- Introduction
- Objective and Motivation
- Experiment
  - Fluid System Description
  - Test sections
  - Experimental Parameters
  - Experiment Operation

- End-To-End Testing
- Experimental Results/Urine Filter
  - Pressure signal
  - Pressure drop
  - Permeability for single phase
  - Permeability with two-phase flows

- The Packed Bed Reactor Experiment – Water Recovery Series (abbreviated as PBRE-WRS) a flight experiment where adiabatic two-phase flow in various fluid components is investigated.

- PBRE-WRS will be conducted using the PBRE and PBRE-2 fluid system hardware with the intended test sections.

- The purpose/approach is to update the test modules by replacing the packed bed column with a setup that will permit installation and removal of any one of eight (8) test sections provided by the PI team at NASA Marshall Space Center (MSFC).

- Directly aligns with high priorities from the NRC Decadal survey on Biological and Physical Sciences (1) and the NRC 2000 report on Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies (2):

  - AP-2: Provide study of a critical multiphase flow component for life support systems.

  - TSES-6: Provide a fundamental study in porous media under microgravity conditions.

- Two-phase components are critical to life support and thermal control systems

https://www1.grc.nasa.gov/space/iss-research/msg/pbre-wrs/

- The objective of the PBRE-WRS project is to investigate the two-phase flow hydrodynamics experienced in the normal and microgravity environments for an array of filters and flow restrictors

- Hydrodynamics encompass:

  - Pressure drop across test articles

  - Visualization on some test articles

  - Flow oscillation and any potential instabilities

Fluid system Description

▪ The fluid system consists of:

- An open loop that provides the ISS N_2 gas into the test module and a closed water loop that provides the water flow rates for each of the experimental runs.

- Nitrogen is acquired from the ISS N_2 source and regulated to the desired pressure via pressure regulators.

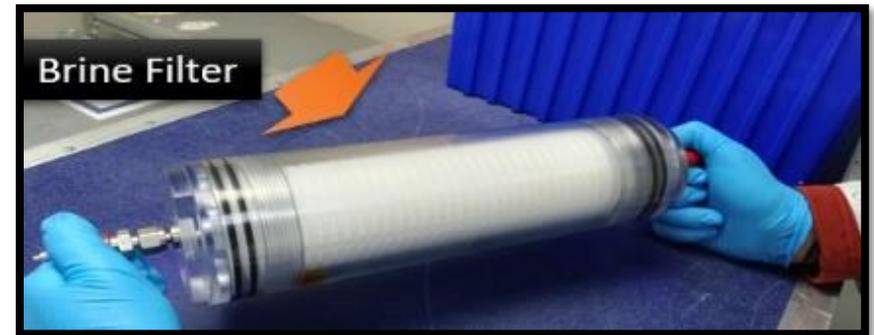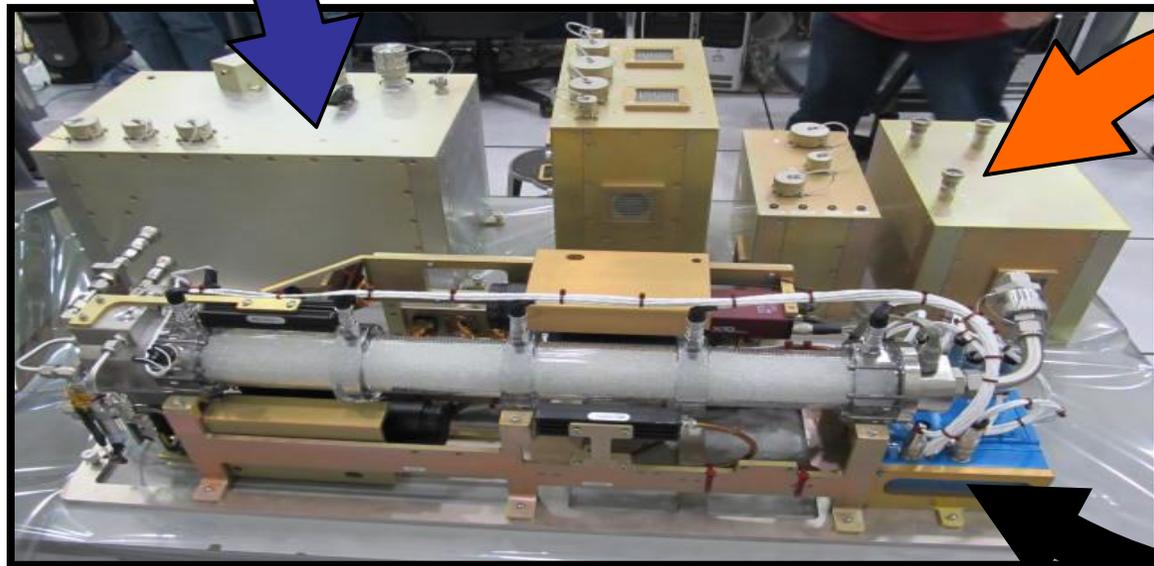- Two gas Coriolis flow meter and flow control valves provide the desired flow rate, with one flow meter dedicated for low flows (< 0.02 kg/hr) and another for the higher flows (>0.02 kg/hr). The nitrogen flow is brought into a mixing chamber where it is mixed with the water flow to generate a two-phase flow through the test article/section.

- After the measurements are taken, the two-phase flow is directed to a centrifugal separator that separates the nitrogen from water and the nitrogen is vented out.

- The water flow is returned to the test section by a positive displacement pump.

- The water flow rate is measured by two different Coriolis flow meters each dedicated for a range of water flow rates.

PBRE Modules

Water outlet to test module

Fill port valve

High and Low Flow Pumps

Water to gas control interface connector

Fill port

GN2 Gas outlet

Two-phase flow inlet

Separator

Mass flow meter 2

Separator pump

Packed Bed Reactor Experiment

GN2 Sub Feed Outlet (To test module)

GN2 main Outlet (To test module)

GN2 inlet (from MSG supply)

Pressure Regulator (2)

Mass Flow Controller (3)

Pressure Relief valve (5)

Gas Control to water control interface connector

Packed Bed Reactor Experiment

Brine Filter

PBRE-1 & -2/WR [front view]

Removed

- Test Column
- 5 Pressure Transducers's & 5 Amplifiers
- Camera/Lens/Mirror #1
- Light Bar Set #1

https://www1.grc.nasa.gov/space/iss-research/msg/pbre-wrs/

Added

- Inlet Manifold
- Outlet Manifold
- Outlet Bracket
- Replaced Connector Mount
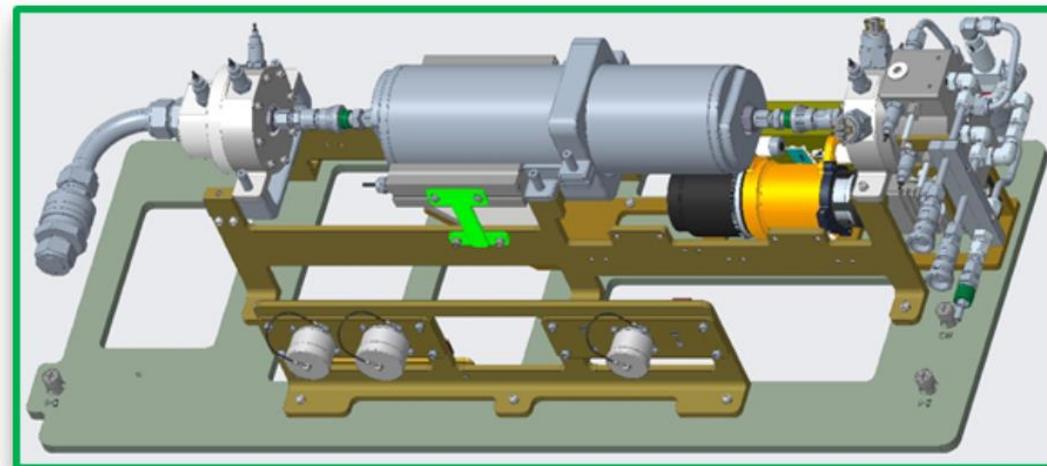
PBRE-WRS [front view]

Test Article or Section	Description of Measurement
Purge Filter	Pressure at the inlet and exit and liquid and gas flow rates with two-phase water-nitrogen flow through the filter 0.8 L/hr < Water Flow Rate < 1.2 L/hr 50% < Nominal Gas flow (Vol%) < 50%
Urine Filter	Pressure at the inlet and exit and liquid and gas flow rates with two-phase water-nitrogen flow through the filter 70 L/hr < Water Flow Rate < 80 L/hr 10% < Nominal Gas flow (Vol%) < 10%
Brine Filter	Pressure at the inlet and exit and liquid and gas flow rates with two-phase water-nitrogen flow through the filter 75 L/hr < Water Flow Rate < 95 L/hr 1% < Nominal Gas flow (Vol%) < 1%
Orifices	Pressure at the inlet and exit and liquid and gas flow rates with two-phase water-nitrogen flow through the each of the 4 orifices of different diameters 4.99 L/hr < Water Flow Rate < 6.804 L/hr 18.22% < Nominal Gas flow (Vol%) < 14.05%
Check Valve	Pressure at the inlet and exit and liquid and gas flow rates with two-phase water-nitrogen flow through the check valve 4.99 L/hr < Water Flow Rate < 6.804 L/hr 50% < Nominal Gas flow (Vol%) < 50%

- PBRE-WRS will be operated autonomously by commanding from ground via the TeleScience Center at NASA-GRC.

- The test matrix that contains the test points (TPs) will be uploaded using the flight software

- TPs will be executed in batches or individually by commanding the TP numbers

- The test matrix contains details about each of the TPs like the instrumentation and image recording rates and durations.

- The test matrix contains details about each of the TPs like the instrumentation and image recording rates and durations.

- Each of the parameters shown in the table for the Brine Filter is executed by the software.

- To execute TP 614, the software decides to use MFC 24 based on the desired flow rate being smaller than the limit (<0.0201 kg/hr).

BRINE FILTER MODULE – 75 W

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (Hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
611	0	10	0	N	300	N
612	0.0010	75	0	N	300	N
613	0.0010	75	20	Y	100	N
614	0.0013	75	0	N	300	N
615	0.0013	75	20	Y	100	N
616	0.0016	75	0	N	300	N
617	0.0016	75	20	Y	100	N
618	0	10	0	N	60	Y

- Since the liquid flow rate is 75 kg/hr (>12.5 kg/hr), flow meter MFM 35 is chosen to deliver the requested water flow rate.

- The parameters on the camera and the duration of the test point as shown in the table are also executed by the software.
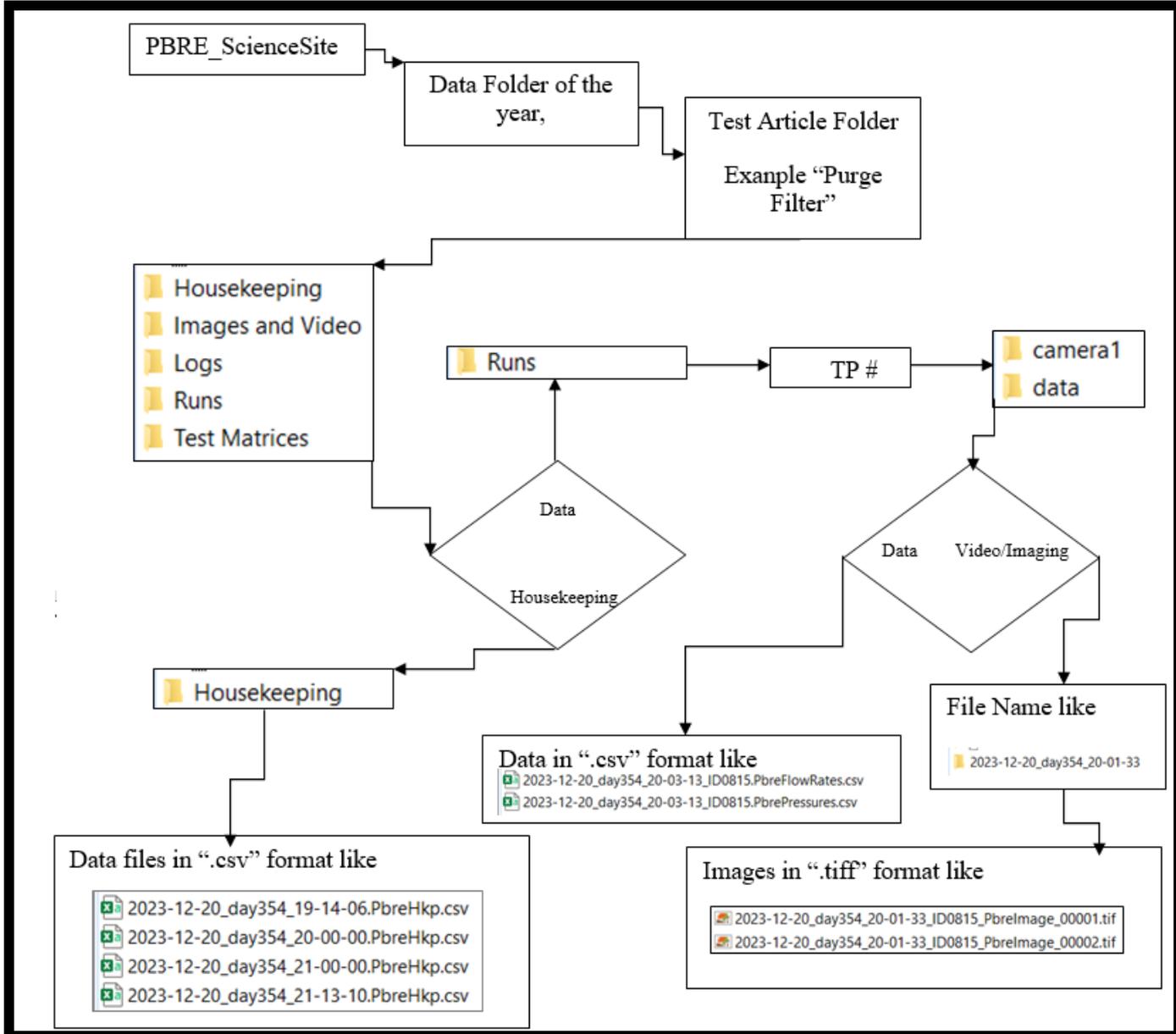
- Housekeeping Data is continuously recorded as TPs are executed and during transition from one TP to another at a lower frequency (1 Hz).

- To match the science data with the housekeeping data, time referencing/matching will be necessary.

- Time signature in science files is written in the science file and such a signature is matched with the time written in the housekeeping file.

PBRE-WRS Data Management

- Structure of files as obtained from the GIPOC server which houses the flight data.

📊 2023-12-21_day355_12-41-35_ID0703.PbreFlowRates	12/21/2023 7:41 AM	Microsoft Excel Co…	88 KB
📊 2023-12-21_day355_12-41-35_ID0703.PbrePressures	12/21/2023 7:41 AM	Microsoft Excel Co…	19,496 KB
📊 2023-12-21_day355_12-48-38_ID0705.PbreFlowRates	12/21/2023 7:48 AM	Microsoft Excel Co…	88 KB
📊 2023-12-21_day355_12-48-38_ID0705.PbrePressures	12/21/2023 7:48 AM	Microsoft Excel Co…	19,413 KB

- Flow rate data in the data file in ".csv" format

- Temperature of the fluid is measured and recorded in the housekeeping files.

- Slight temperature increase (~1 to 2 °C) is expected as the TPs are executed consecutively due to some heating from operating the system.

Date	Day	Time	ElapsedSecs	Id	MFC23 (kg/h)	MFC24 (kg/h)	MFM34 (kg/h)	MFM35 (kg/h)	BPC37 (psia)
12/21/2023	355	12:39:55:219	0.096	703	-0.0009178	-1.77E-05	73.0375	-0.0121761	14.4837
12/21/2023	355	12:39:55:313	0.19	703	-0.0011153	-2.20E-05	73.084	-0.0122015	14.4867
12/21/2023	355	12:39:55:409	0.286	703	-0.0012621	-2.55E-05	73.091	-0.0121773	14.4872
12/21/2023	355	12:39:55:503	0.38	703	-0.0014179	-3.55E-05	73.0523	-0.0121612	14.4868
12/21/2023	355	12:39:55:600	0.477	703	-0.0015296	-3.46E-05	73.0912	-0.0121534	14.4872
12/21/2023	355	12:39:55:702	0.579	703	-0.0015797	-3.38E-05	73.044	-0.0121768	14.4875
12/21/2023	355	12:39:55:801	0.678	703	-0.0016111	-3.87E-05	73.0904	-0.0121981	14.4876
12/21/2023	355	12:39:55:900	0.777	703	-0.0016221	-3.81E-05	73.0351	-0.0122107	14.4875
12/21/2023	355	12:39:56:001	0.878	703	-0.0016221	-3.38E-05	73.0279	-0.0121954	14.4873
12/21/2023	355	12:39:56:101	0.978	703	-0.001569	-3.99E-05	72.997	-0.0121829	14.4868
12/21/2023	355	12:39:56:201	1.078	703	-0.0014826	-5.72E-05	73.0071	-0.012175	14.487
12/21/2023	355	12:39:56:300	1.177	703	-0.0013808	-5.76E-05	72.9715	-0.0121874	14.4875
12/21/2023	355	12:39:56:400	1.277	703	-0.0012778	-5.86E-05	73.0054	-0.0122103	14.4873
12/21/2023	355	12:39:56:501	1.378	703	-0.0011799	-5.93E-05	72.935	-0.0122138	14.4875

- Pressure science data is recorded in the raw voltage and engineering unit formats

Science Data	Frequency (Hz)
Pressure (psi)	910
Flow rate (kg/hr)	10
Housekeeping	1

Date	Day	Time	ElapsedSecs	Id	PT06 (psia)	PT07 (psia)	PT08 (psia)	PT09 (psia)	PT21 (psia)	PT23 (psia)	PT25 (psia)	PT32 (psia)	PT36 (psia)	PT38 (psia)	PT06(V)	PT07(V)	PT08(V)	PT09(V)	PT21(V)	PT23(V)	PT25(V)	PT32(V)	PT36(V)	PT38(V)	Camera1 SyncOut 2(V)
12/21/2023	355	12:39:55:	0	703	24.7552	26.0116	14.8316	14.5487	121.777	109.128	57.9662	30.5649	36.2338	14.7881	2.53512	2.54111	1.46786	1.4788	3.0899	2.74445	2.87936	3.07875	0.927	1.47162	-10
12/21/2023	355	12:39:55:	0.002	703	24.7531	26.0061	14.8402	14.5504	121.793	109.134	57.9494	30.6007	35.6711	14.7848	2.53491	2.54058	1.4687	1.47896	3.09032	2.74461	2.87853	3.08226	0.91318	1.4713	-10
12/21/2023	355	12:39:55:	0.003	703	24.7499	26.0082	14.8334	14.5492	121.797	109.15	57.9514	30.6136	36.587	14.7803	2.5346	2.54079	1.46804	1.47885	3.09041	2.745	2.87863	3.08352	0.93567	1.47085	-10
12/21/2023	355	12:39:55:	0.004	703	24.7525	26.0106	14.8263	14.545	121.811	109.146	57.9571	30.536	37.3216	14.7791	2.53486	2.54101	1.46735	1.47843	3.09076	2.7449	2.87891	3.07592	0.95371	1.47073	-10
12/21/2023	355	12:39:55:	0.005	703	24.7542	26.0158	14.8253	14.5454	121.823	109.149	57.9715	30.6558	36.6031	14.7838	2.53502	2.54152	1.46725	1.47847	3.09106	2.74497	2.87962	3.08766	0.93607	1.4712	-10
12/21/2023	355	12:39:55:	0.006	703	24.7548	26.0177	14.8251	14.545	121.83	109.132	57.971	30.7445	35.8181	14.7832	2.53508	2.54171	1.46723	1.47844	3.09124	2.74455	2.87959	3.09634	0.91679	1.47114	-10
12/21/2023	355	12:39:55:	0.007	703	24.7616	26.0185	14.8301	14.547	121.801	109.123	57.9588	30.7324	35.5489	14.7825	2.53576	2.54178	1.46772	1.47863	3.09051	2.74435	2.87899	3.09516	0.91018	1.47107	-10
12/21/2023	355	12:39:55:	0.008	703	24.7613	26.0172	14.8266	14.5481	121.84	109.096	57.9589	30.7379	35.2544	14.7835	2.53573	2.54167	1.46738	1.47874	3.09149	2.74367	2.879	3.0957	0.90295	1.47116	-10
12/21/2023	355	12:39:55:	0.009	703	24.761	26.0201	14.8267	14.5464	121.833	109.111	57.9383	30.7915	34.0718	14.7879	2.5357	2.54194	1.46739	1.47857	3.09132	2.74405	2.87799	3.10094	0.87391	1.4716	-10
12/21/2023	355	12:39:55:	0.01	703	24.7643	26.0242	14.8265	14.5489	121.843	109.136	57.978	30.7668	33.1087	14.7857	2.53603	2.54235	1.46737	1.47882	3.09156	2.74466	2.87994	3.09852	0.85026	1.47138	-10
12/21/2023	355	12:39:55:	0.011	703	24.7611	26.0227	14.823	14.5429	121.831	109.155	57.9622	30.6151	32.9269	14.7807	2.53571	2.54219	1.46703	1.47823	3.09125	2.74511	2.87916	3.08366	0.8458	1.47089	-10
12/21/2023	355	12:39:55:	0.012	703	24.7651	26.0244	14.8241	14.5432	121.865	109.112	57.9876	30.6253	31.6551	14.7873	2.53611	2.54236	1.46713	1.47825	3.0921	2.74406	2.8804	3.08467	0.81457	1.47154	-10
12/21/2023	355	12:39:55:	0.013	703	24.7631	26.0242	14.8257	14.5395	121.824	109.094	57.9738	30.5519	32.053	14.7838	2.53591	2.54234	1.46729	1.47788	3.0911	2.74362	2.87973	3.07748	0.82434	1.47119	-10
12/21/2023	355	12:39:55:	0.014	703	24.7612	26.0249	14.8235	14.5399	121.873	109.126	57.9819	30.5151	33.7416	14.7813	2.53572	2.54242	1.46708	1.47793	3.09231	2.7444	2.88012	3.07387	0.8658	1.47095	-10
12/21/2023	355	12:39:55:	0.015	703	24.7597	26.0224	14.8275	14.5418	121.828	109.127	57.9716	30.6339	34.3203	14.7863	2.53556	2.54216	1.46746	1.47812	3.09119	2.74444	2.87962	3.08551	0.88001	1.47144	-10
12/21/2023	355	12:39:55:	0.017	703	24.7565	26.014	14.8252	14.5426	121.816	109.118	57.9718	30.5875	33.8943	14.7786	2.53525	2.54135	1.46724	1.4782	3.0909	2.74421	2.87963	3.08096	0.86956	1.47069	-10
12/21/2023	355	12:39:55:	0.018	703	24.7573	26.0124	14.8251	14.5414	121.828	109.14	57.9741	30.6365	34.1804	14.7801	2.53533	2.5412	1.46723	1.47808	3.09118	2.74475	2.87974	3.08577	0.87658	1.47084	-10
12/21/2023	355	12:39:55:	0.019	703	24.7505	26.0086	14.8204	14.5382	121.862	109.151	57.9974	30.608	34.9019	14.7856	2.53465	2.54083	1.46677	1.47776	3.09203	2.74502	2.88089	3.08297	0.8943	1.47137	-10
12/21/2023	355	12:39:55:	0.02	703	24.7529	26.0128	14.8203	14.5356	121.847	109.173	57.997	30.5484	35.9725	14.7892	2.53489	2.54123	1.46676	1.4775	3.09167	2.74557	2.88087	3.07714	0.92059	1.47172	-10
12/21/2023	355	12:39:55:	0.021	703	24.7514	26.0109	14.8239	14.5357	121.873	109.178	57.9886	30.4723	36.3433	14.7908	2.53475	2.54105	1.46712	1.47751	3.09231	2.74569	2.88045	3.06968	0.92969	1.47188	-10

- Video data is recorded in the ".tiff" format with different frame rates as dictated by the test matrix. Example of a series of tiff files is shown

- A slug of nitrogen shown traveling in the graduated tube downstream of the exit of orifice 3

File	Date	Type
2023-12-19_day353_22-50-07_ID0427_PbreImage_00350	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00351	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00352	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00353	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00354	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00355	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00356	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00357	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00358	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00359	12/19/2023 5:50 PM	TIF File
2023-12-19_day353_22-50-07_ID0427_PbreImage_00360	12/19/2023 5:50 PM	TIF File
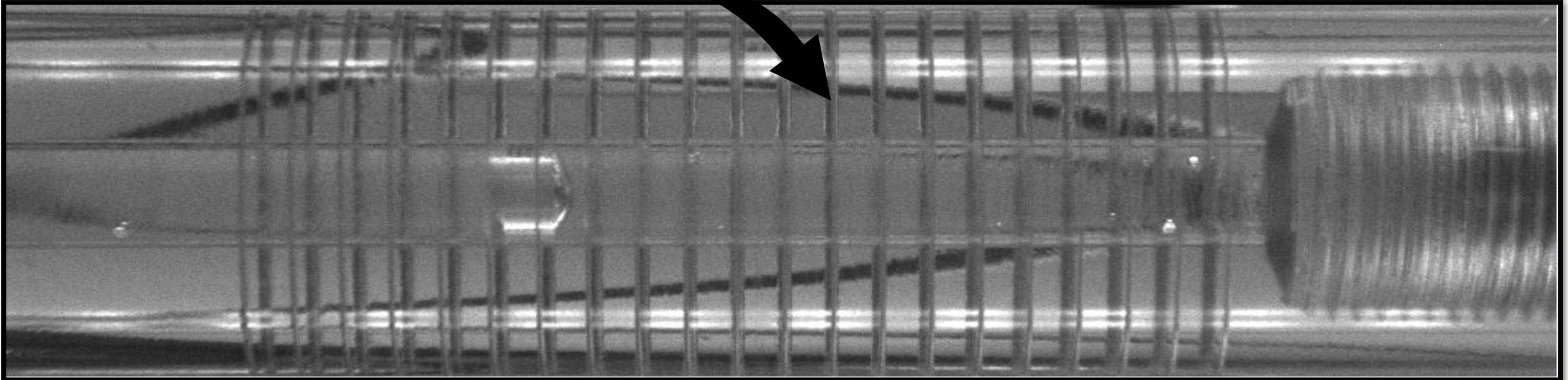
1.0 ORIFICE MODULE 1 – Water Only

Orifice 1

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
101	0	10	0	N	300	N
102	0	4.990	0	N	300	N
103	0	4.990	200	Y	100	N
104	0	5.443	0	N	300	N
105	0	5.443	200	Y	100	N
106	0	5.897	0	N	300	N
107	0	5.897	200	Y	100	N
108	0	6.350	0	N	300	N
109	0	6.350	200	Y	100	N
110	0	6.804	0	N	300	N
111	0	6.804	200	Y	100	N
112	0	0	0	N	20	Y

1.5 ORIFICE MODULE 1 – 15 W

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
161	0	10	0	N	300	N
162	0.00095	6.804	0	N	300	N
163	0.00095	6.804	20	Y	100	N
164	0.00142	6.804	0	N	300	N
165	0.00142	6.804	20	Y	100	N
166	0.00189	6.804	0	N	300	N
167	0.00189	6.804	20	Y	100	N
168	0	10	0	N	60	Y

5.0 CHECK VALVE MODULE – Water Only

Check Valve

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
501	0	10	0	N	300	N
502	0	4.990	0	N	300	N
503	0	4.990	20	Y	100	N
504	0	5.443	0	N	300	N
505	0	5.443	20	Y	100	N
506	0	5.897	0	N	300	N
507	0	5.897	20	Y	100	N
508	0	6.350	0	N	300	N
509	0	6.350	20	Y	100	N
510	0	6.804	0	N	300	N
511	0	6.804	20	Y	100	N
512	0	0	0	N	20	Y

5.5 CHECK VALVE MODULE – 15 W

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
561	0	10	0	N	300	N
562	0.0084	6.804	0	N	300	N
563	0.0084	6.804	20	Y	100	N
564	0.0103	6.804	0	N	300	N
565	0.0103	6.804	20	Y	100	N
566	0.0126	6.804	0	N	300	N
567	0.0126	6.804	20	Y	100	N
568	0	10	0	N	60	Y

4.0 ORIFICE MODULE 4 – Water Only

Orifice 4

| Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
401	0	10	0	N	300	N
402	0	4.990	0	N	300	N
403	0	4.990	200	Y	100	N
404	0	5.443	0	N	300	N
405	0	5.443	200	Y	100	N
406	0	5.897	0	N	300	N
407	0	5.897	200	Y	100	N
408	0	6.350	0	N	300	N
409	0	6.350	200	Y	100	N
410	0	6.804	0	N	300	N
411	0	6.804	200	Y	100	N
412	0	0	0	N	20	Y

4.5 ORIFICE MODULE 4 – 15 W

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
461	0	10	0	N	300	N
462	0.00129	6.804	0	N	300	N
463	0.00129	6.804	20	Y	100	N
464	0.00194	6.804	0	N	300	N
465	0.00194	6.804	20	Y	100	N
466	0.00259	6.804	0	N	300	N
467	0.00259	6.804	20	Y	100	N
468	0	10	0	N	60	Y

6.0 BRINE FILTER MODULE – Water Only

Brine Filter

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
601	0	10	0	N	60	N
602	0	75	0	N	300	N
603	0	75	20	Y	100	N
604	0	85	0	N	300	N
605	0	85	20	Y	100	N
606	0	95	0	N	300	N
607	0	95	20	Y	100	N
608	0	0	0	N	60	N

6.3 BRINE FILTER MODULE – 95 W

Test Point	Gas Rate (kg/hr)	Water Rate (L/hr)	Camera Rate (hz)	High Speed Data (Y/N)	Duration (secs)	Wait When Done (Y/N)
631	0	10	0	N	300	N
632	0.0023	95	0	N	300	N
633	0.0023	95	20	Y	100	N
634	0.0029	95	0	N	300	N
635	0.0029	95	20	Y	100	N
636	0.0035	95	0	N	300	N
637	0.0035	95	20	Y	100	N
638	0	10	0	N	60	Y

All test matrices start with water flows only followed by specified flow rates of water and nitrogen

- End-to End testing performed at ZIN in December 2023
- Each test article was installed in the vertical direction and tested with water only and with water and nitrogen flows
- Video imaging performed on test articles equipped with sight glass tube
- Present PRELIMINARY Observation from Urine filter ground testing with single phase (water only) flow
  - Pressure Drop
  - Permeability Based on Darcy's Law for single phase flow
- Present PRELIMINARY test results from Urine filter ground testing with single phase (water only) flow
  - Two-phase flow pressure drop
  - Potential scaling with two-phase friction factor

Urine Filter-Summary Table

Test Section
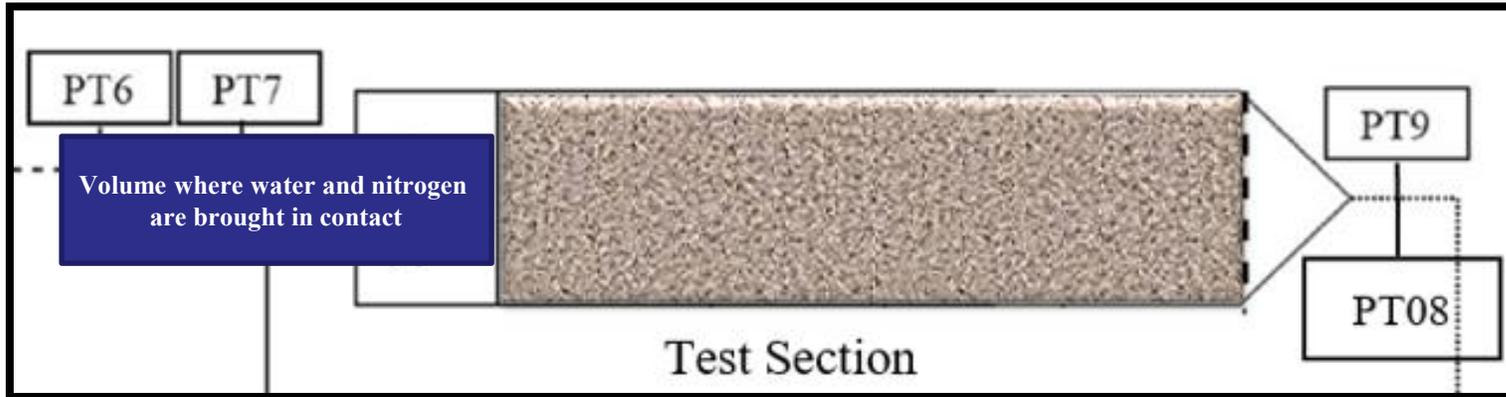
- **Inlet Pressure in measured by two pressure transducers PT06 and PT07**
- **Exit pressure is measured by PT08 and PT09**

| Test Point	date	MFC23	StdDev$_{MFC23}$	MFC24	StdDev$_{MFC24}$	MFM34	StdDev$_{MFM34}$	MFM35	StdDev$_{MFM35}$	PT06	StdDev$_{PT06}$	MaxDev$_{PT06}$	PT07	StdDev$_{PT07}$	MaxDev$_{PT07}$	PT08	StdDev$_{PT08}$	MaxDev$_{PT08}$	PT09	StdDev$_{PT09}$	MaxDev$_{PT09}$
ID0703	2023-12-21	0	0	0	0	72.9013	0.0914511	0	0	24.7658	0.0153467	0.0588711	26.0263	0.0157747	0.0598866	14.8166	0.00883718	0.0442124	14.5384	0.00727069	0.316912
ID0705	2023-12-21	0	0	0	0	80.988	0.250622	0	0	26.9937	0.0483892	0.156897	28.3156	0.0499363	0.156506	14.8038	0.00862316	0.0449777	14.541	0.00777717	0.309878
ID0707	2023-12-21	0	0	0	0	89.0972	0.0644487	0	0	29.5244	0.0178276	0.0598307	30.9155	0.0182891	0.0599171	14.7905	0.00831038	0.0431705	14.5415	0.00780671	0.294971
ID0713	2023-12-21	0	0	0.0143915	0.00003385 08	72.8975	0.194395	0	0	27.7489	0.215371	0.677923	29.0904	0.222531	0.705068	15.5587	0.315759	3.89199	15.2822	0.312604	3.58889
ID0715	2023-12-21	0	0	0.0184003	0.00004012 71	72.8988	0.124494	0	0	28.1872	0.18738	0.61326	29.5396	0.193584	0.635556	15.6259	0.32302	3.76343	15.3581	0.319811	3.45933
ID0717	2023-12-21	0.022471	0.000390843	0	0	72.9027	0.151067	0	0	28.5844	0.234247	0.731896	29.9438	0.241706	0.757025	15.6998	0.33905	3.30283	15.4403	0.335677	3.01183
ID0723	2023-12-21	0	0	0.017797	0.00005212 44	80.9998	0.13838	0	0	31.1665	0.148369	0.53345	32.5975	0.152947	0.549916	15.6206	0.261497	3.8555	15.3776	0.258966	3.5773
ID0725	2023-12-21	0.0226097	0.000114611	0	0	80.9999	0.109948	0	0	31.8234	0.152739	0.569242	33.2709	0.157606	0.589377	15.7336	0.270408	3.01918	15.4993	0.267742	2.74268
ID0727	2023-12-21	0.0277972	0.000124876	0	0	80.9977	0.142918	0	0	32.3739	0.185138	0.667276	33.8354	0.191002	0.682085	15.7967	0.345285	4.83001	15.571	0.341872	4.55851
ID0733	2023-12-21	0.0214211	0.00008071 49	0	0	89.1025	0.123413	0	0	35.0323	0.166206	0.668102	36.566	0.171391	0.685321	15.6298	0.21511	3.50821	15.4181	0.213032	3.24711
ID0735	2023-12-21	0.0274217	0.00007864 42	0	0	89.097	0.144718	0	0	35.9119	0.151675	0.47559	37.4698	0.156306	0.494686	15.7615	0.224885	2.82916	15.559	0.22274	2.59816
ID0737	2023-12-21	0.0329928	0.00134002	0	0	89.0858	0.182631	0	0	36.6788	0.224557	0.872785	38.257	0.231301	0.899894	15.8373	0.291463	3.27669	15.6424	0.288692	3.04479
ID0737	2023-12-21	0.0337018	0.00008594 82	0	0	89.0959	0.162737	0	0	36.834	0.192934	0.620253	38.4157	0.198876	0.640819	15.8135	0.303443	3.88252	15.627	0.300495	3.65082
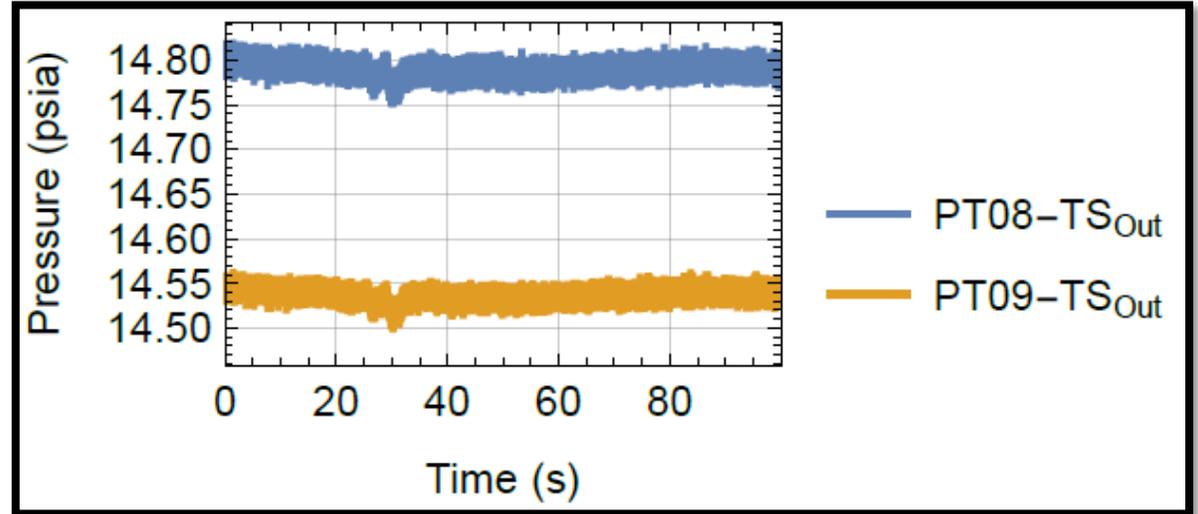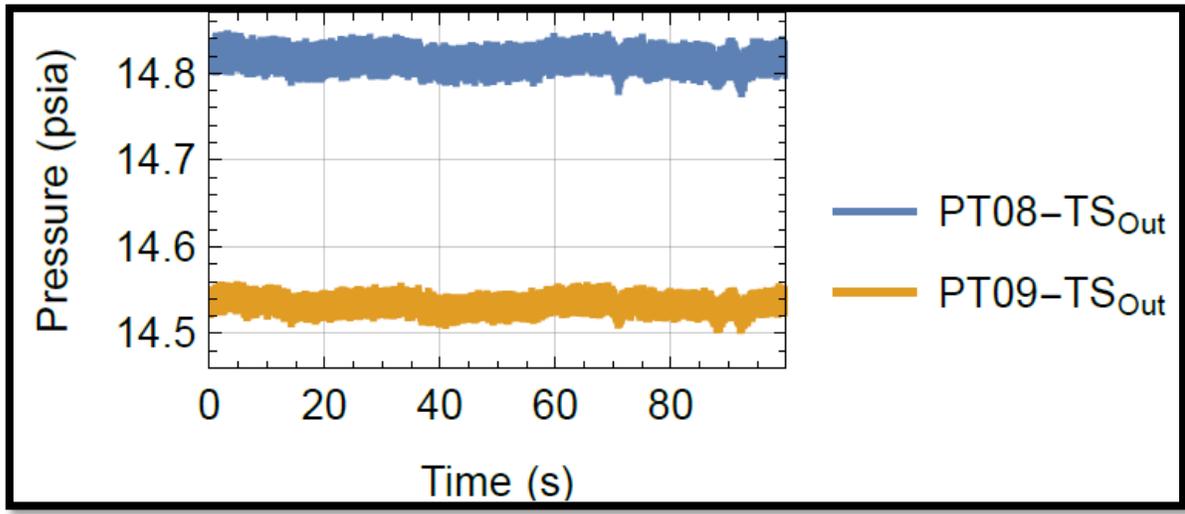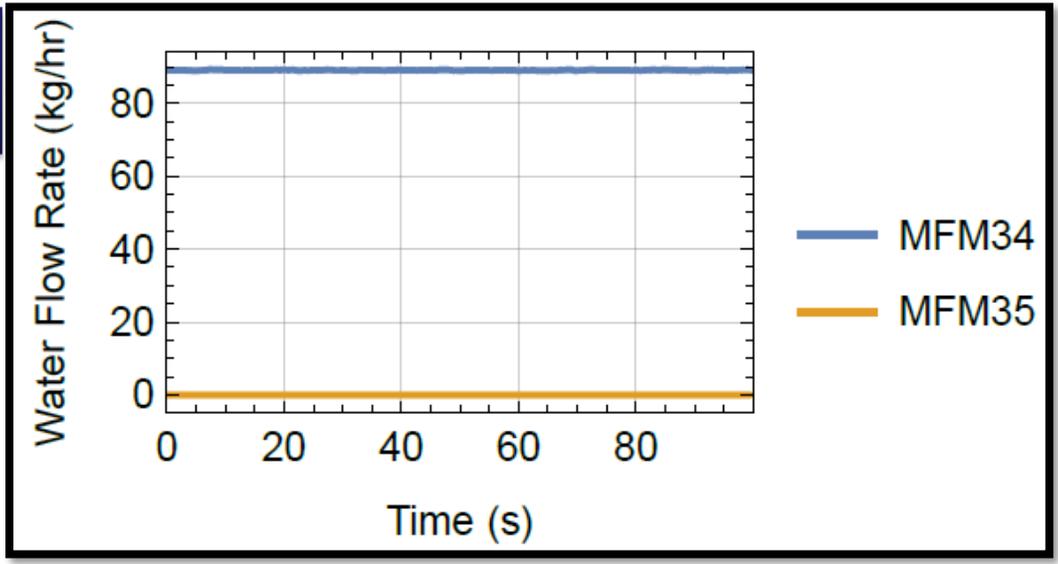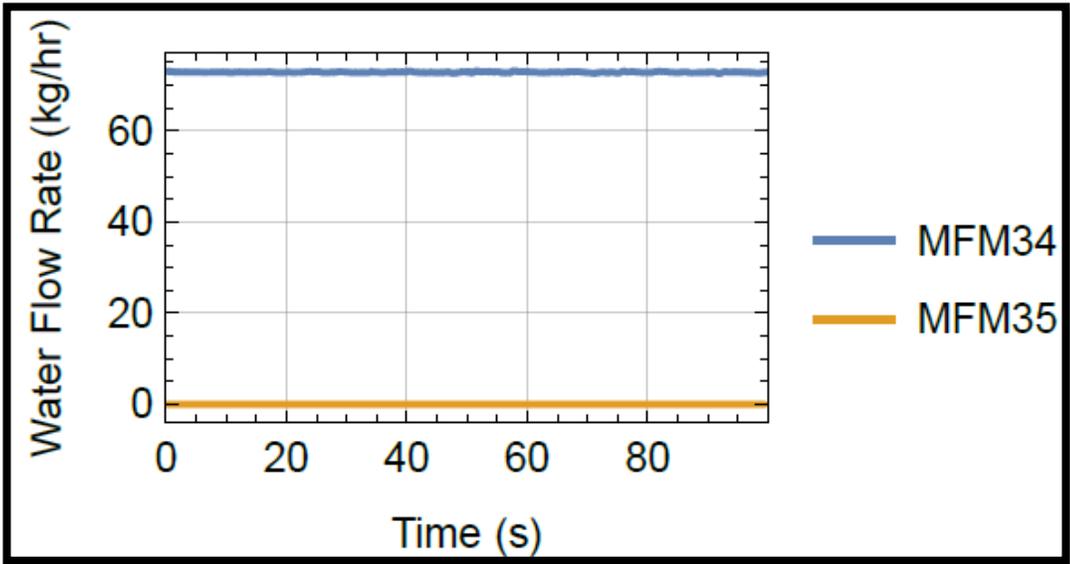
Pressure signature of the presence of bubbles exiting the Urine Filter
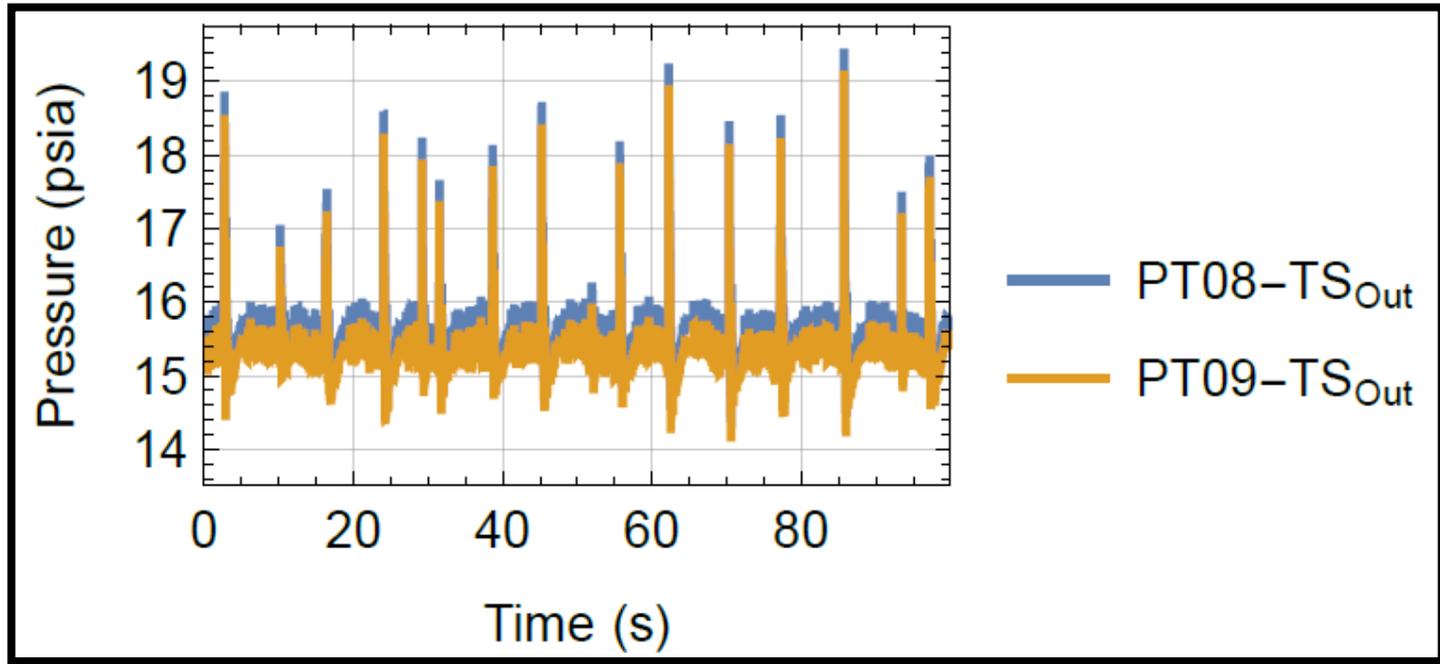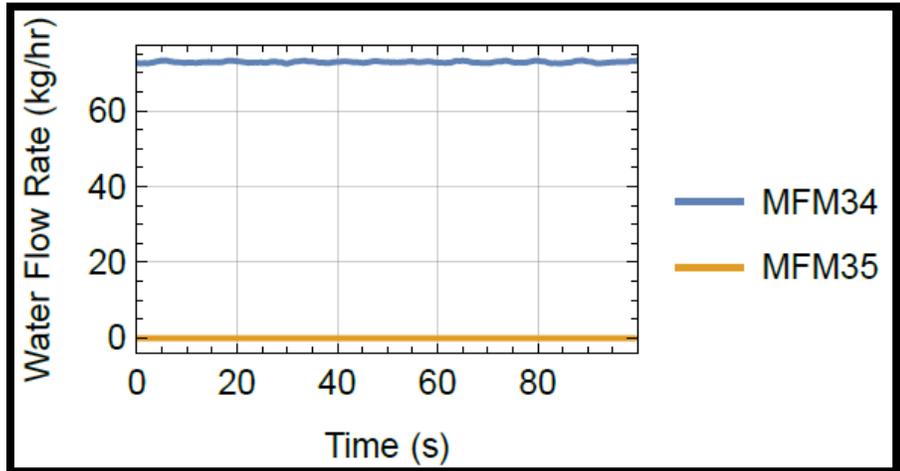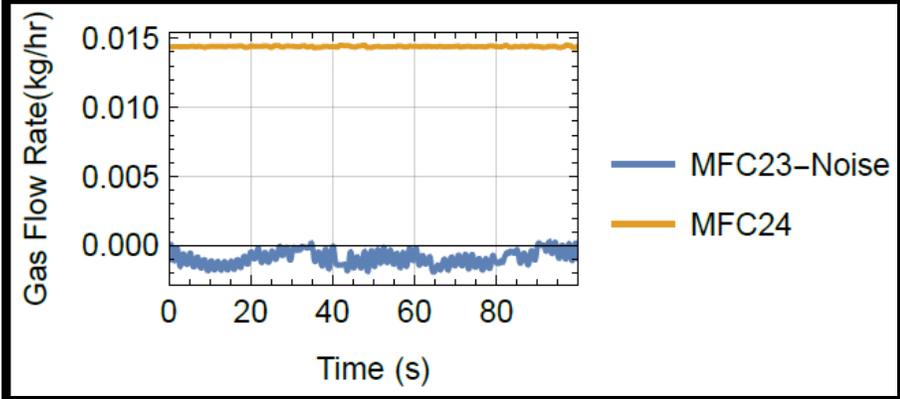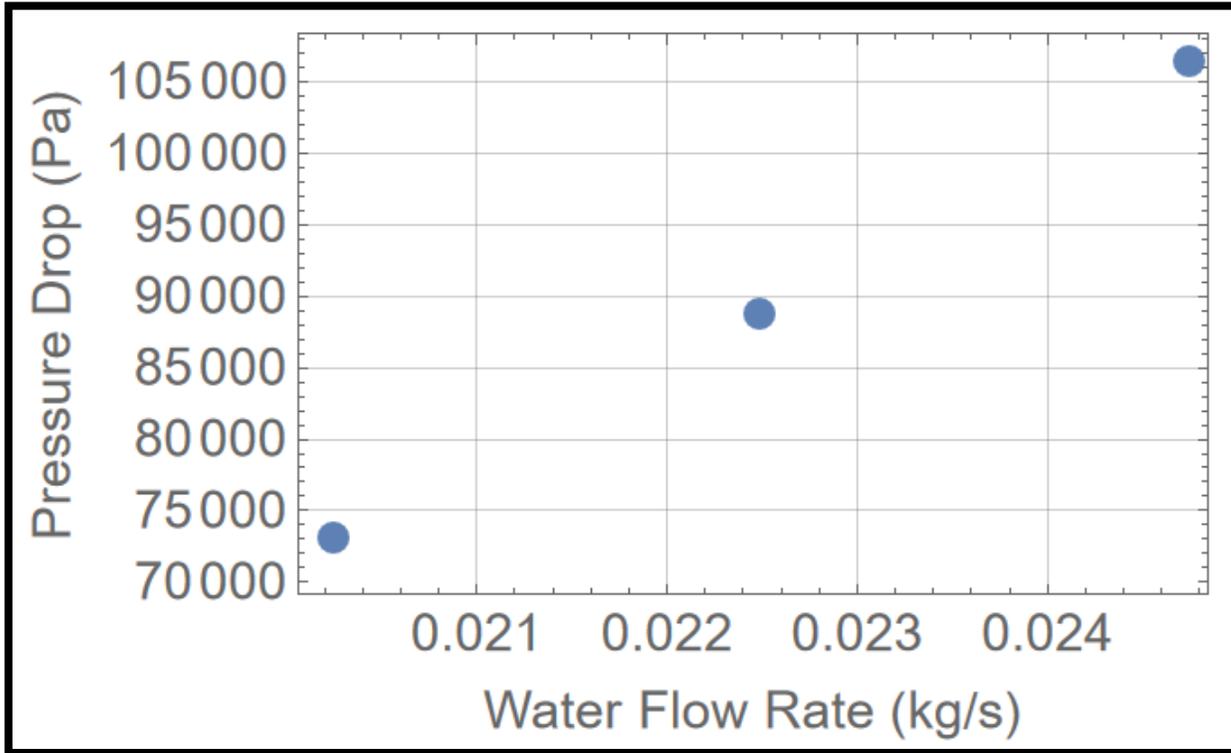
Pressure drop versus water flow rate for the Urine filter
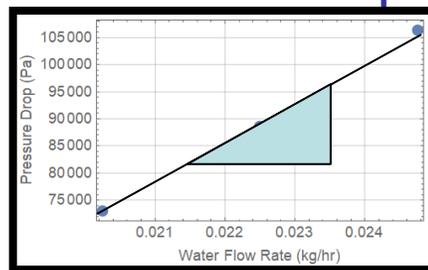
Darcy's Constitutive Equation for Isotropic Porous Medium

$$q = -\frac{k}{\mu}\nabla p$$

$$\begin{cases} q = \dfrac{Q}{A} \\[2mm] \nabla p = \dfrac{\Delta p}{L} \end{cases}$$

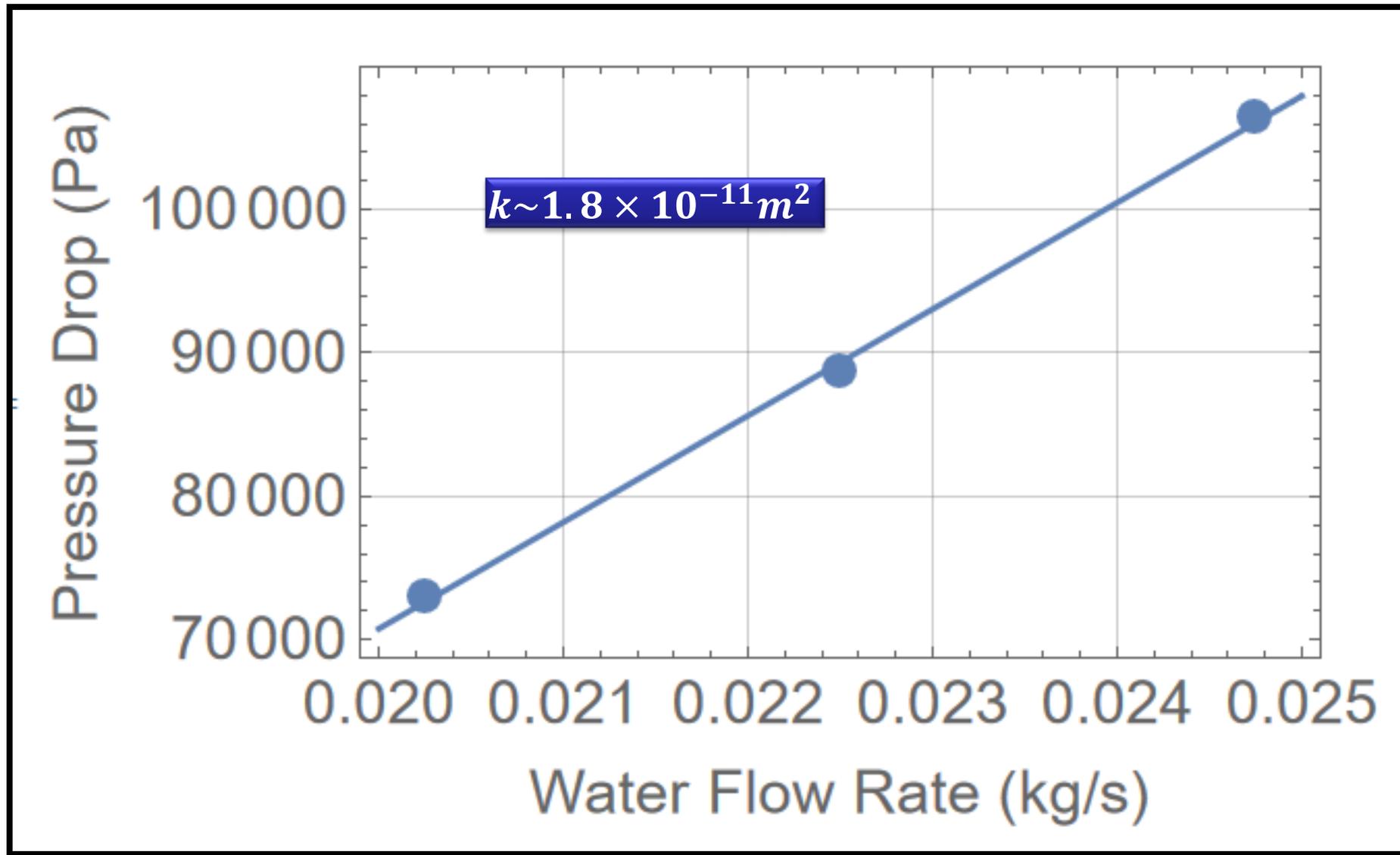$$\frac{Q}{A} = -\frac{k}{\mu}\frac{\Delta p}{L}$$

$$Q = \frac{kA}{\mu L}\Delta p$$

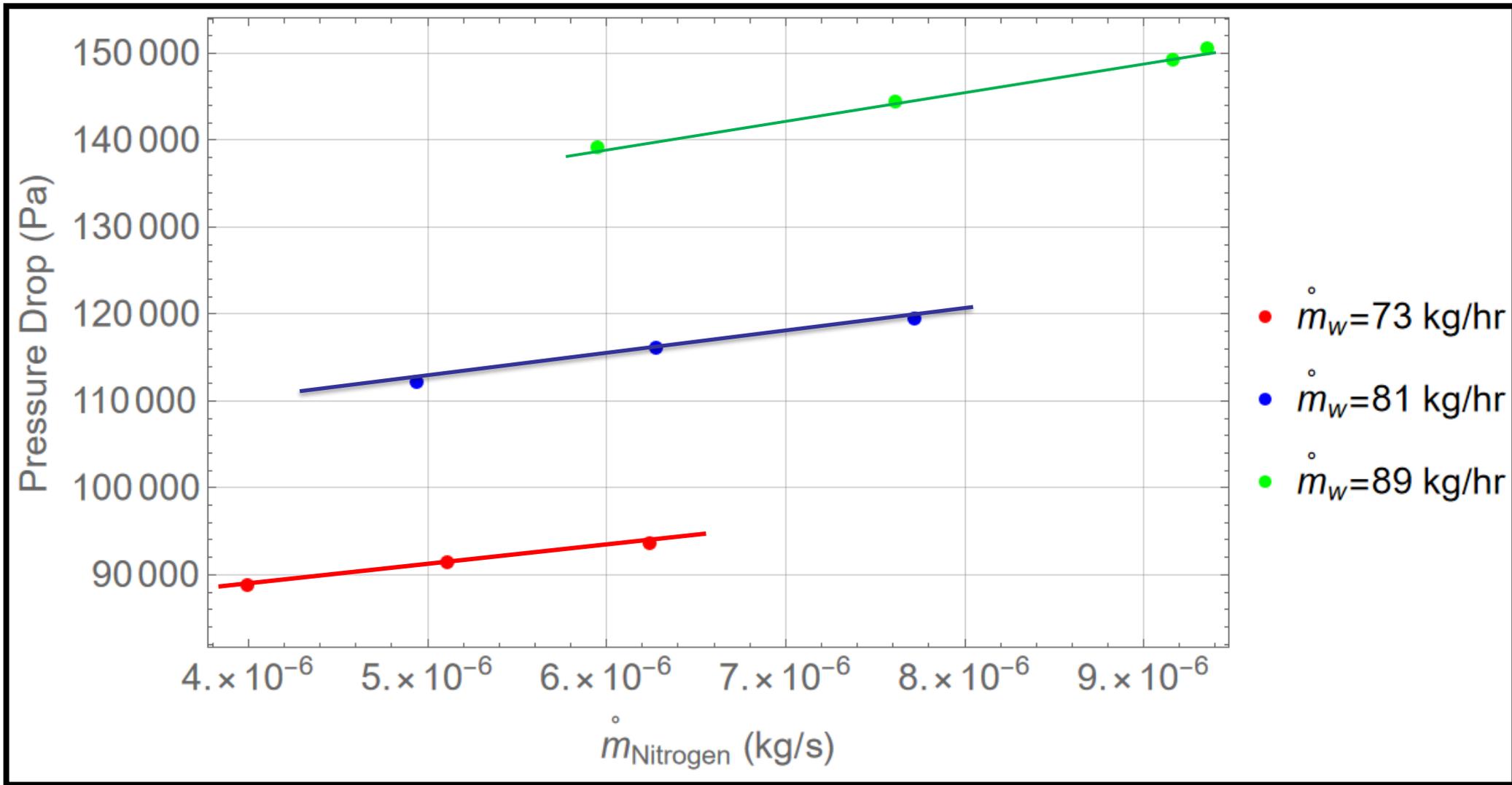$$\Delta p = \left(\frac{kA}{\mu L}\right)^{-1} Q = \left(\frac{\mu L}{kA}\right)\frac{\dot{m}_W}{\rho_W}$$

$$Slope = \left(\frac{\mu L}{kA\rho_W}\right)$$

$$k = \left(\frac{\mu L}{Slope\, A\rho_W}\right)$$

Pressure drop as a function of nitrogen mass flow rate. Note a slight increase of slope with increasing liquid flow rate

$$\left(\frac{\mu}{\rho}\right)_{Two-Phase} = \frac{(\text{mdotf} + \text{mdotg}) \, \mu f \, \mu g \left(\text{mdotg} + \text{mdotf} \left(\frac{\rho g}{\rho f}\right)^{2/3}\right)}{(\text{mdotg} \, \mu f + \text{mdotf} \, \mu g) \left(\text{mdotg} \, \rho g + \text{mdotf} \, \rho f \left(\frac{\rho g}{\rho f}\right)^{2/3}\right)}$$

Liquid Water Flow Rate (kg/hr)	Slope	Two-Phase Permeability (m^2)
73.	2.16106×10^9	6.18294×10^{-14}
81.	2.59521×10^9	6.18908×10^{-14}
89.	3.24571×10^9	6.19557×10^{-14}

Concluding Remarks

- PBRE-WRS is planned for launch in early August onboard of NG-21 mission
- PBRE-WRS will be operated after install autonomously
- Pressure drop data will be collected for the three filters, the 4 orifices and the check valve
- The End-to-End testing showed that the PBRE-WRS system performed well
- From a first order look at the Urine Filter data, it was shown that the increase in liquid flow rate showed a very small increase or practically no increase in the two-phase permeability based on averaged viscosity and density
- Single phase permeability was shown to be much greater than the two-phase permeability
  - This may be due to the presence of trapped gas within the filter
- Two phase friction factor and two-phase Re and We numbers is under development and will be applied to reduce the filters flight data
- Video analysis will be performed to correlate with the pressure signals obtained from the pressure transducers.

- Thank you for your attention

- Questions?