 parameters for the different scale brands. The pump cables are supplied to interface with the remote control connector on the user selected pumps as shown in the example below.



Control System Back Panel Input/Output Connections

Pressure Sensors

Pressure sensor cables provided with the system accept the PendoTECH Single Use Pressure Sensors (see below). Even though these are called single use, they are robust enough to be re-used for process development work where cross-contamination is not a concern.

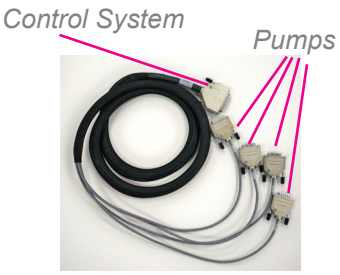


PendoTECH Single Use Pressure Sensors

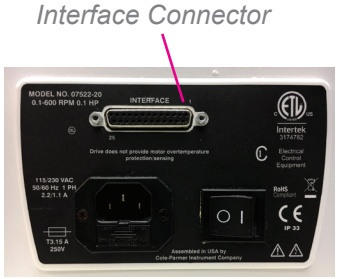
Pressure Sensor Cable

Pumps

Pump Module

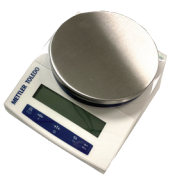


Pump Cable for 4 pumps (Masterflex Pump Cable Shown)



Example of Pump Back Panel with remote interface connector

Scales



Most scales have RS232 communication built-in and a cable either integral or available separately to connect to the system

PC

PC Requirements:

Windows 7 or 10, 2 GHz or faster, 4GB of RAM with at least 2 available USB ports

Graphical User Interface (GUI) Software has resolution of 1366x768 pixels so this resolution on the PC is preferred. A higher resolution the unused area will be grey or the display settings can be adjusted to match.

PENDOTECH
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1) PendoTECH Diaphragm Pump Module

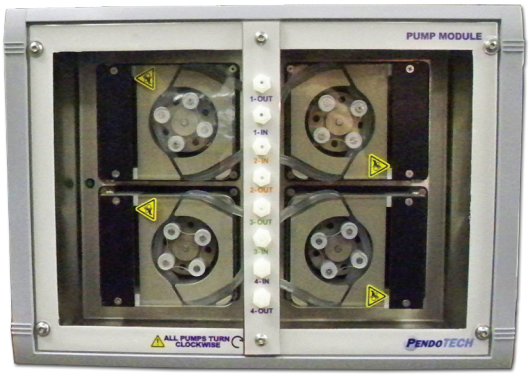
Product Features

- Low shear, long life diaphragm pump technology
- Minimal drop in flow while pumping against back pressure
- Stepper motor control “Rapid Intake” stroke technology that minimizes pulsation
- Space-saving design with quiet operation
- Precise pumping from 2.0mL/min to 100mL/min
- Low internal hold-up volume
- Broad range of chemical compatibility (product contacting internal pump components are all fluoropolymer based)
- May be run dry

2) PendoTECH Peristaltic Pump Module

Product Features

- Peristaltic design with easily changeable fluid path that uses commonly available tubing
- Minimal drop in flow while pumping against back pressure
- Stepper motor control technology that pumps precisely
- Space-saving design with quiet operation
- Precise pumping from 1mL/min to 120mL/min
- May be run dry



3) Third Party Pumps

Pumps from popular manufacturers like Masterflex and Watson-Marlow may already be owned and if it has the interface connector on the back panel, it can be used. Also, these pumps may be purchased directly from PendoTECH with the system. These pumps offer flexibility to use a wide range of tubing sizes and also may be used for other lab applications when not interfaced with the system.

Masterflex L/S

Uses the full range of L/S tubing sizes for wide flow range capability

4 Pumps Required - Each is controlled independently by the system

Watson Marlow 120U

Compact design minimizes bench space required

4 Pumps Required - Each is controlled independently by the system

PENDOTECH
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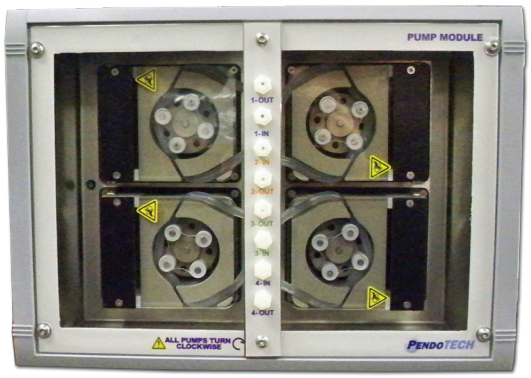
Filter Screening System
Peristaltic Pump Module

The Peristaltic Pump Module is an accessory for the PendoTECH Filter Screening System. The module can only be operated by interfacing with the system and is not designed to be operated independently. The pumps in the module are compact peristaltic pumps that are controlled from the Filter Screening System.



Compact, High-Powered Integrated System for Normal Flow Filter Screening and Sizing

The Pump Module combined with the system and PC based GUI provides a compact, high-powered system. Using these precision pumps, the Filter Screening System scale inputs may be disabled, and the total volume filtered is calculated by the control system based on the pumped volume. This is an alternative to using multiple scales.

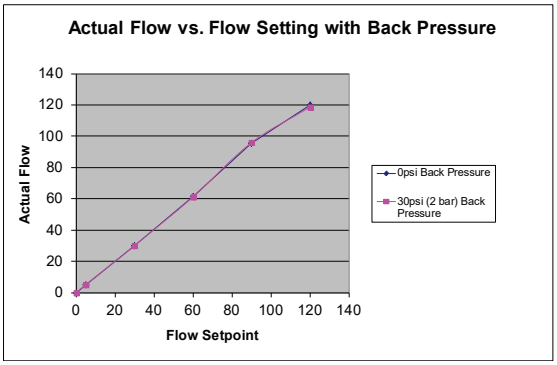
Easily Loaded

To change tubing the Lexan front cover is opened which in turn releases the tubing. It can then be easily removed for replacement.

For 1/8inch ID tubing (size 16) there are 1/8inch hose barb fittings behind the panel for connection of tubing to the pump. On the front panel, there are 1/8inch fittings for each pump inlet and outlet so process connections can be made quickly and easily from the pump front panel. Tubing with 1/16inch ID can also be used along with 1/16inch fittings.

Performance Against Back-Pressure

The pump continues to deliver the set flow rate across the range of back-pressures that may be encountered during a normal flow filtration process. The data in the graph represents minimal flow decay as pressure downstream of the pump increases when tested up to the tubing pressure limit.



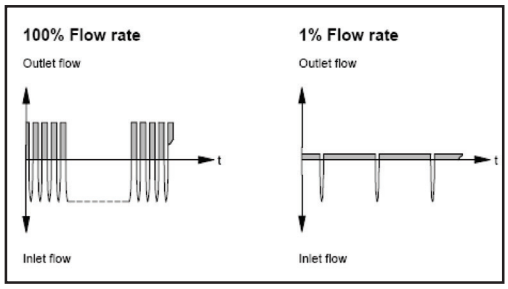
Filter Screening System Diaphragm Pump Module

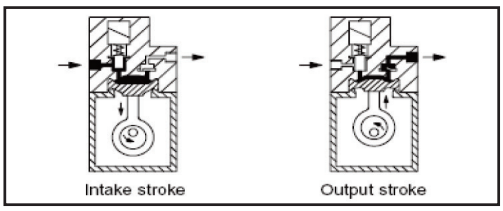
The Diaphragm Pump Module is an accessory for the PendoTECH Filter Screening System. The module can only be operated by interfacing with the system and is not designed to be operated independently. The pumps in the module are precision diaphragm pumps that are controlled from the Filter Screening System.

Compact, High-Powered Integrated System for Normal Flow Filter Screening and Sizing

The Pump Module combined with the system and PC based GUI provides a compact, high-powered system. Inlet/outlet fittings are compression fittings to secure size 16 tubing (1/8inch ID/ 1/4inch OD). There is a re-movable Lexan™ cover secured by thumbscrews & 35 micron inlet filters included in-line to protect pump check valves.

The diaphragm pump technology has the ability to generate pressures up to 60psi/4bar which is generally not achievable with peristaltic technology.





The "Heart" of the System - Precision Diaphragm Pump

The stepper motor driven diaphragm pump provides the required accuracy and precision along with low shear in a compact design. This pump also has low pulsation due to its unique operating method where the intake stroke is very rapid compared to a varied outlet stroke so that liquid is dispensed evenly. (See picture at left)

A flexible diaphragm is moved up and down by an eccentric connected to the motor shaft. During its downward movement, liquid is sucked through the inlet valve into the chamber; by its upward movement, liquid is pushed through the outlet valve. The pump's working chamber is hermetically separated from the motor to protect the liquid from contamination. The intake stroke is carried out at maximum speed, and the output stroke is varied so liquid can be dispensed evenly — resulting in a quasicontinuous, low-pulsation flow.

The pump continues to deliver the set flow rate across the range of back-pressures that may be encountered during a normal flow filtration process.

Expansion Options

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Expansion Module

Expansion options are available through use of the Analog Inputs Connector on the back panel. External measurements can be logged with all of the other process data. Cables are available to connect pre-configured expansion options or by use of the Expansion Module, individual transmitters may be connected. Popular external measurements are turbidity and temperature.

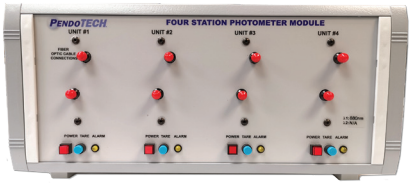
Breakout Box for External Inputs

Turbidity Flow Cell & Measurement Unit

For turbidity, there are different options depending on measurement range and the number of measurements desired. A single photometer/transmitter can be used or 4 units can be contained in one enclosure

- 880nm LED light source
- Hose barb, luer or sanitary connections to flow path
- 1cm flow path for up to 2750NTUs
- 6.5cm flow path for up to 425NTUs

Photometer/transmitter

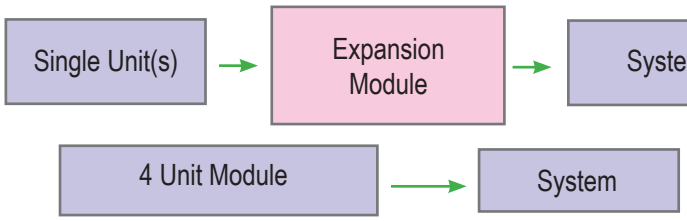


4 Unit Turbidity Module

6.5cm single use flow cell

6.5cm single use flow cell installed in stand

6.5cm flow cell with luer connection



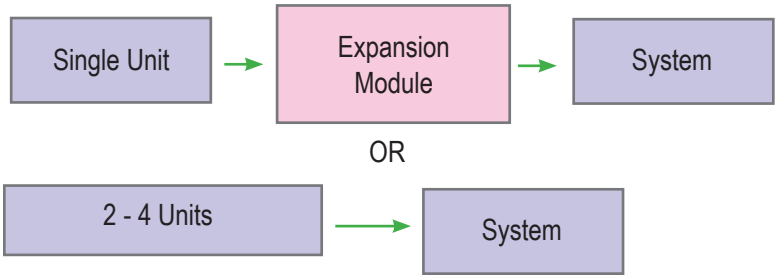
For more detail: http://www.pendotech.com/products/cell_removal/Turbidity_Cell_Info.pdf

Temperature

For temperature, the PendoTECH luer temperature sensor conveniently fits in-line for an accurate measurement of fluid temperature. A transmitter is required to read the sensor and send the value to the control system. One to four transmitters in one box are offered. A disposable probe is also available.

Luer Sensor

Luer Sensor Installed in Luer Tee

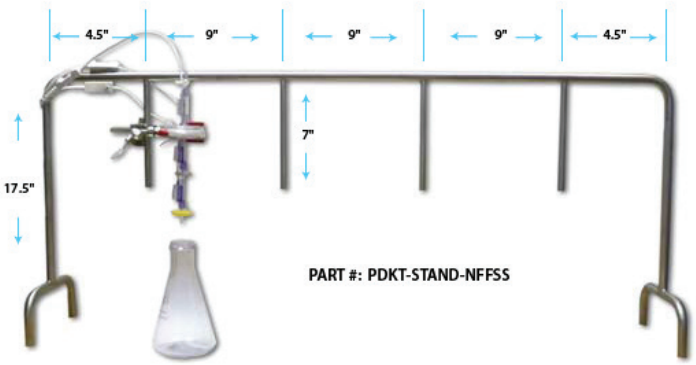


Disposable Probe

Hose Barb Temperature sensor - 1/8inch, 1/4inch, 1/2inch available

PendoTECH Filter Stand

The Filter Stand allows the bench space to remain clear for scales and also aides greatly in organizing the cables.



Turbidity Application Note:
Using the Turbidity Measurement System with the Filter Screening System

Introduction

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 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 those directly from a bioreactor or fermentation vessel. The post-filtration measurement may indicate that undesired components are “breaking through” the filter, meaning the filter is losing its retention, including absorption to a charged media, 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, and cables to connect to the Filter Screening System.

In-Line versus Off-Line Measurement

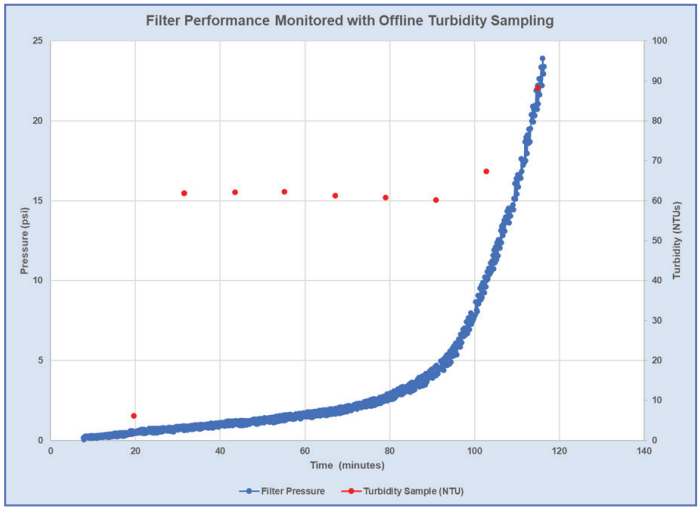
Some off-line measurement units can detect the scattering of light that passes either straight through the sample (forward light scattering), scattering at 90 degrees, scattering back toward the light source, or some combination of all scattering modes. The PendoTECH Turbidity System exclusively uses forward light scattering, therefore, because of its In-line nature, and its ability to only measure forward light scattering, the precision/repeatability may not be comparable to a benchtop off-line unit. Off-line samples can be collected as sample fractions and measured immediately or measured at the end of an experiment. The Filter Screening System software has the ability to enter time-stamped notes. This feature can be used to mark the sample number at the point it is taken and later the turbidity at that sample point can be entered into the data file.

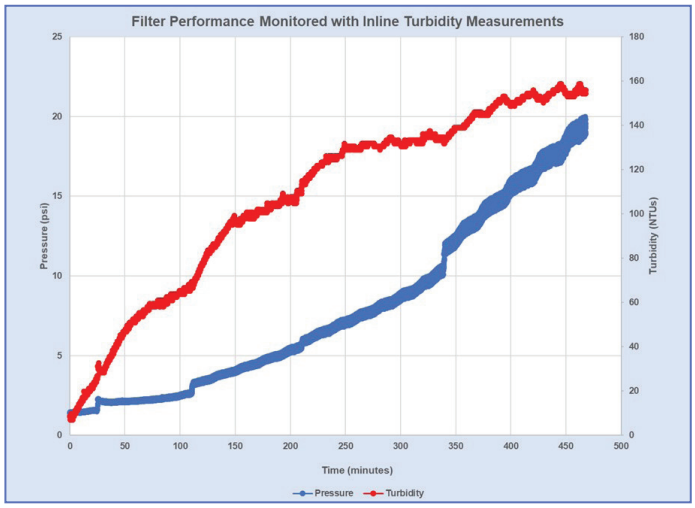
In-Line Measurement

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 Absorption Units (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 and post-filtration the 6.5cm cell is most often used. Pre-filtration a 1cm cell is most often used. The raw measurement of AUs can be measured and by testing an off-line sample, direct correlation of NTUs can be determined. The ability to trend turbidity real-time during screening experiments may have advantages to intermittent, more precise data depending on the nature of the experimentation being conducted. With the Analog Trend feature of the Filter Screening System software, enables viewing of the trend real-time and data is also written to the file for later analysis.

Comparison of Measurement Data

Shown below are two graphs from a process running with a pump delivering liquid to the filter at a constant flow rate. With time on the x-axis, the volume filtered is linear to the time and not shown. The graph on the left shows turbidity sampling results at time intervals of post depth-filtration in a cell culture clarification process. The filter used is a cellulosic depth filter (Zeta Plus from 3M*). The turbidity is relatively constant up to about 90 minutes and the pressure is about 4psi. The pressure continues to rise from that point and the sample is taken at 103 minutes, when the pressure increases to 11psi, when an apparent break-through has occurred. A continuous reading would have ideally detected the time point (and the volume) when this occurred. The graph on the right shows a continuous inline measurement of a protein solution post-depth filter using a 0.2 micron filter. The turbidity reading on a continuous basis gives a very clear relationship as compared to pressure buildup which would not be as clear with sampling. As can be observed, the inline method can be impacted by foam and air bubbles causing a curve that is not smooth.

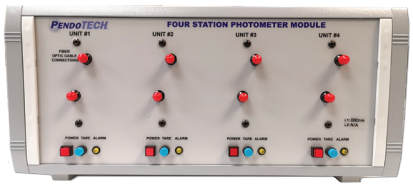




We would like to acknowledge 3M for their support to gather this data

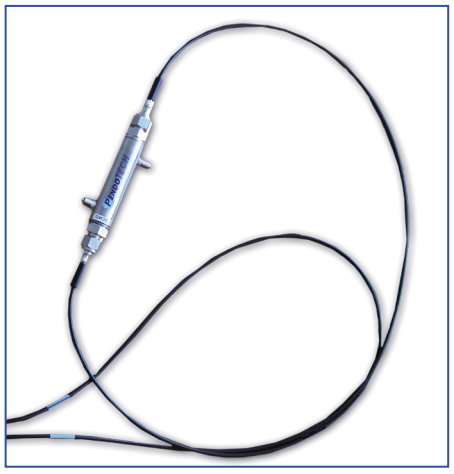
Equipment Options for Turbidity Measurement with the Normal Flow Filter Screening System

For turbidity, there are different options depending on measurement range and the number of measurements desired. A single photometer/transmitter can be used or 4 units can be contained in one enclosure

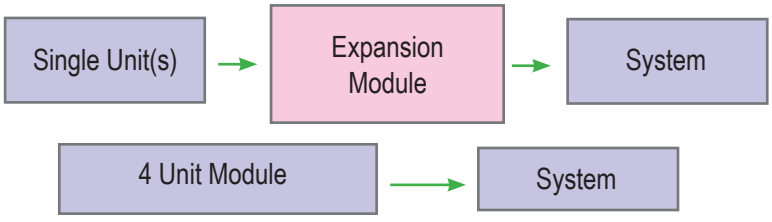


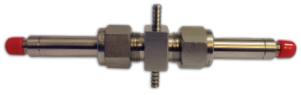
4 Unit Turbidity Module

Photometer/transmitter



Flow Cell Shown Connected to Fiber Optic Cables





Low hold-up absorbance flow cell for turbidity up to ~2750NTUs

PART #: SPEC-880-1CMLH

6.5 cm flow cell with luer connection for turbidity up to ~425NTSs

PART #: SPEC-880-5MMLH

Specifications

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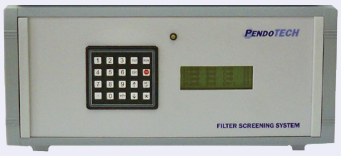
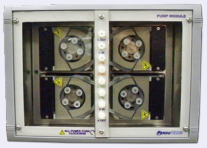


Filter Screening System Specification Table

Detail	Specifications
Enclosure Dimensions (HxWxD)	4.8inch x 13.8inch x 10.3inch (12.2x35.1x26.3cm)
Enclosure Weight	9lbs (4.1kg)
Enclosure Material	Aluminum
Power Requirements	100 - 240Volts, 50 - 60 Hertz, 2amp max
Pressure Sensor Inputs	PendoTECH Pressure Sensors default configuration- other full-bridge type sensors optional
Pump Control (1 for each pump)	Speed Control: 4 - 20mA or 0 - 10V output
Spare Inputs (standard)	Four of 4 - 20mA and four of 0 - 10V inputs

CE



Peristaltic Pump Module Specification Table

System Component	Specifications
Enclosure (with legs not retracted)	H x W x D: 9.85inchx13.8inchx10.3inch (25 x 35.1 x 26.3cm). Approx: 20lbs. (6.80kg), Material: Aluminum with powder polyester paint Front panel: 304 Stainless Steel with REGLO-E Peristaltic Panel mount pump; Back panel: anodized aluminum
Power Inlet With Power Switch	IEC 320 cord connection, 100 – 240Volts, 50 – 60Hertz, 2amp max
Fuse	2amps (housed integral with the Power Switch) at full voltage range
Environmental Operating Range	All components rated to a temperature range of 5 to 40°C. Humidity: 0 to 95% Relative Humidity, no condensation
Tubing Sizes	1/8inch ID x 1/4inch OD (Masterflex Size 16), 1/16inch ID x 3/16inch OD (Masterflex Size 14)
Fluid Property Range	Function of tubing material and pressure rating performance tested up to 30psi
Analog Pump Control	One DB-25 male connector. Configured for 0-5V signals from PendoTECH Filter Screening System. Control System Settings for Pump Setup: Maximum RPMs: 160 Size 16: 0.75mL/rot for max flow of 120mL/min Size 14: 0.188mL/rot for max flow of 30mL/min Accuracy: +/- 5% of value, Repeatability: +/- 1%
Tubing for Connection of Pump to Panel	1/8inch (0.3175cm) Hose barb Inlets/Outlets 1/16inch (0.15875cm) Hose barb Inlets/Outlets

CE

Diaphragm Pump Module Specification Table

System Component	Specifications
Enclosure (with legs not retracted)	H x W x D: 9.85inchx13.8inchx10.3inch (25 x 35.1 x 26.3cm). Approx: 15lbs. (6.80kg), Material: Aluminum with powder polyester paint Front panel: 304 Stainless Steel with Lexan® cover; Back panel: anodized aluminum
Power Inlet With Power Switch	IEC 320 cord connection, 100 – 240Volts, 50 – 60Hertz, 2amp max
Fuse	2amps (housed integral with the Power Switch) at full voltage range
Environmental Operating Range	All components rated to a temperature range of 5 to 40°C. Humidity: 0 to 95% Relative Humidity, no condensation
Pump Diaphragm Lifetime	>10,000 hours
Diaphragm Pump Fittings	Compression fitting for 1/8inch ID/1/4inch OD tubing (Masterflex Size 16)
Fluid Property Range	Permissible temperature of the medium being handled: 5 to 80°C. The dosing pump has been developed for liquids with viscosities of up to 150cSt. If particles greater that 25micron are present, a filter is recommended.
Analog Pump Control	One DB-25 male connector. Configured for 4-20mA signals from PendoTECH Filter Screening System (if in analog mode) Control System Settings for Pump Setup: 0.5ml/rotation Maximum RPMs: 200 Flow Range: 2.0 to 100mL/min Accuracy: +/- 5% of value Repeatability: +/- 1%
Diaphragm Pump Hold Up Volume	Total pump: ~0.530mL
Tubing for Connection of Pump to Panel	1/8inch ID ID: 0.318cm Length: 12cm per piece Hold-up: 1mL per piece Tubing total: 2mL for one train
Hold Up Volume per Train	~2.5mL

CE

Ordering Information

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SYSTEM	
PDKT-PCS-NFFSS	PendoTECH Normal Flow Filtration Screening System w/ PC software

PUMPS	
PUMP-MF-LS-TW	Masterflex General Purpose Drive, with RPM display only, 600RPM with EasyLoad II pump head for thin wall L/S tubings
PUMP-MFD-LS-TW	Masterflex Peristaltic Digital Pump w/DB25 remote control port for control from system. 600RPM drive w/ EasyLoad II for precision thin wall L/S tubing
PUMP-WM-120-TW	Watson-Marlow 120U/DV 200RPM Pump Fitted with 114DV flip-top four roller pumphead for thin wall tubing

PUMP MODULES	
PDKT-NFFSS-PPM	Peristaltic Pump Module for PendoTECH Filter Screening System
PDKT-NFFSS-PUMP	Diaphragm Pump Module for PendoTECH Filter Screening System

SCALES	
SCALE-OHAUS-6200-1	Ohaus Scout Pro model SPX-6201 (6200g x 0.1g) top loading balance w/RS232 output set up for PendoTECH Systems

VESSELS	
PDKT-NFFSS-CP	Constant pressure vessel: 0-25psi regulator, 0-60psi gauge, 12in polysulfone container with 2.5in TC (~800mL) with outfitted endcaps
PDKT-NFFSS-CP-NR	Constant pressure vessel: 12in polysulfone container with 2.5in TC (~800mL) with outfitted endcaps
ADDITIONAL ACCESSORIES FOR USING MULTIPLE VESSELS	
CP-07391-04	Low Pressure John Guest ball valve for 1/4inch OD Tube for air shut off
MC-5779K318	Splitter for tubing with 1/4inch OD Tube - one inlet and four outlets

TURBIDITY	
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-L-1-RU-880	Benchtop turbidity System w/ 880nm light source, 4-20mA output, 2 one meter fiber optic cables, 2 optical couplers for reusable flow cells, 24VDC power supply
SPEC-880-4	Four Station Turbidity System w/880nm Light Source, 4-20mA Output, panel model, 8 Fiber optic cables, 8 Optical couplers to connect to 4 Flow Cells
SPEC-880-6CM-L	Turbidity flow cell, stainless steel with 6.5cm path length - inlet / outlets luer
SPECPS-880-6CM	Single Use Turbidity Flow Cell, 6.5cm path length, non-sterile, polysulfone, 3/4inch Sanitary Flange Inlet/Outlet
PDKT-UV1-V-NFFSSB	Cable from single channel photometer Hirose connector to the PDKT-BOX-NFFSS breakout box, Voltage signal, 6ft

ACCESSORIES	
PDKT-STAND-NFFSS	Stainless steel stand for filter screening system
PDKT-BOX-NFFSS	Breakout box for analog inputs to 8 connectors (Expansion Module)
PDKT-NFFSS-WM25-WM15	Adapter cable from DB25 Watson Marlow 520 pump cable to Watson Marlow 120 pump, 6in
PDKT-NFFSS-MF25-WM15	Adapter cable from DB25 MasterFlex L/S pump cable to Watson Marlow 120 pump, 6in

FOR PENDOTECH PRESSURE SENSORS	See www.pendotech.com/pressure
FOR PENDOTECH TEMPERATURE SENSORS	See www.pendotech.com/temperature

Comes with every system - PDKT-NFFSS-KIT

PendoTECH Control System accessories kit with PREPS-N-000 luer inlet/outlet polysulfone sensors, 3 – way polycarbonate stopcocks and variety of luer to barb fittings

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