Emerging Water Technology Symposium
15 May 2024

Measuring Pressure Losses in Plumbing Fittings at the NIST Plumbing Hydraulics Laboratory

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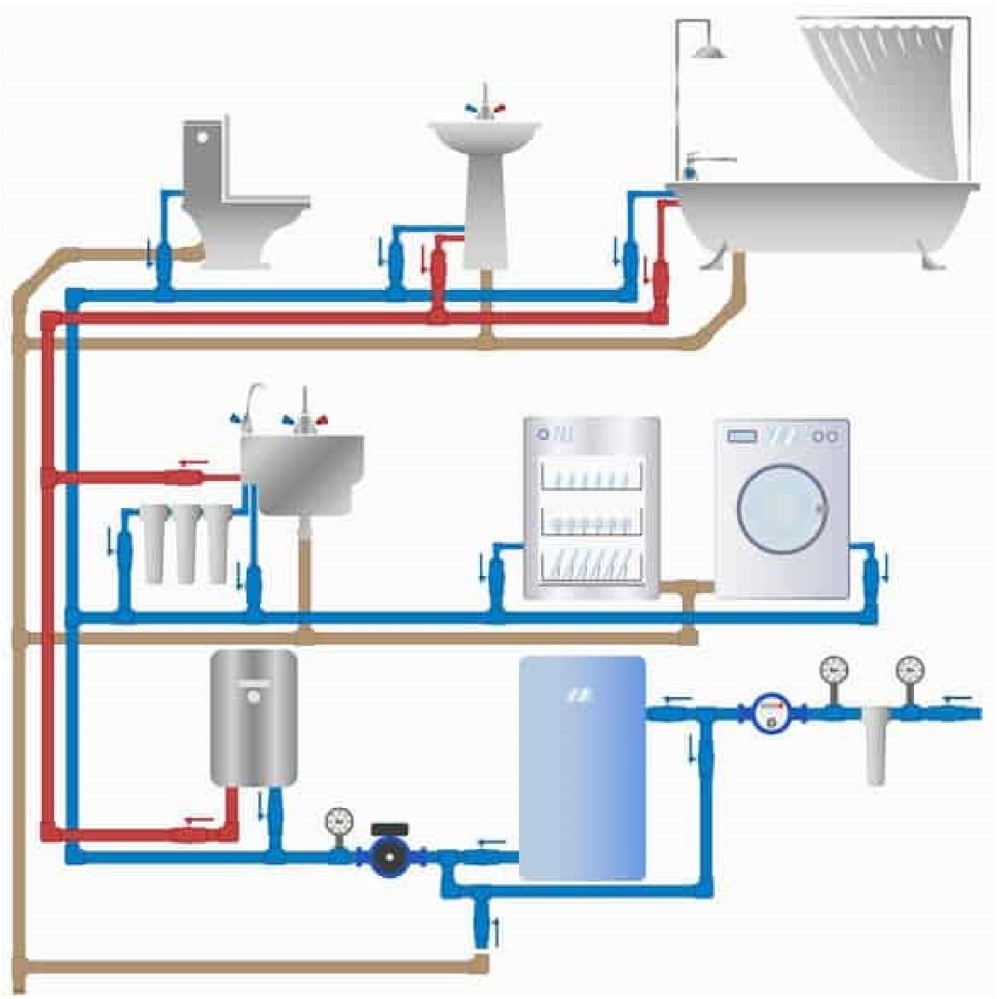
National Institute of Standards and Technology
U.S. Department of Commerce

engineering laboratory

Pressure Loss in Plumbing Systems
- necessary to system design



Straight pipes: $$\Delta P_{\text{loss}} = f\,\frac{L}{D}\,\frac{\rho V^2}{2}$$ (Darcy Equation)

f - friction factor, determined by Moody chart or correlations

Fittings: $$\Delta P_{\text{loss}} = K\,\frac{\rho V^2}{2}$$

K - loss coefficient, a function of D, Re, roughness, geometry

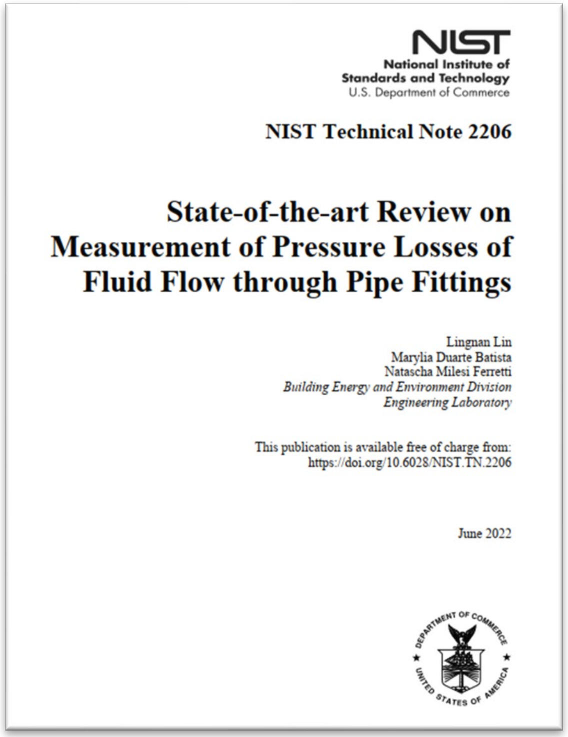
varies with manufacturer

Problems:

- No standard test method for pressure loss in fittings
- Measured data not widely available for specific fittings and configurations
- Often estimated from literature values that may not be accurate

What about literature data?

- Reviewed literature since 1920, including handbooks and research papers
- A large portion of data are pre-1950, based on iron/steel fittings
- Very limited data for copper, PEX, and CPVC fittings, especially with $D \leq 1$ in.
- Large variation across data for the same type of fitting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NIST Technical Note 2206

State-of-the-art Review on Measurement of Pressure Losses of Fluid Flow through Pipe Fittings

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June 2022

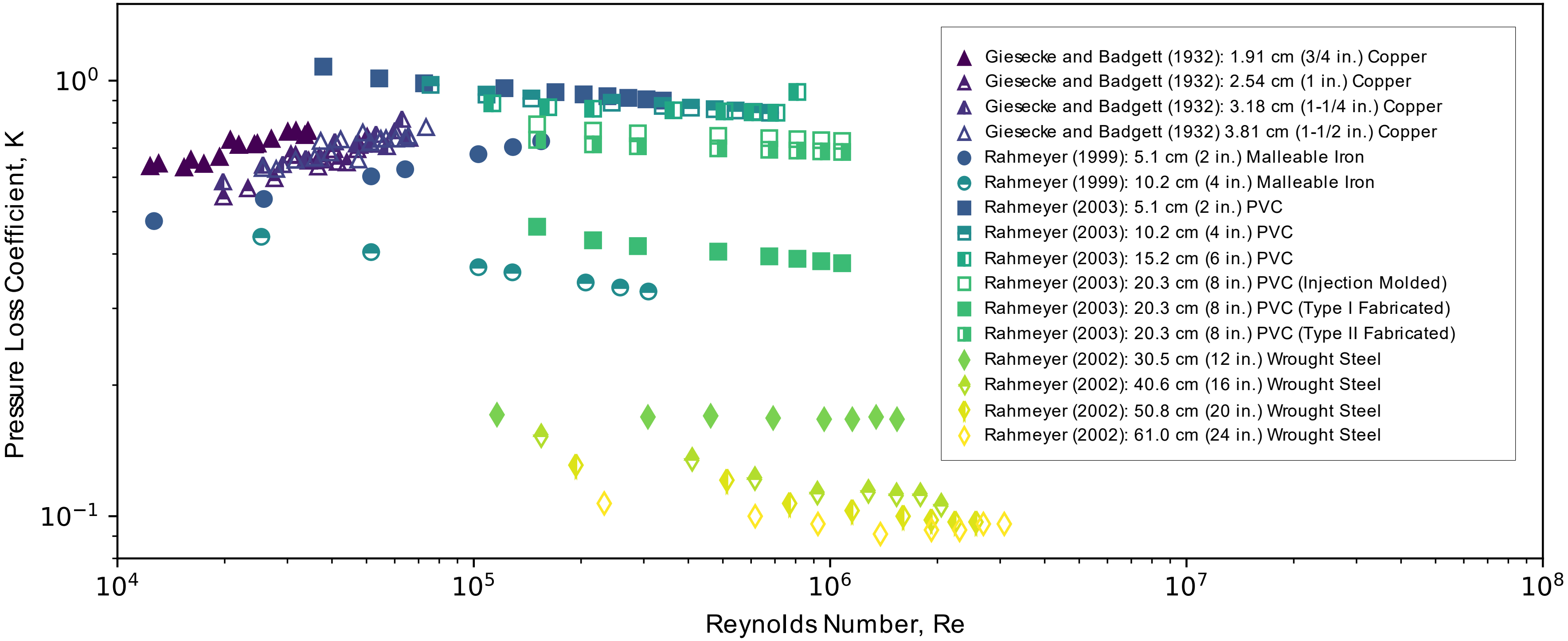


Figure 1. Existing data for elbows (data source: Giesecke and Badgett (1932) [5]; Rahmeyer (1999) [6]; Rahmeyer (2002) [7]; Rahmeyer (2003) [8]).

Project Objectives

NIST

To develop the **measurement science** needed to establish **standardized** and **precise** means of characterizing pressure loss of modern plumbing fittings

Specifically ...

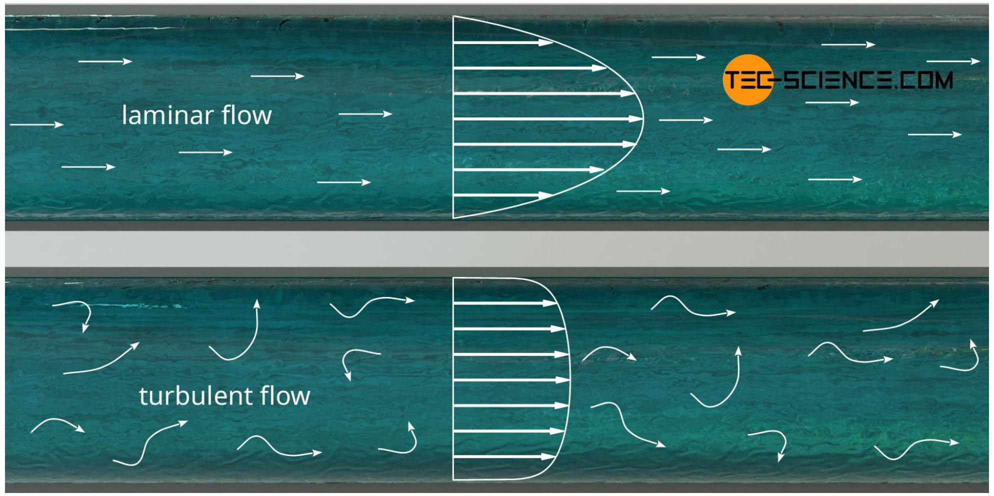
- Establish a new lab facility to measure pressure loss in fittings
- Provide benchmark data for common fittings
- Develop a test method to be submitted to an appropriate standards organization for consideration as an industry consensus

How Pressure Losses Occur

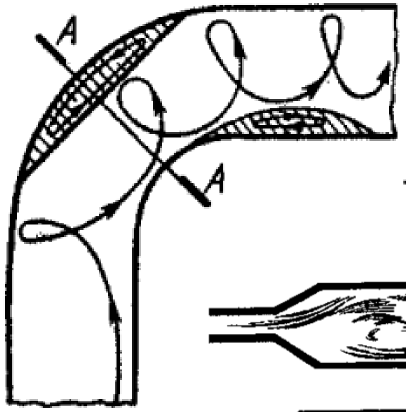
Pressure Loss: irreversible loss of mechanical energy (≠ Pressure Drop)

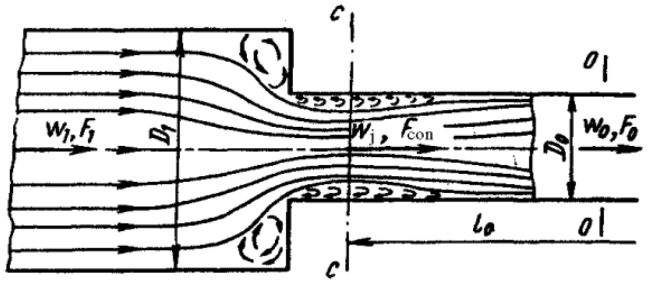
Root cause: Viscosity & Turbulence

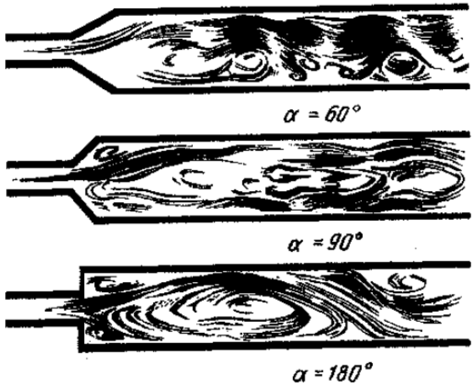
Straight pipes:
Friction between fluid and pipe wall

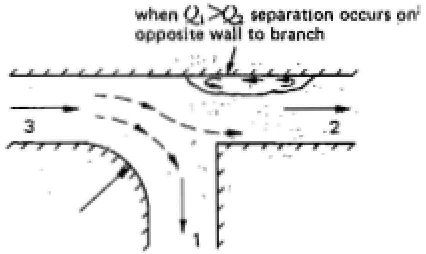


Fittings:
Friction; Flow separation: Secondary flow

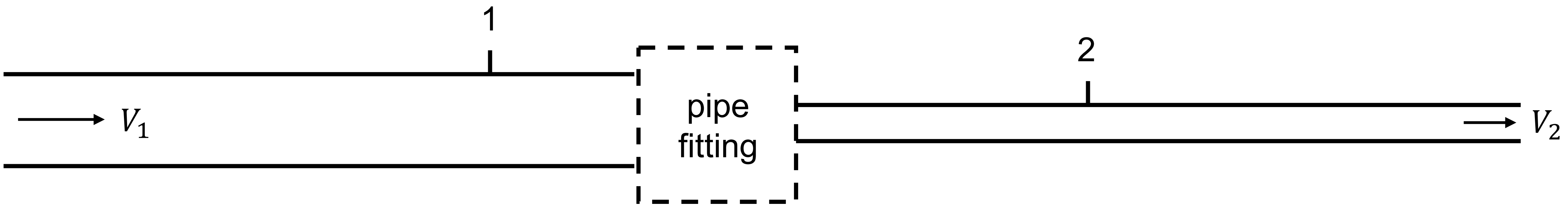








Pressure Loss Measurement: Traditional Method (two-tapping-location)



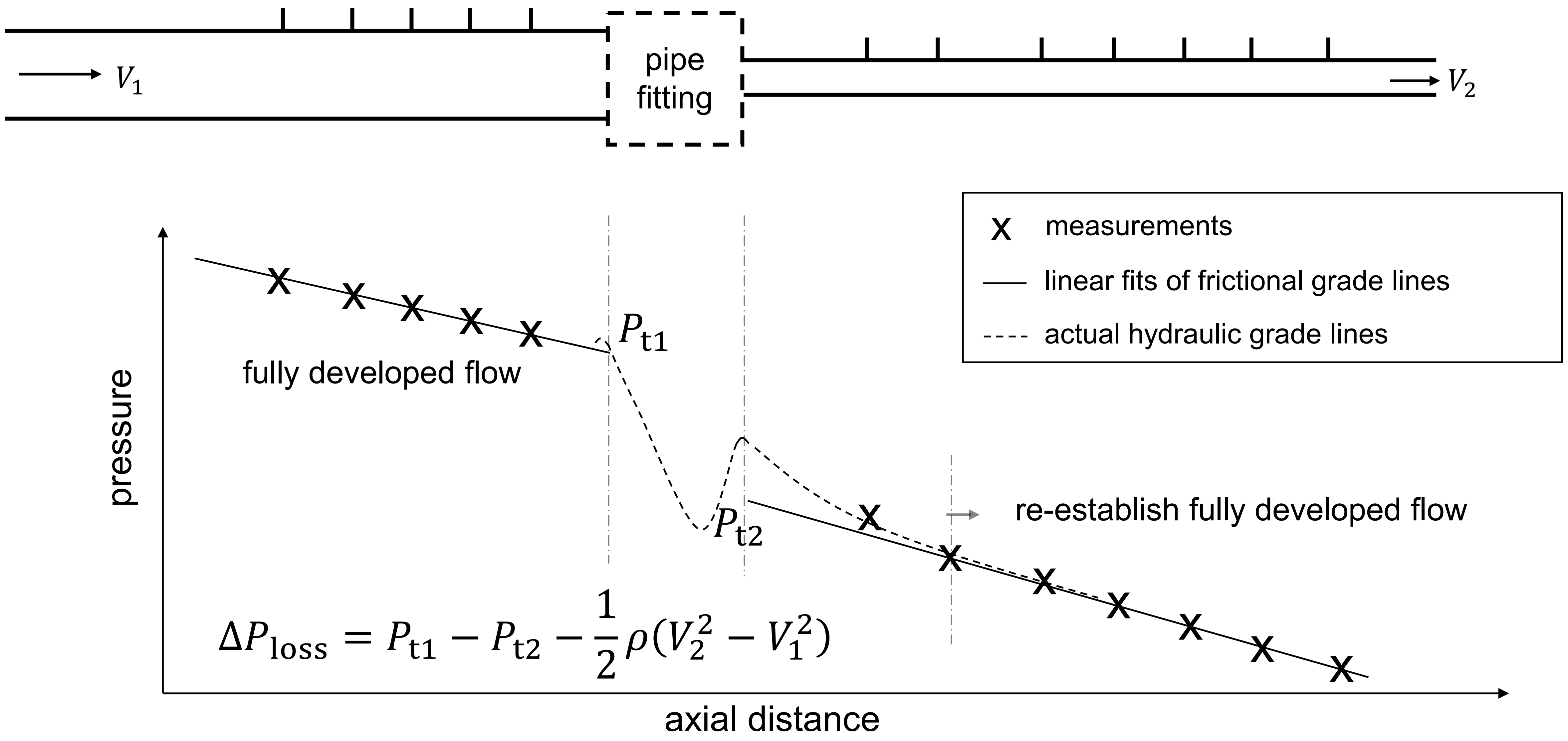
$$\Delta P_{\text{loss}} = (P_1 - P_2) - \Delta P_{\text{friction},1} - \Delta P_{\text{friction},2} - \frac{1}{2}\rho(V_2^2 - V_1^2)$$

No established predictive method

- Pressure taps 1 and 2 should be located where the flow is fully developed.
- Friction loss in straight pipes need to be measured in a separate experiment.

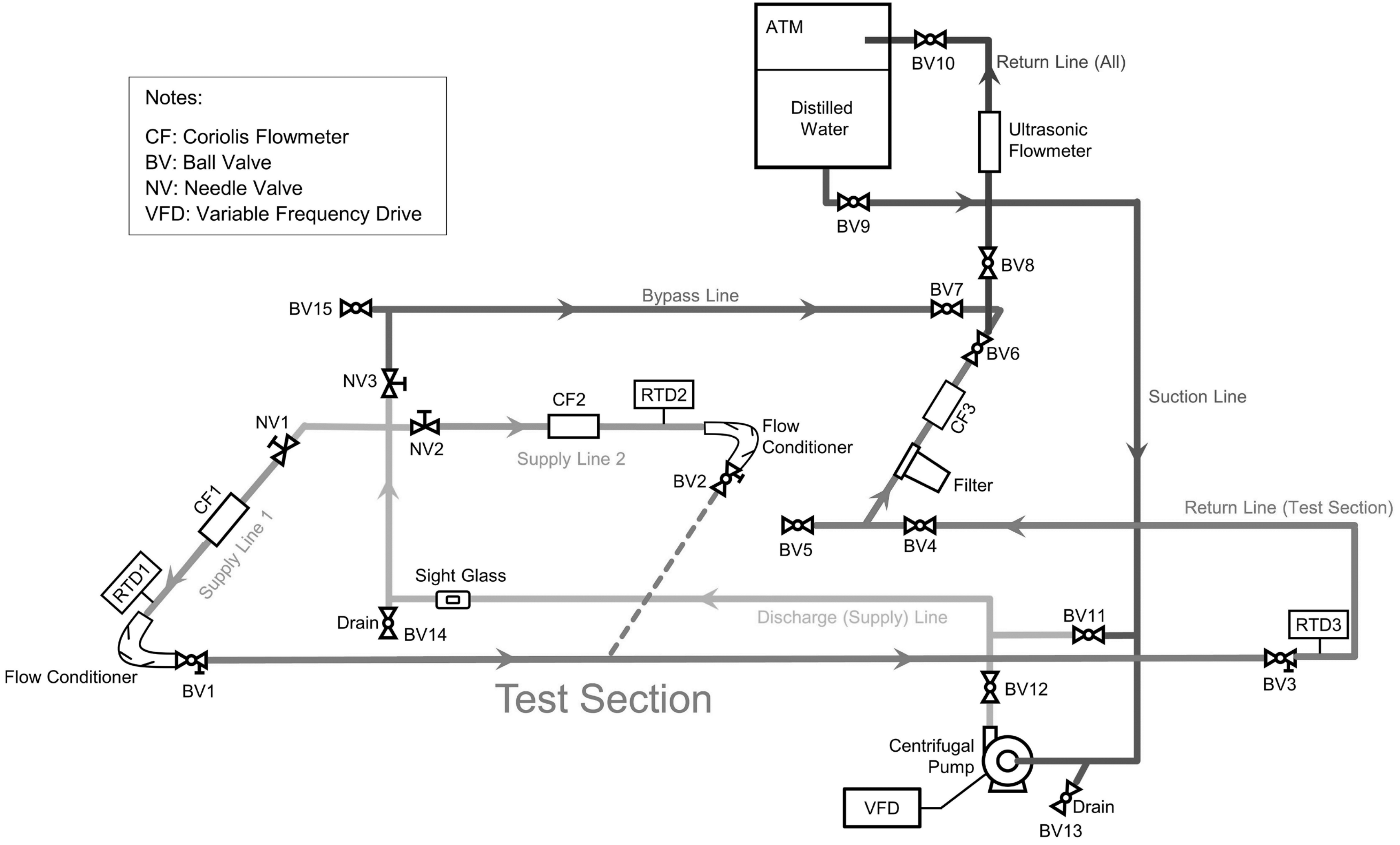
Introducing additional uncertainties

Pressure Loss Measurement: Alternative Method (multi-tapping-location)

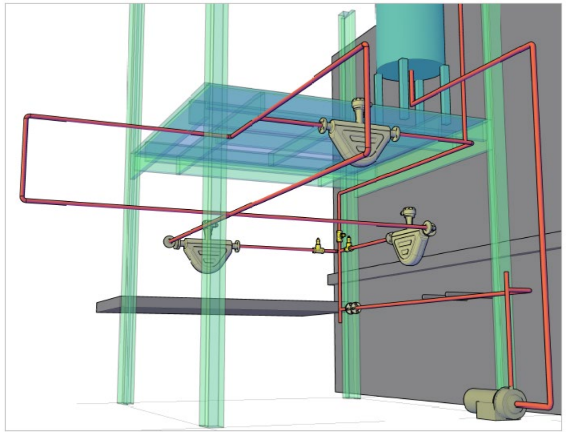


$$\Delta P_{\text{loss}} = P_{\text{t1}} - P_{\text{t2}} - \frac{1}{2}\rho\left(V_2^2 - V_1^2\right)$$

NIST Pressure-Flow Test Facility

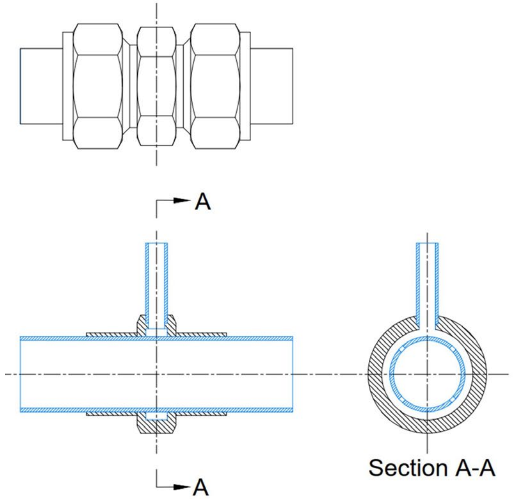


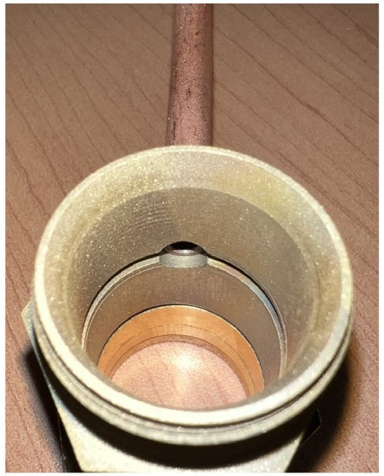
Schematic of the test facility.



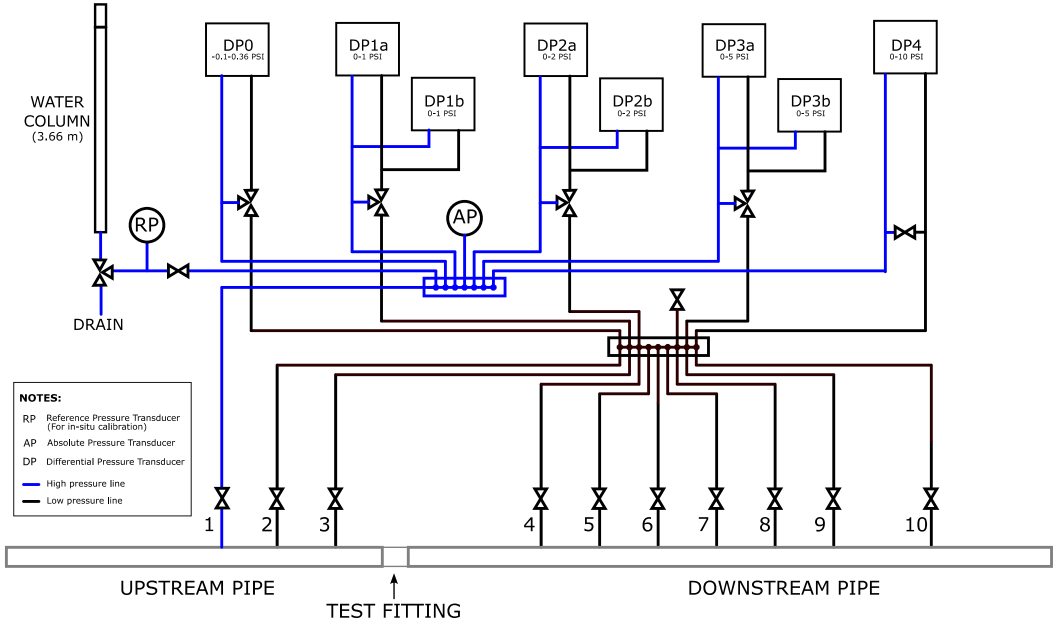
Pressure Measurement System

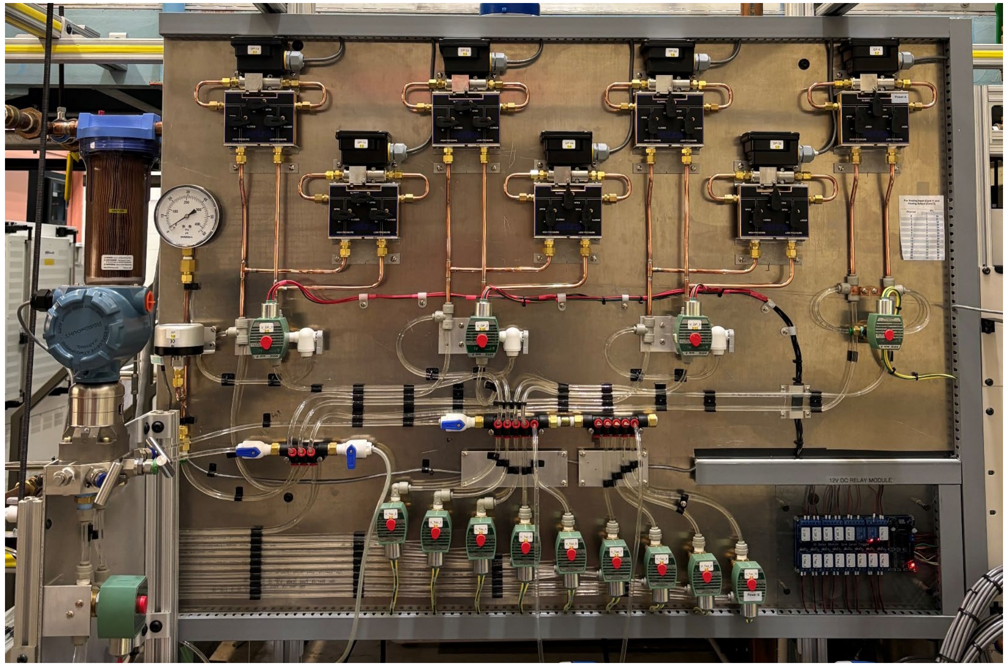
Pressure Tap Design (piezometer ring)



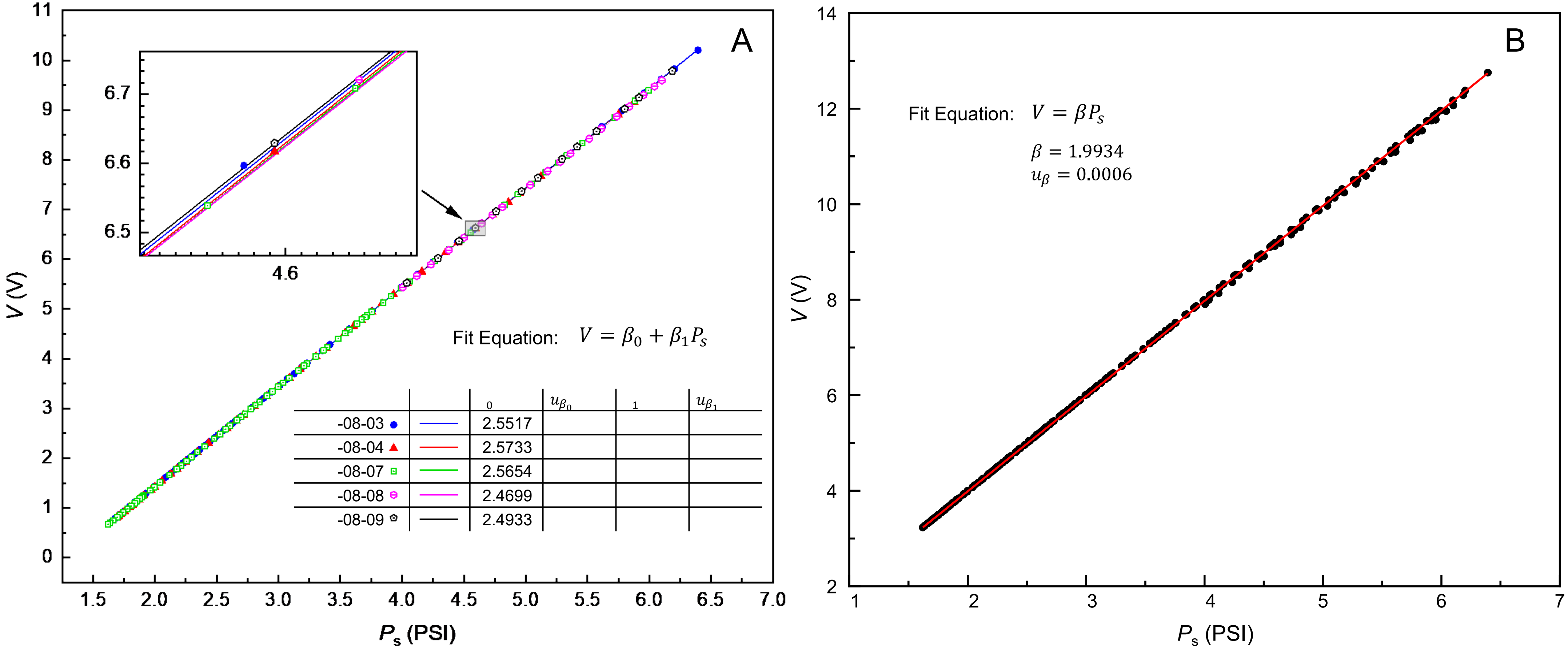


Automated Pressure Distribution Measurement System

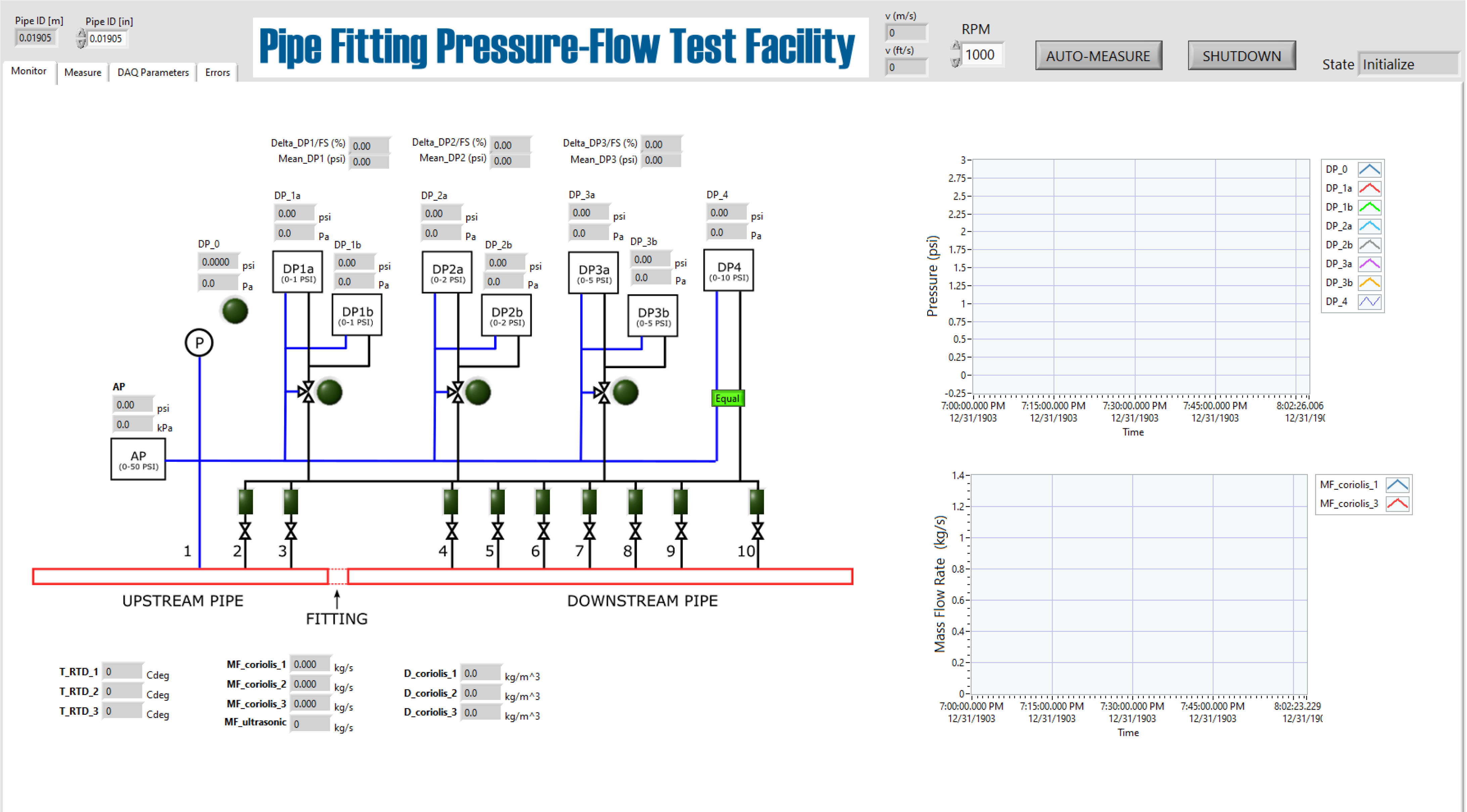




Calibration



Graphical User Interface: Monitor Mode



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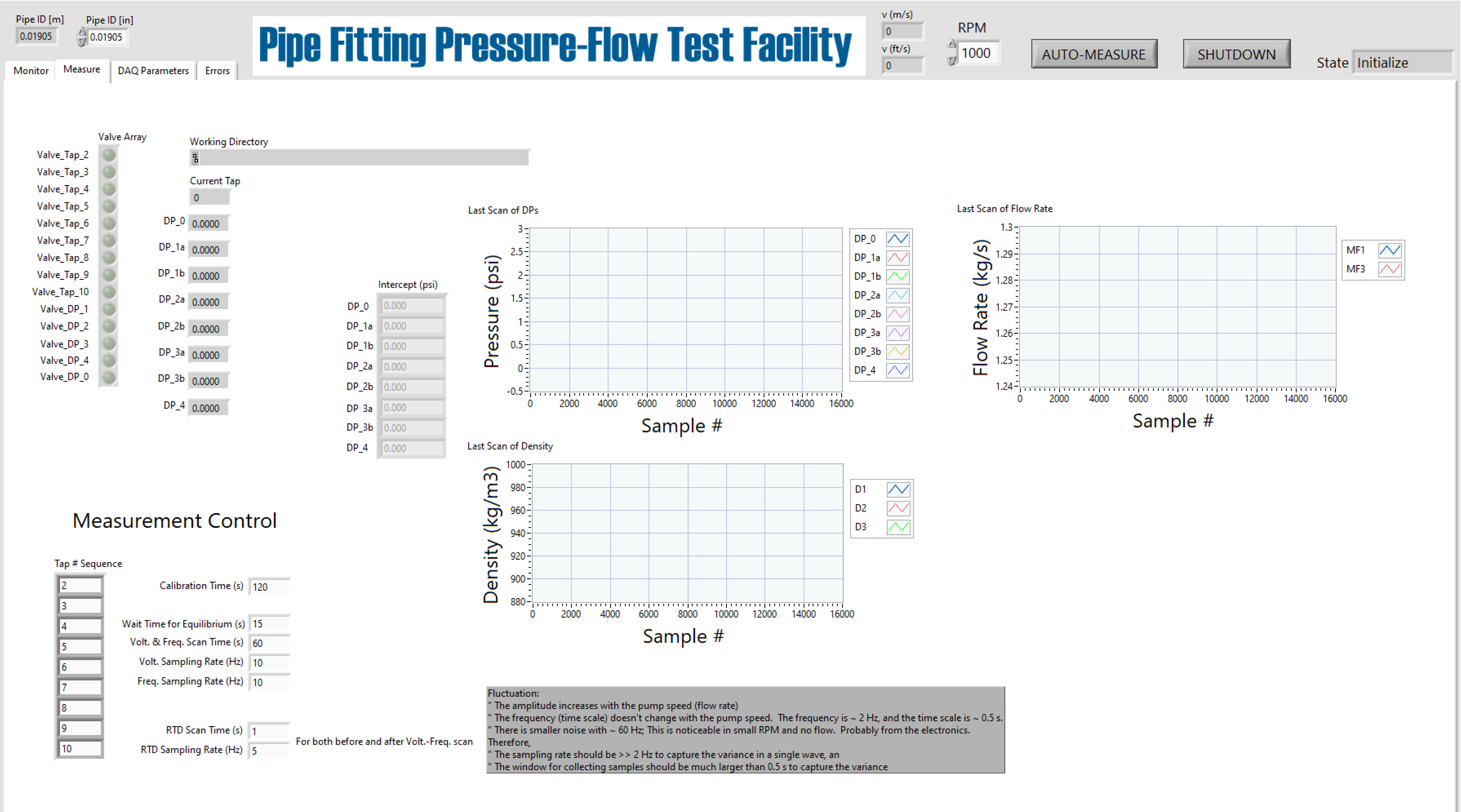
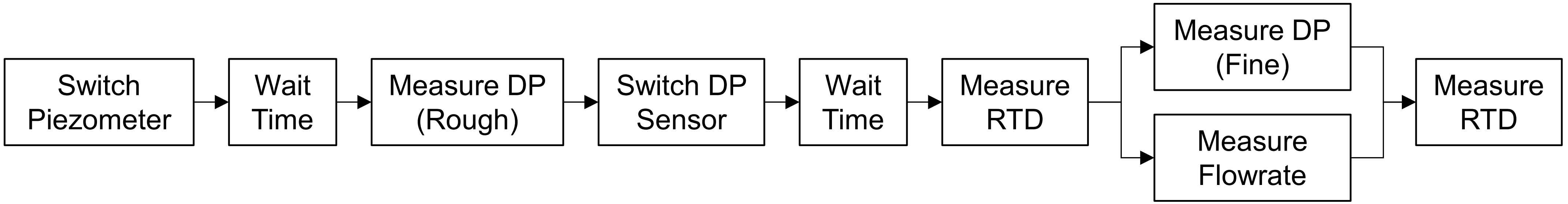
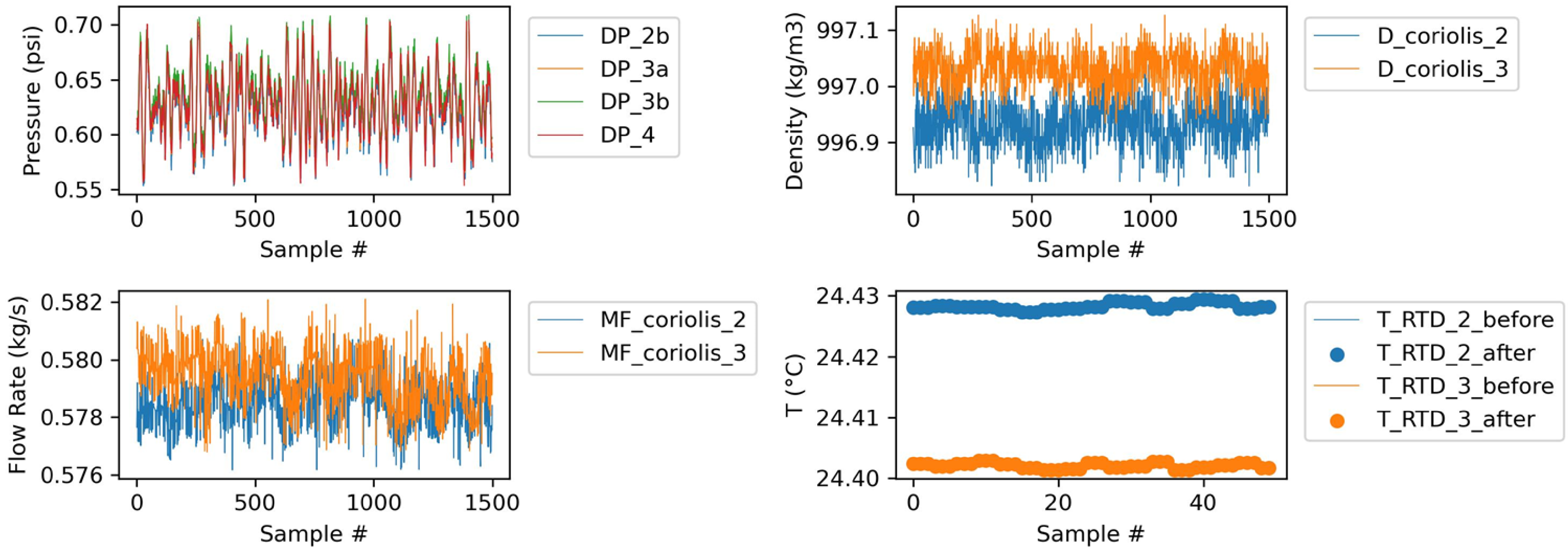


Data Collection and Post-processing

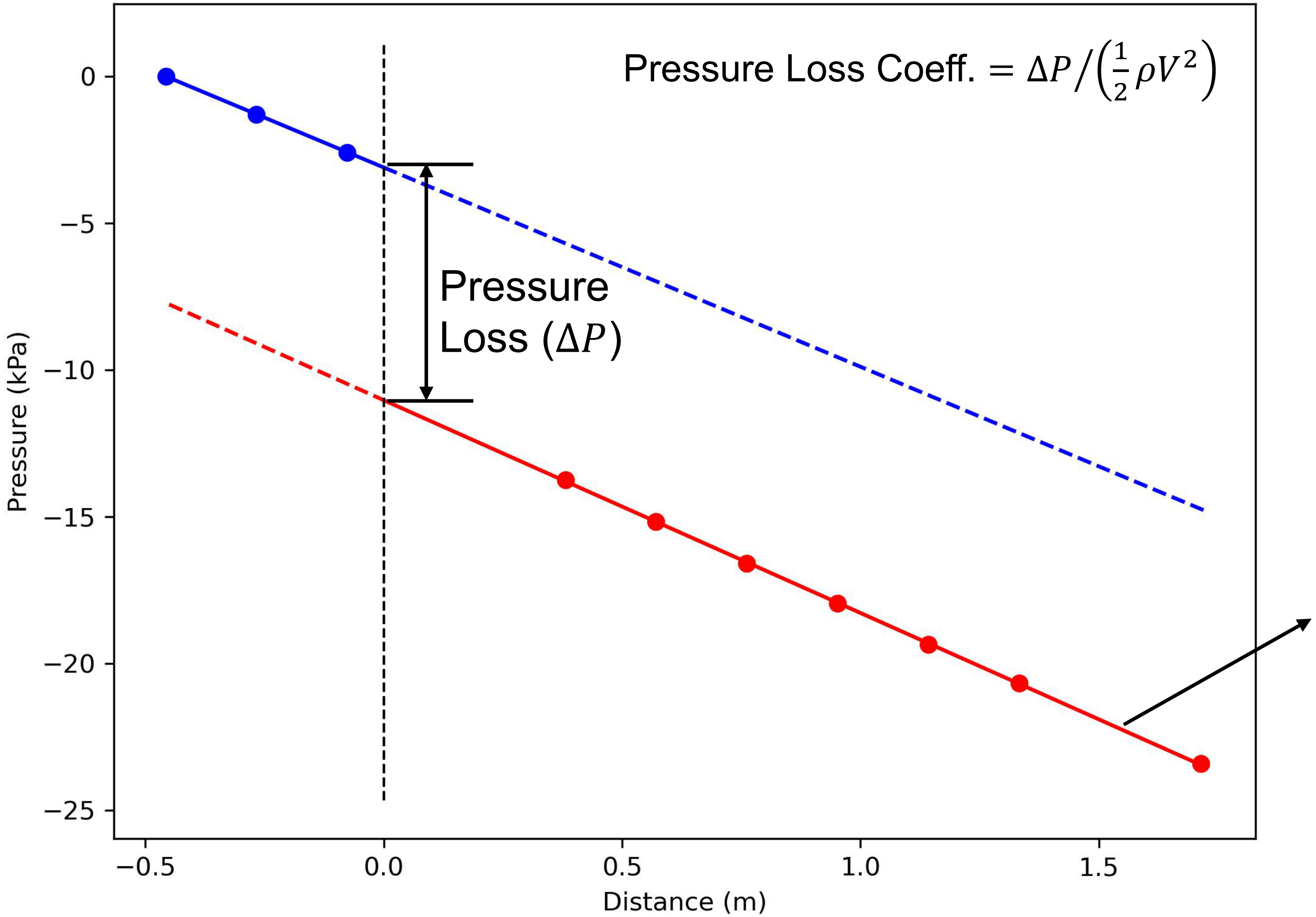


TAP 7



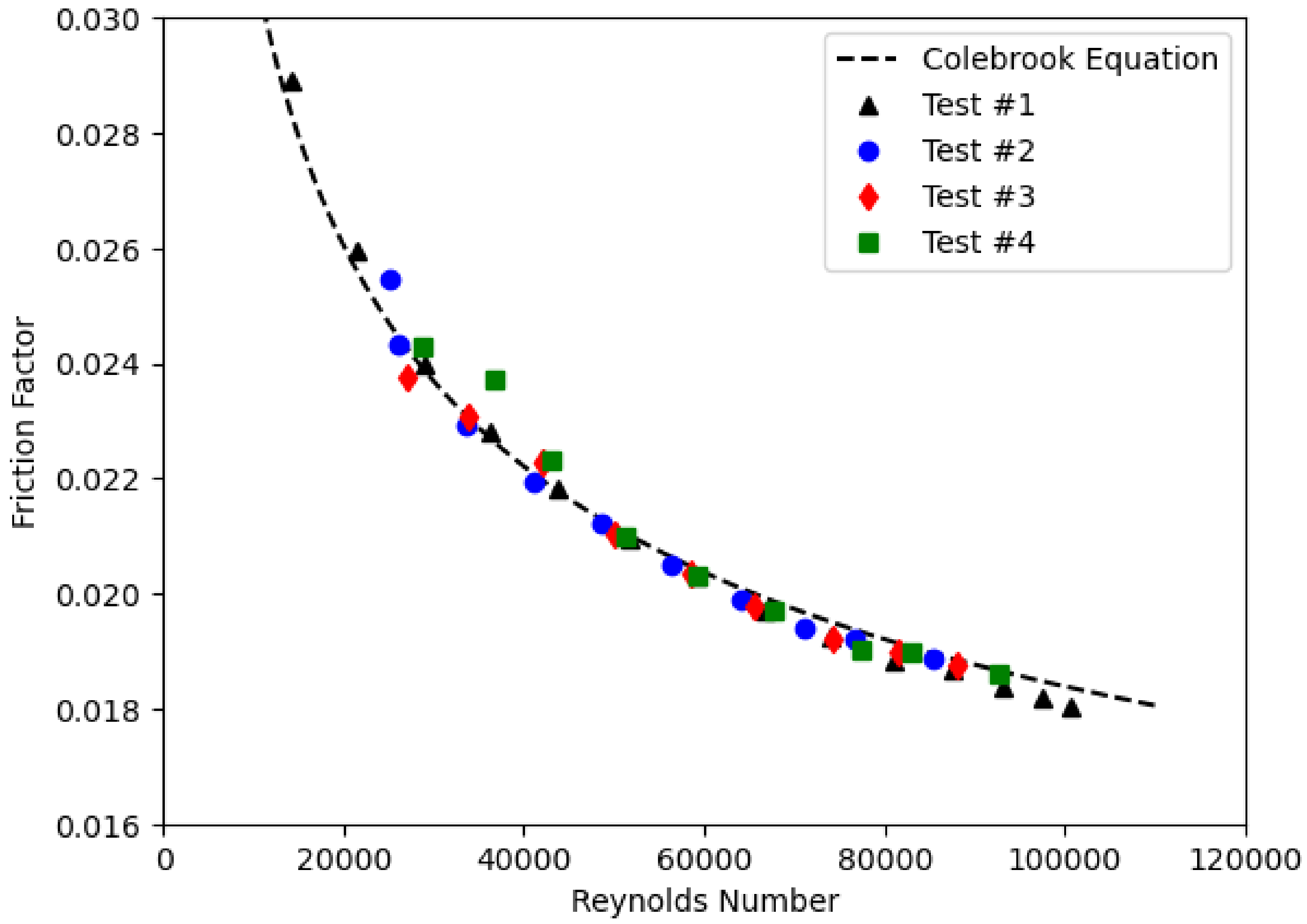
Average Values for All Taps

V_{avg} = 6.0 ft/s



Friction Factor = $\frac{\text{Slope} \times D}{\frac{1}{2}\rho V^2}$

Sample Data – Straight Pipe



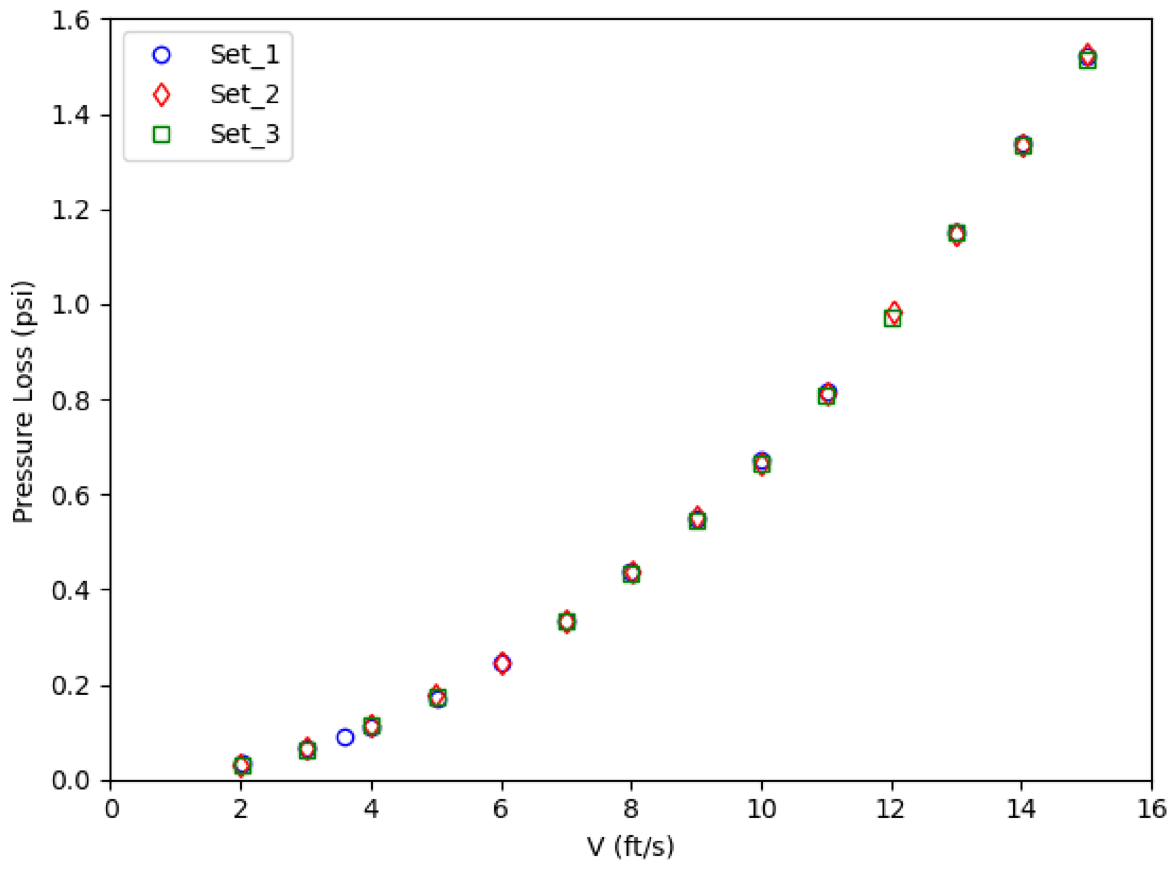
Copper Pipe, NPS ¾, Type L

Inside Diameter = 20.11 mm

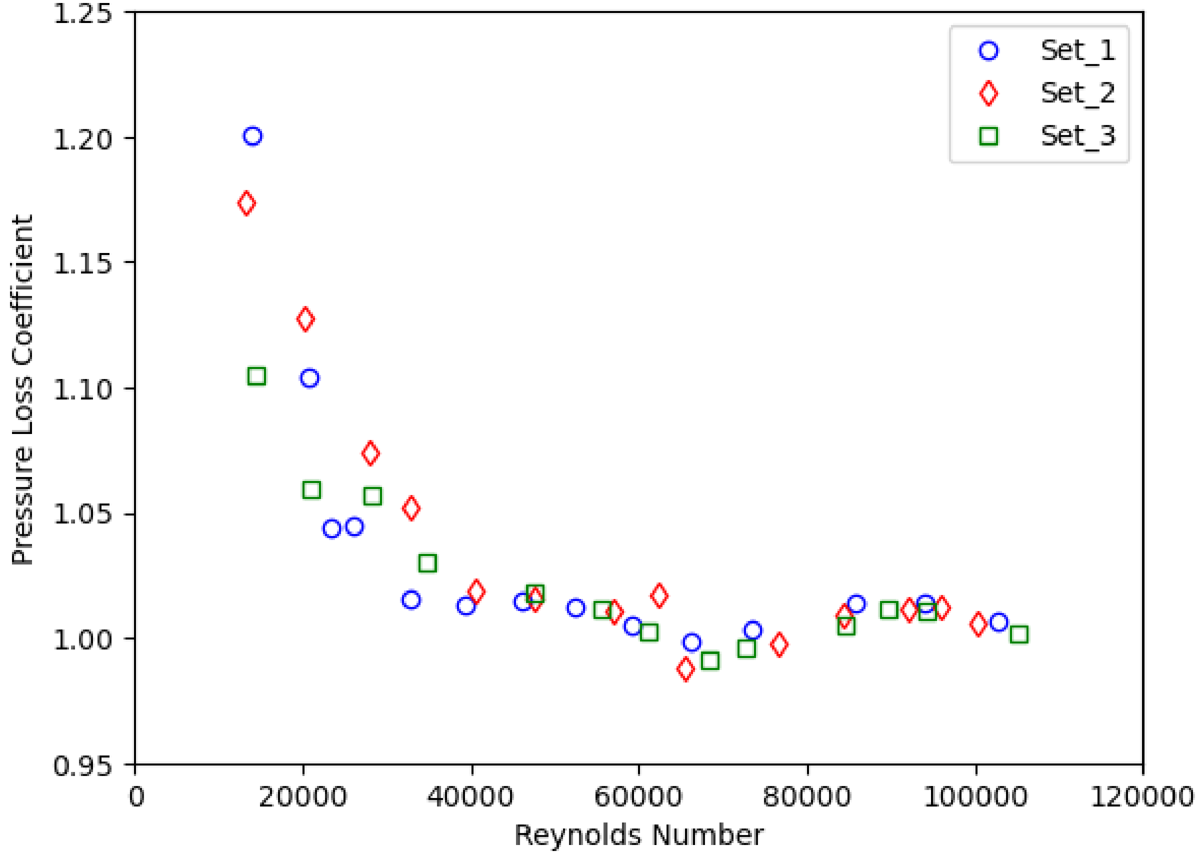
Mean Absolute Deviation = 6%

Error of Colebrook Eq. = ~ 15%

Sample Data – Elbow

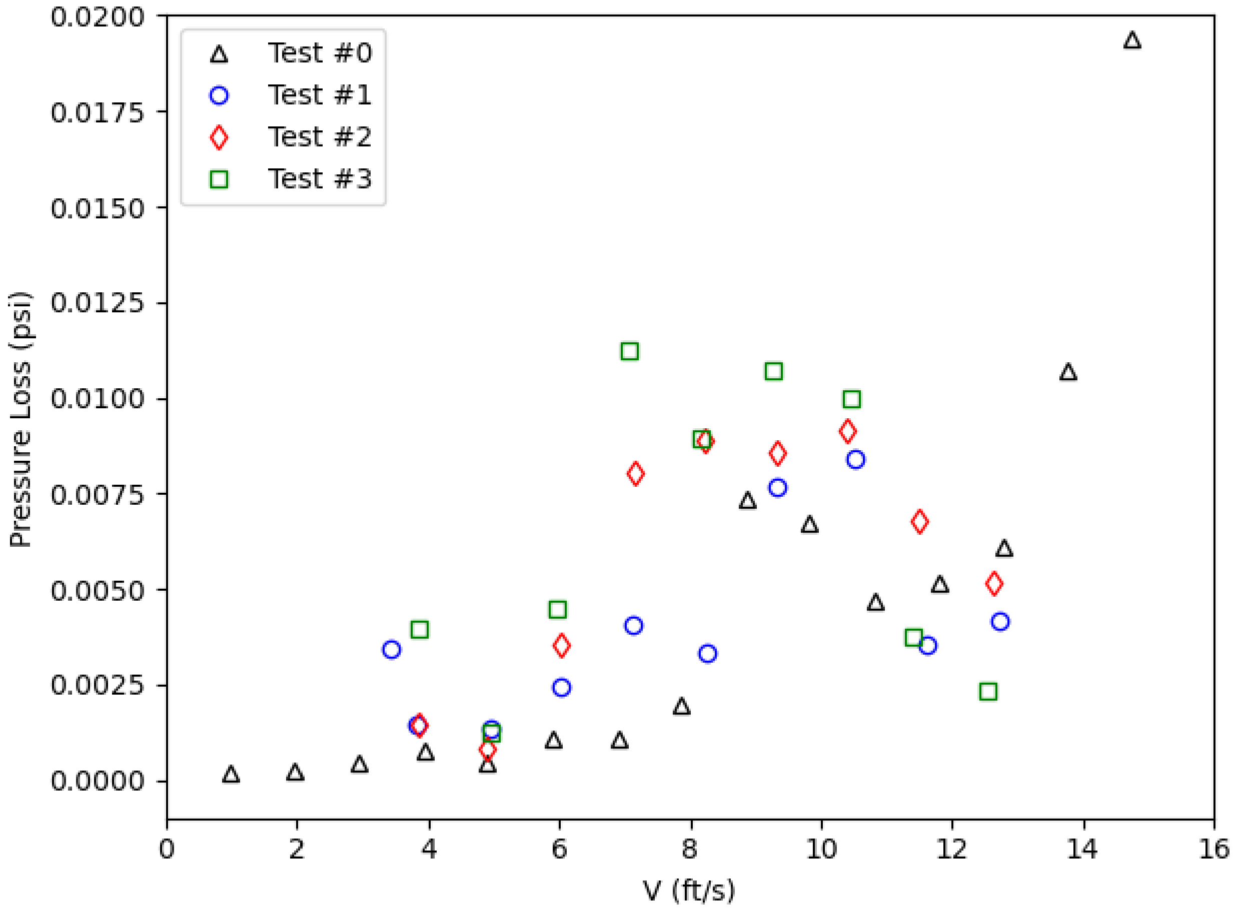


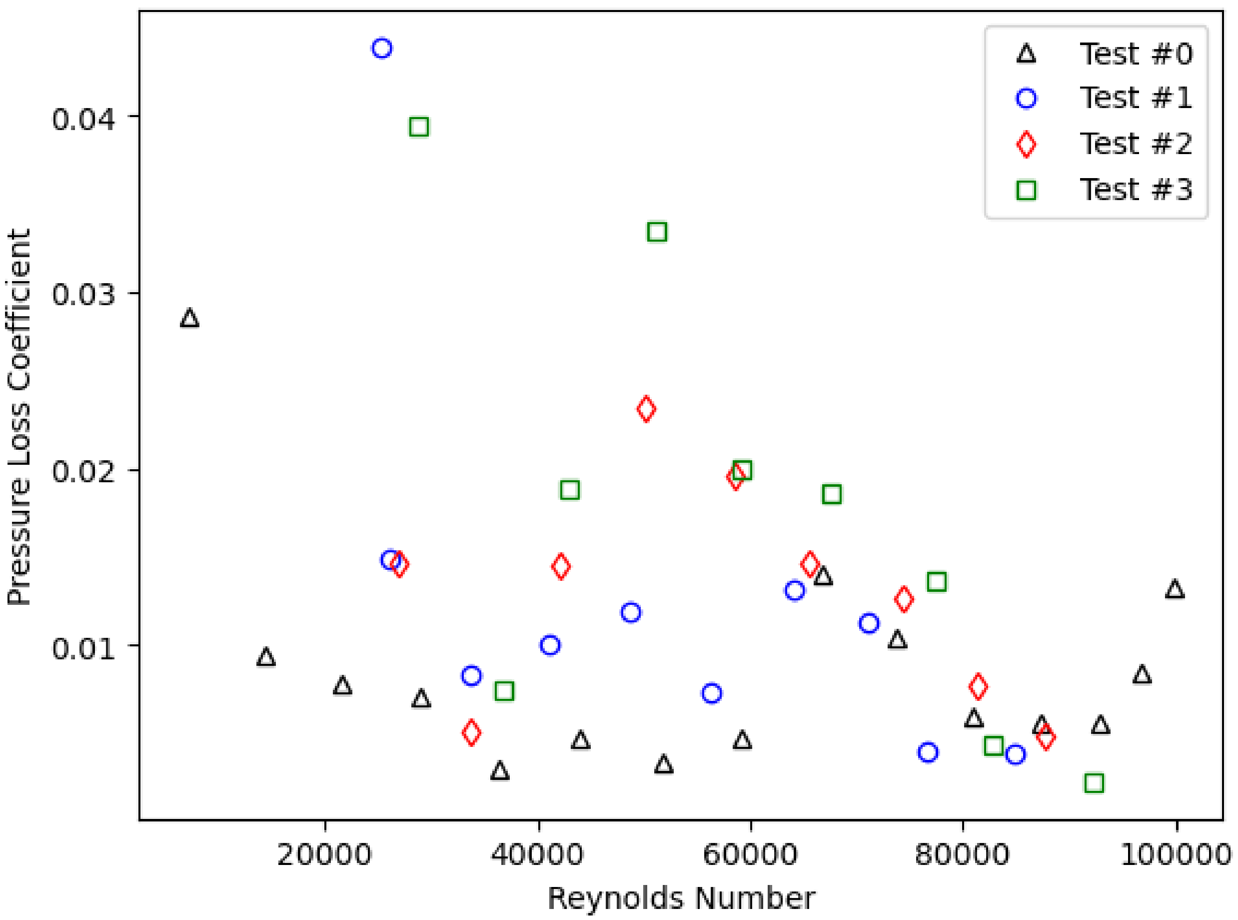
Pressure Loss Coeff. $= \Delta P / \left(\frac{1}{2}\rho V^2\right)$



$\mathrm{Re} = \rho V D / \mu$

Sample Data – Coupling





$$\mathrm{Re} = \rho V D / \mu$$

Conclusions

Measuring pressure drop is challenging, particularly at low flows, and for straight sections.

Preliminary findings show the methodology is promising to repeatably establish pressure drop for both straight couplings and elbows.

Data is consistent with established relationships for straight pipe, and provides measured results for modern fittings.

Future Plans

Current Plans:

- Measure pressure loss in elbows of various materials (e.g., copper, PVC, PEX, and other plastics) from different manufacturers
- Collaborate with industry & academia
- Draft test method for consideration by a standards development organization

Other NIST research results

Laboratory To Study Opportunistic Premise Plumbing Pathogens (OPPPs) in Hot Water Systems

Draw pattern	Volume removed per day [L (gal)]	Stagnation time (hours)	Draws per day	Volume per draw [L (gal)]
1	75.7 (20)	6	4	18.9 (5)
2	75.7 (20)	24	1	75.7 (20)
3	151.4 (40)	6	4	37.9 (10)
4	151.4 (40)	24	1	151.4 (40)

TECHNICAL APPROACH

- Establish test bed to simulate building hot water systems (from water heaters to plumbing fixtures)
- Create novel methods for real-time physical and chemical water quality parameters measurements
- Improve measurement science for quantifying microbial concentrations in plumbing systems

EXPERIMENTAL OBJECTIVE

- Investigate the impact of **water use pattern**, **setpoint temperature**, and **incoming water quality parameters** on the occurrence of OPPPs at the top and bottom of electric storage WHs

METHODOLOGY

- <u>Bench scale measurements:</u> chlorine residual, pH, turbidity, conductivity, and hardness
- <u>Culture methods:</u> Heterotrophic Plate Counts (HPCs)
- <u>Molecular methods using Droplet Digital PCR (ddPCR):</u> *Legionella pneumophila*, *Mycobacterium avium*, *Pseudomonas aeruginosa* and *Naegleria fowleri*

Other NIST research results

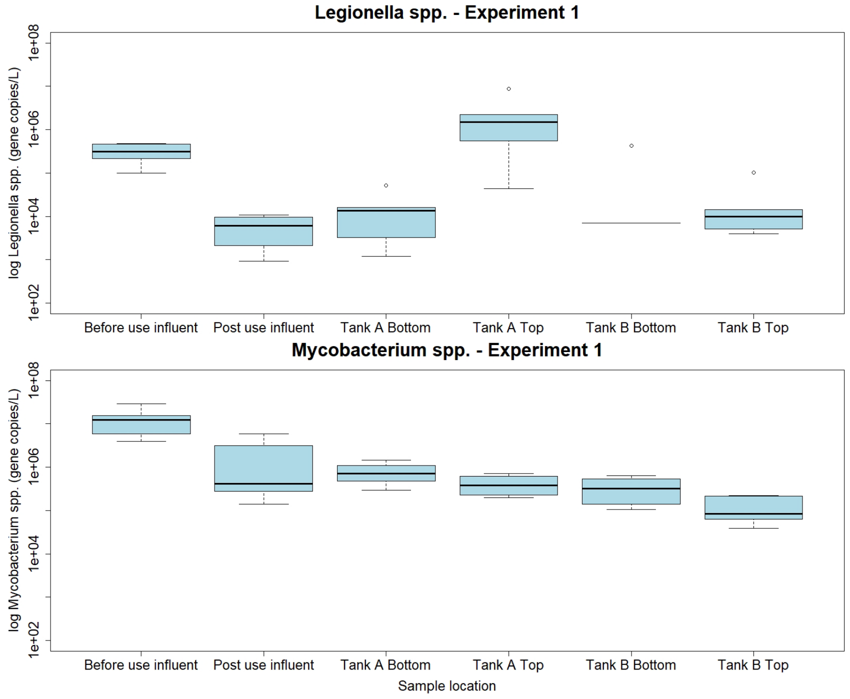
Preliminary Results

Top of WHs:

- Draw volume per day and setpoint temp have an inverse relation with concentrations of both *Legionella* and *Mycobacterium* spp.

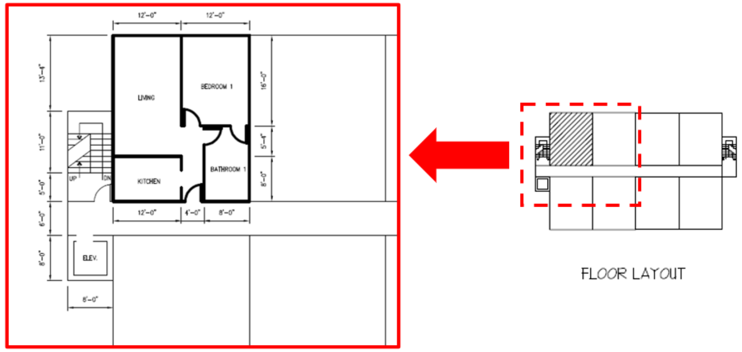
Bottom of WHs:

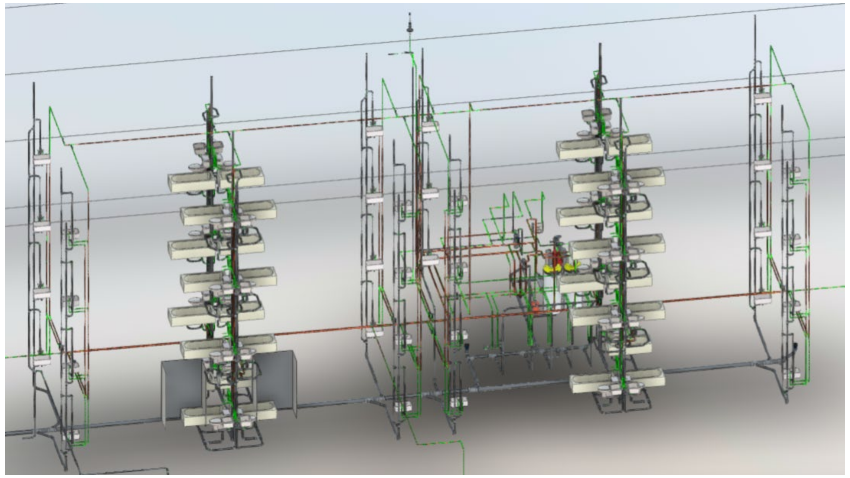
- Stagnation time (time between draws) and setpoint temp have effect of *Legionella* spp.
- Only stagnation time has effect of *Mycobacterium* spp.



Other NIST research results

Plumbing System Models for a Set of Reference Buildings





TECHNICAL APPROACH

- Designed plumbing systems according to 2018 International Plumbing Code
- Produced Revit files for all models (architectural and plumbing)
- 3 residential & 4 commercial buildings

NIST TN-2266

Table 1. Description of reference buildings (*from NIST TN-2266*)

BUILDING SOURCE	NAME	FLOOR AREA (m^2)	FLOORS	BATHROOMS	KITCHEN
NIST suite of homes	Single family, detached home (DH-A(7))	107	1	1	Yes
	Single family, detached home (DH-F(4))	329	3	2.5	Yes
	Mid-rise Apartment (APT-2A(7))	2300	4	31	Yes
DOE prototype building models	Medium Office	4980	3	6	No
	Stand-Alone Retail	2290	1	2	No
	Primary School	6870	1	28	Yes
	Full-Service Restaurant	511	1	2	Yes

Other NIST research results

NIST

CHALLENGES

Building types best representative models

- Cost effective

Different codes and standards governing plumbing system design

- International Plumbing Code (IPC), Uniform Plumbing Code (UPC), states use their own codes based on IPC or UPC, ADA

Other codes used for architectural and plumbing designs: International Residential Code (IRC) 2018, International Building Code (IBC) 2018, Americans with Disabilities Act Accessibility Guidelines (ADAAG) 2010, National Fire Protection Association (NFPA) 101 2018

Create a product that can be used by a wide audience

- Revit files that can be translated by researchers to fit their study

Reference Plumbing Designs website

Acknowledgment

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*Former NIST Staff

Collaborators

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- Lance MacNevin

Thank you! Questions?