

## PendoTECH Process Control Systems: Pump Calibration

### 1. Introduction

The PendoTECH Filter Screening System (NFF) and TFF Process (TFF) allow users to automatically control flowrates throughout the duration of an experiment or process. Any pump capable of accepting a remote-control signal can be interfaced with PendoTECH control systems. PendoTECH systems control pumps by sending an analog signal which is proportional to the flowrate entered by the user on the system's graphical user interface (GUI). The analog output is scaled linearly from the pumps minimum flowrate to its calculated maximum flowrate. The following note describes the process of configuring a pump with its nominal flow values and making any necessary adjustments to compensate for the inherent inefficiencies associated with pump technology.

### 2. Connecting Pumps

#### a. PendoTECH NFF System

The PendoTECH NFF system is capable of independently controlling four pumps simultaneously. A custom cable is included with purchase of the system that must be specified to match the manufacturer of the pump to be used with the system, i.e. Masterflex or Watson-Marlow. The four pumps must also be of identical make and model in order to be used simultaneously. The use of an adapter cable is available, upon request, if there is a need to use a pump of different make and model. An example of a Masterflex pump cable is shown at right and the pump cable input is called out in the figure below.

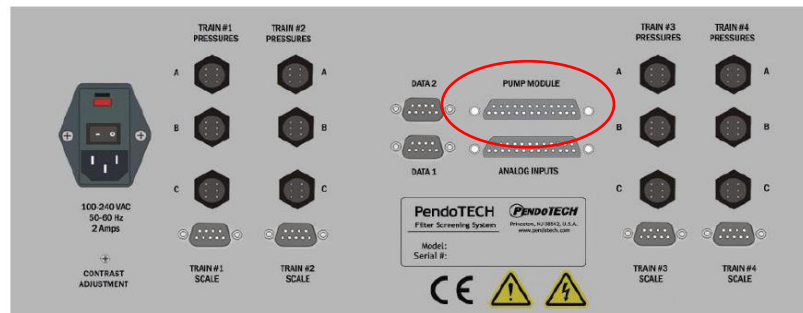
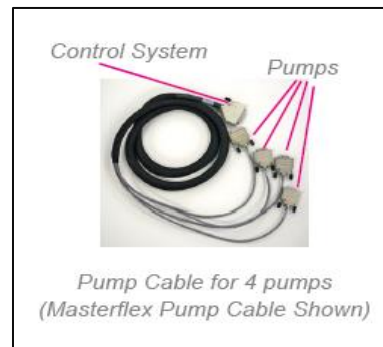


Figure 2.1 Back Panel of NFF Control System

#### b. PendoTECH TFF System

The PendoTECH TFF system can control up to three pumps simultaneously, specifically a main circulation pump, a diafiltration pump, and a Filtrate/Permeate pump. Unlike the NFF system, the pumps being used on the TFF system do not need to be of the same make and model. However, it is important to note that the connection cable between the control system and pump will vary between different model pumps. The pump inputs for the TFF system are called out below.

**Note - Only one of the following inputs will be used: Circulation Pump/Circ Pump Alternate**

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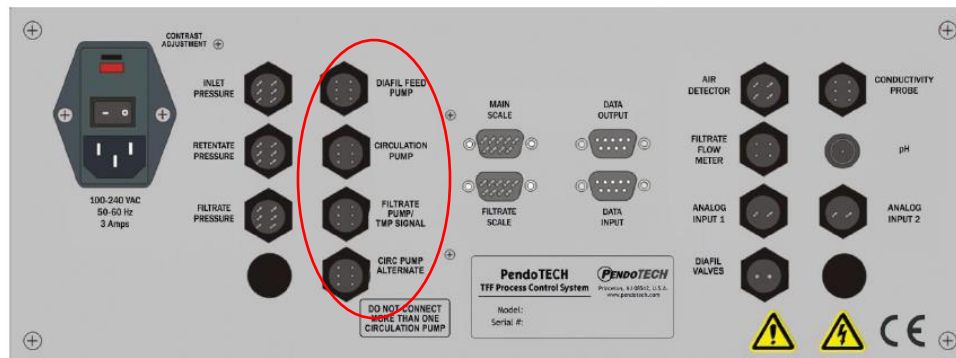


Figure 2.2 Back Panel of TFF Control System

## 3. Calibrating Pumps

There are two primary parameters that determine the performance of a particular pump; the maximum rotations per minute (RPM) of the pumps drive and the amount of liquid that is moved per revolution. The first parameter is labeled in PendoTECH control systems as Max RPM and the second is labeled as mL/rotation. These parameters must be input on the “Maintenance View” tab of the control system software each time a new pump is connected to the system. Once the pump calibration parameters are input they will be saved to the internal memory of the control system. The parameters are also stored within the PC program and re-sent to the control system each time the PC software is opened. This is done to confirm the correct settings are stored in the control system.

The following screenshot from the NFF control system software shows where the max RPM and mL/rot values are entered. The control system has a drop-down menu that allows the user to select from a list of standard pump offerings and will populate the nominal performance values for each pump across all four trains. The user can also select “Custom Settings” if their pump is not listed or if they want to tweak the nominal settings for more accurate flow control. Refer to section 4 for the process of verifying the calibration of each pump.

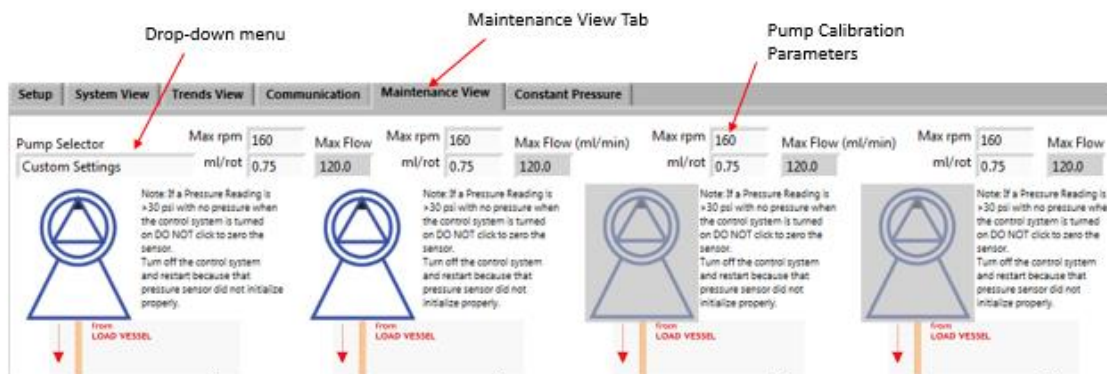


Figure 3.1 NFF GUI "Maintenance View" Tab

Calibrating pumps on the TFF Process Control System software is done in a similar manner. The calibration parameters are entered on the “Maintenance View” tab however, there is no drop-down pump selector. Users normally connect different models of pumps to serve as the circulation pump and diafiltration feed pump in order to achieve optimal flows. Therefore, each pump calibration must be input separately into the fields noted below. Selection guides available from PendoTECH for popular peristaltic pump models that provide this information based on tube size.

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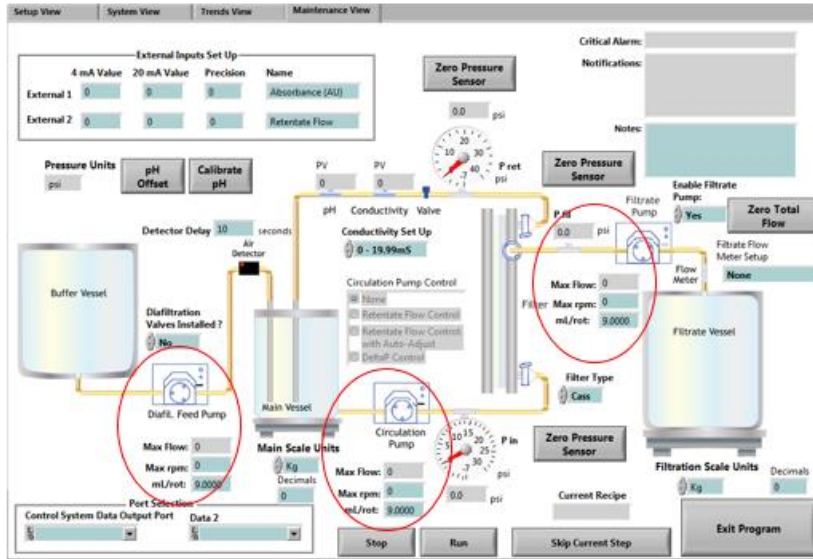


Figure 3.2 TFF GUI "Maintenance View" Tab

**Note:** The input fields for the “Filtrate Pump” will only appear if “Yes” is selected from the drop-down menu located below the text reading “Enable filtrate Pump”.

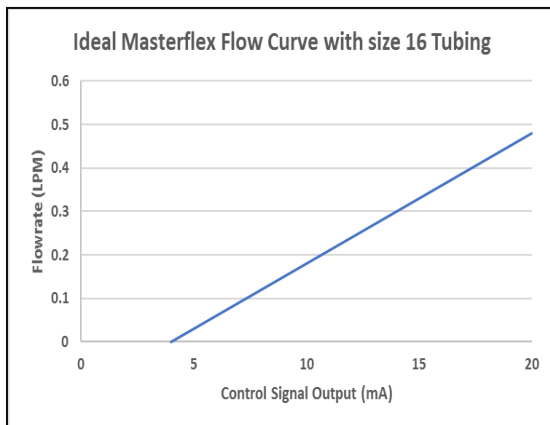
The following table lists some of the most popular nominal pump calibration parameters for PendoTECH’s standard offering of pumps used with either the NFF or TFF control system. As shown below, the mL/rot parameter for peristaltic pumps is dependent on tubing size while it is constant for diaphragm pumps irregardless of the size of tubing connected to the inlet/outlet. The nominal values listed below are taken directly from manufacturer documentation.

Manufacturer	Model	Max RPM	ml/rot (Size 14)	ml/rot (Size 16)	ml/rot (Size 17)	ml/rot (Size 24)	ml/rot (Size 36)
Quattroflow	Q150	3000			1		
Quattroflow	Q1200	1200			17		
Quattroflow	Q4400	583			99		
Masterflex	L/S	600	0.22	0.8	2.8	2.8	4.8
Watson-Marlow	120U	200	0.14	0.47	N/A	N/A	N/A

Please refer to vendor documentation provided on PendoTECH.com or contact PendoTECH customer service if you do not see your pump or tubing size listed above. In most cases, the mL/rot is the maximum flow in mL/min divided by the maximum RPMs.

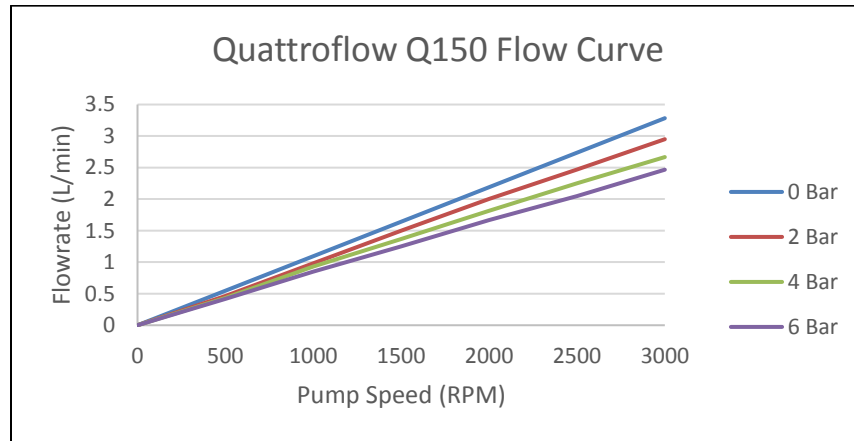
## 4. Flow Verification

This section will illustrate how to further calibrate pumps if the nominal settings described in section 3 are insufficient. The PendoTECH NFF and TFF systems control pumps, set to remote control, by sending analog signals, generally 4-20 mA, that are proportional to the flowrate entered by the user. The user enters the unique calibration values for the pump they are using as described in section 3. The system then scales the output linearly from the minimum flow value (0 LPM) to the calculated maximum flowrate which is simply equal to MAX RPM \* mL/rotation. The following graph shows the control logic for a Masterflex L/S pump with size 16 tubing installed.



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Using an output that is scaled linearly assumes an ideal relationship between pump revolution and displacement at all speeds. This is a fairly safe assumption at lower flowrates, due to limited back pressure acting on the pump, and will generally yield stable results within 3-5% of the user entered flowrate. However, with larger systems and higher flowrates, backpressure increases and inefficiencies in the pumping mechanisms are exacerbated leading to a non-linear flowcurve. A more realistic flowcurve is shown in the graph below. At low-moderate drive speeds the Quattroflow Q150 flowcurve is still largely linear but as the motor speed and backpressure increase the curve begins to flatten out as the pump is no longer operating as efficiently.



In order to compensate for the inefficiencies described above PendoTECH recommends conducting a flow verification during a conditioning or flushing step. An off-line bucket check can be performed to determine the exact flowrate being output by the system. If a retentate flow meter is in line, the permeate can be closed and the flow meter can be used to monitor pump output flow. The following data demonstrates an extreme case of non-linearity. Data provided by Triangle Process Equipment during testing of Quattroflow Q4400 with PendoTECH TFF Process Control System.

Shaft Speed RPM	HMI set point (LPM)	Actual (LPM)	Variance
215	21.66	20.7	- 4.5%
297	31	28.2	- 9%
400	40.7	37.88	- 7%

If an error of 5-10% is unacceptable by process standards than a one-point calibration can be performed to dial in the required flowrate. This can be done by tweaking the ml/rot factor on the maintenance view seen as described in section 3. For example, if a 31 LPM flowrate was required, the data above shows that the system was producing a flowrate that was 9% less than the expected value. To address this, the user could simply decrease the ml/rot value for the circulation pump by 9% which would lead to the system delivering exactly the required flowrate. A flowchart can be found in the appendix of this document which details how to properly execute this procedure.

It is important to note that only the ml/rot value should be changed and not the Max RPM. If necessary this routine can be performed for each pump operating as part of the system. In the case of the NFF, different ml/rot values can be entered for each pump by selecting custom settings then tweaking the parameter accordingly.

This calibration procedure is not unique to PendoTECH control system. For example, the flowrate displayed on a Masterflex L/S during manual use is simply the pump assuming a linear flowcurve and using the nominal values listed in section 3. The pump can then be further calibrated by the end user in order to increase the accuracy of the system. The default pump calibration procedure is essentially changing the pump's nominal mL/rotation parameter. For pumps that have an RPM display only, the user

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must develop a single or multi-point calibration to define the relationship between RPMs and flow which is defined by mL/rotation factor.

Please visit [PendoTECH.com](http://PendoTECH.com) or contact PendoTECH customer service if any further information is required.

## 5. Appendix

Flow verification Flowchart

