Pressure Noise Anslysis in a Pipe Break Incident

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CNNC China Nuclear Power Engineering Co., Ltd. · 6 July 2026

Introduction

Method

Simulation and Results

Test

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1 Introduction

1.1 Presenter / Team

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Senior Engineer

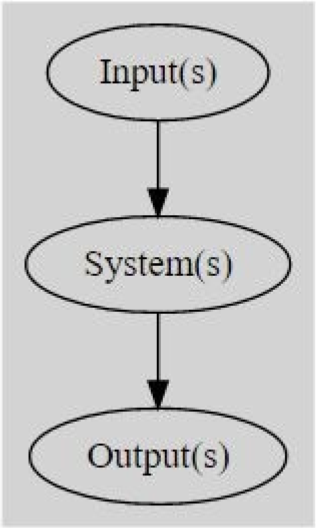
Shanghai Jiao Tong University	BS in mechanical engineering & automation, 2010
Pennsylvania State University	MS in mechanical engineering, 2012 PhD in nuclear engineering, 2019
China Nuclear Power Engineering Co., Ltd.	Instrumentation & Control Division, 2019 - now ❑ I&C design for HPR1000 ❑ Sensor state online monitoring ❑ AI applications for nuclear power ❑ IEC, ISO standards

1.2 Objective

- Detect **whether** and **when** a pipe break occurs
  - Using pressure noise analysis
- Detect **where** a pipe break occurs
  - Using time domain analysis

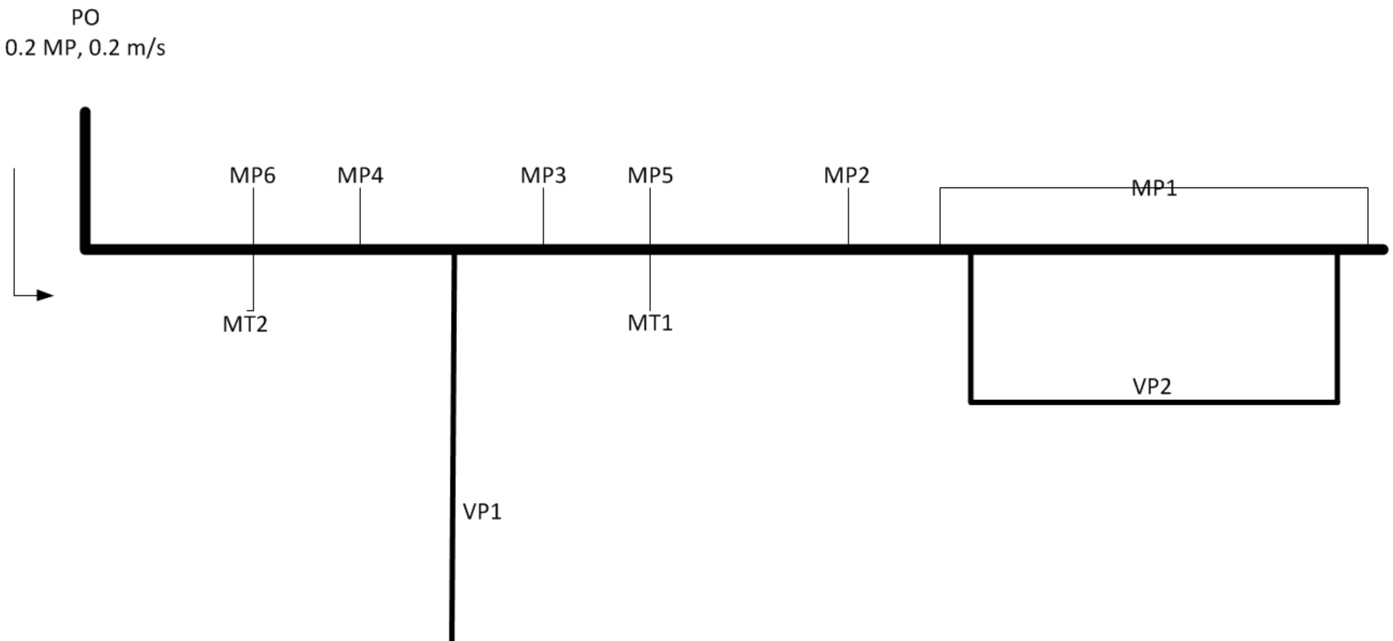
1.3 Subjects

- **Pressure Noise Analysis**
  - Pressure Fluctuations
  - Stochastic Baseline (at low frequencies)
  - Anomalous Shift (due to piping conditions)
- **Pipe Break Incidents**
  - Happening in pipes and at valves etc.
  - Similar effects as pipe narrowing



1.4 Scenario Setup

- Upstream and downstream of the break point
  - Pressure transmitters installed at both locations
  - Resistance Temperature Detectors (RTDs) installed at both locations

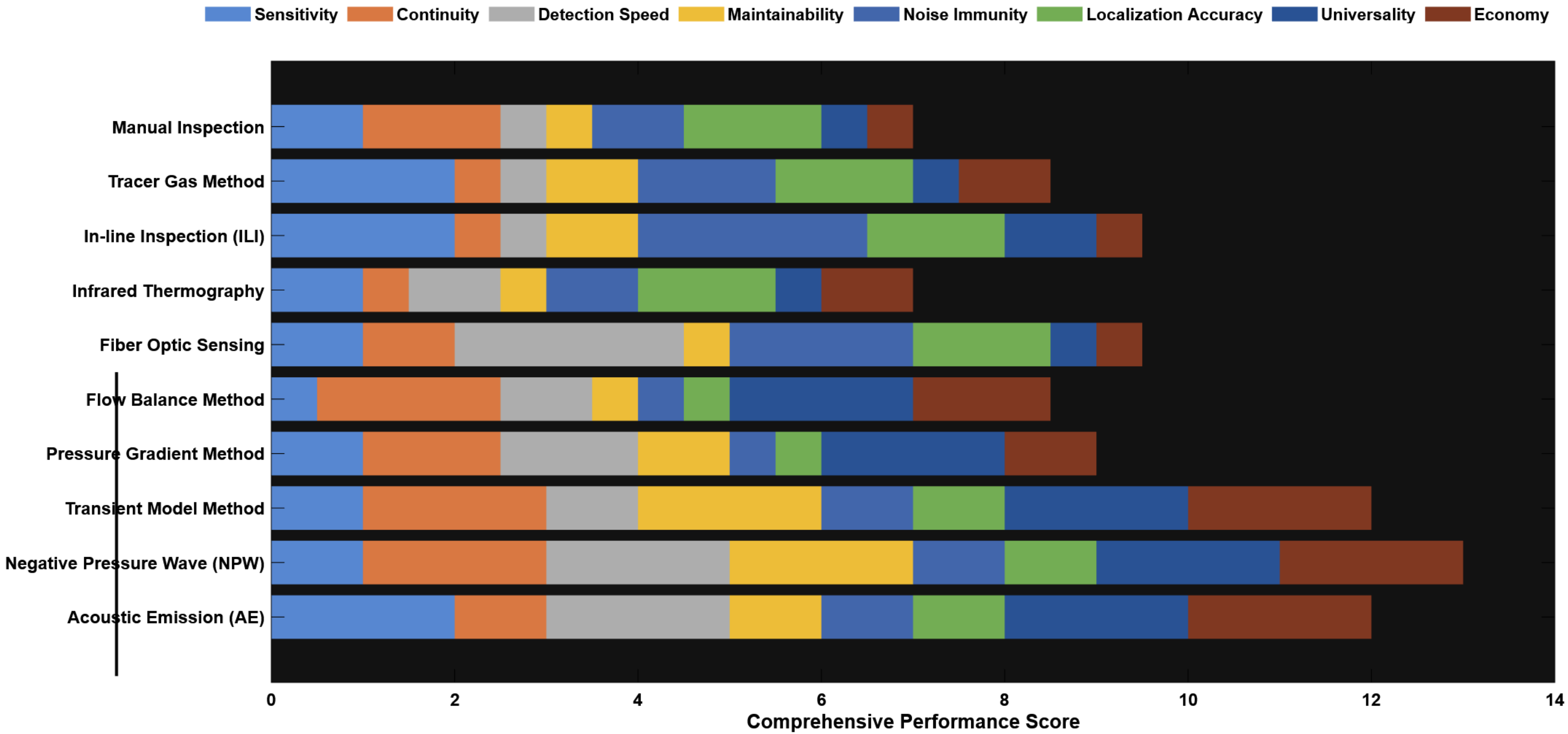


1.5 Methodology

- **Theory**
  - Pressure wave propagation theory
  - Noise analysis techniques
- **Simulation & Experiment**
  - Different-size pipe-break simulations and tests
  - High-frequency data collected from pressure transmitters and RTDs

2 Method

2.1 Background

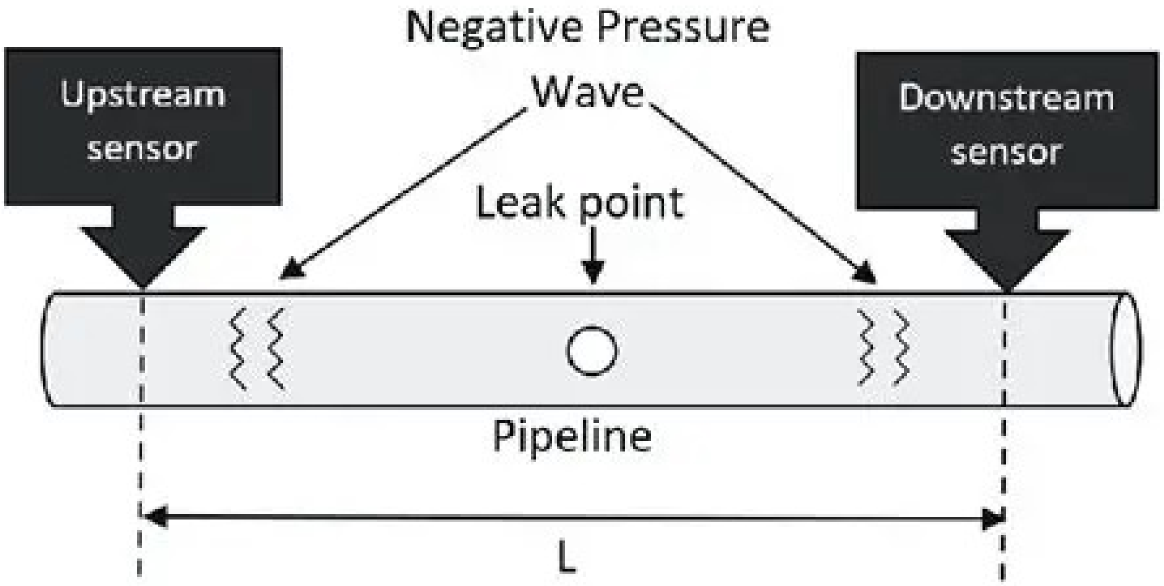


(Cao et cl., Leakage Detection and Localization of Fluid Pipeline Based on Elman Neural Network, 2020)

2.2 Transient Modeling

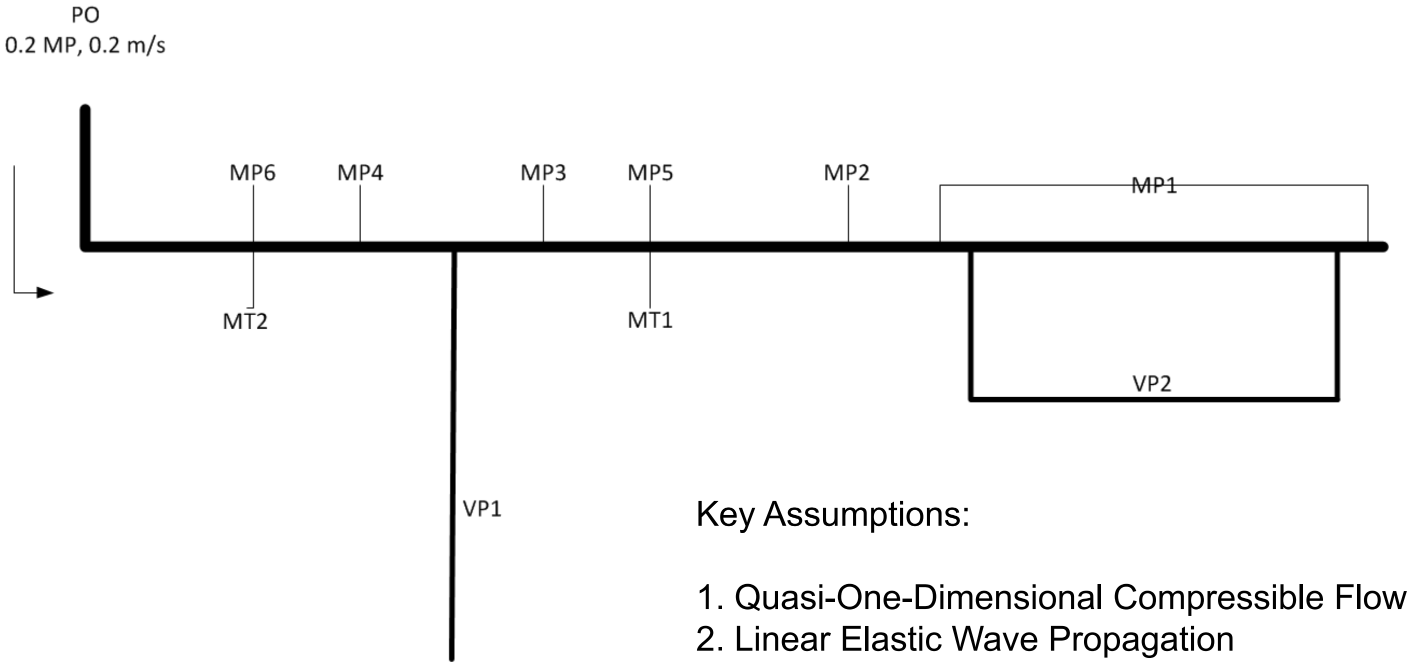
- **Concept**: Uses real-time boundary conditions (e.g., pressure, flow rate) to solve governing fluid dynamics equations
- **Typical Approach**: Insert time-dependent hydraulic events (like valve closures, pump trips, or sudden ruptures)
- **My Proposal**: Assuming random noise and applying noise analysis

2.3 Negative Pressure Wave (NPW)



3 Simulation and Results

3.1 Simulation setup



Key Assumptions:

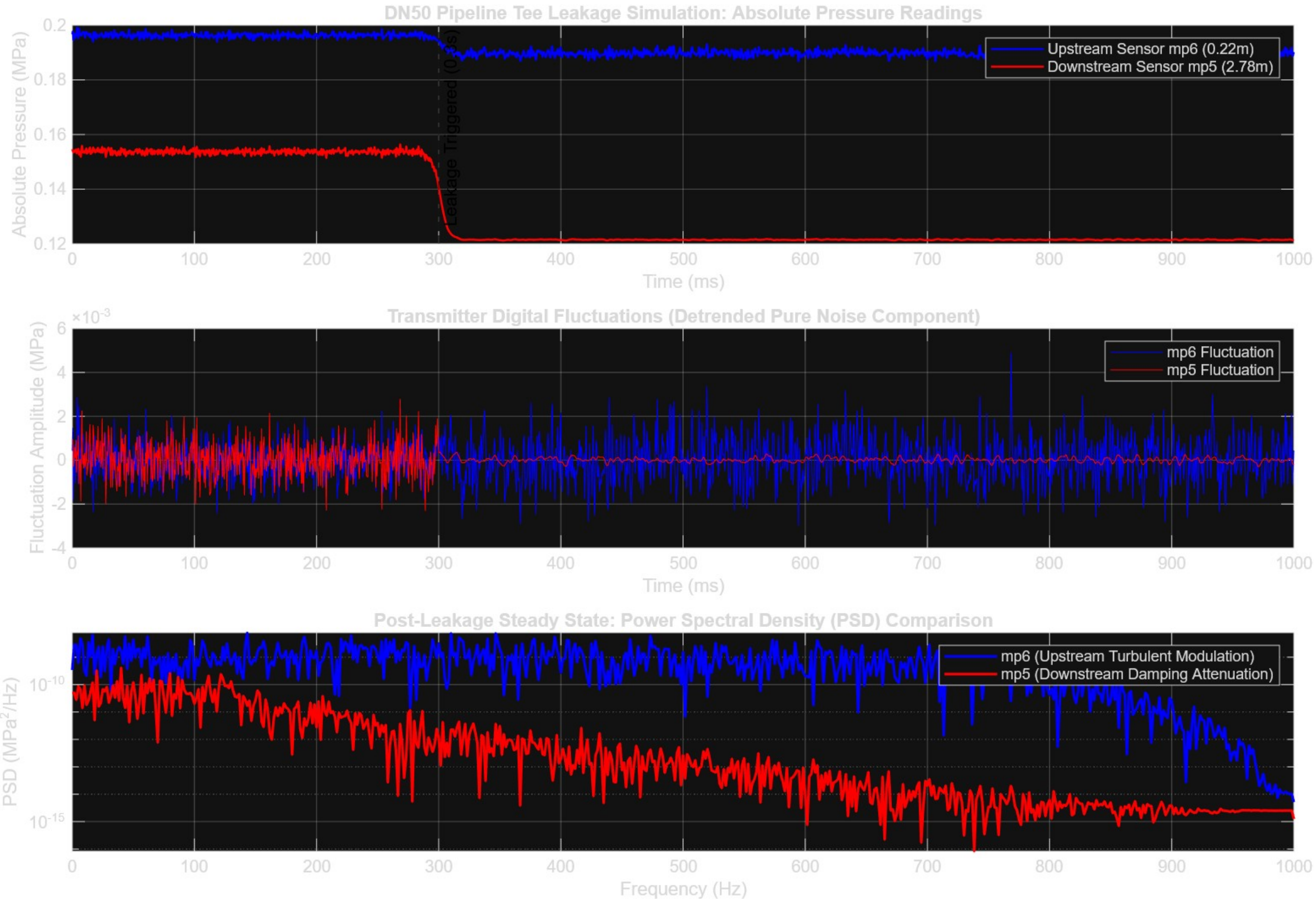
1. Quasi-One-Dimensional Compressible Flow
2. Linear Elastic Wave Propagation
3. Pseudo-Steady State Friction Model
4. Ergodic Gaussian White Noise Source
5. **Empirically Modulated Localized Turbulence**

3.2 Simulation Flowchart

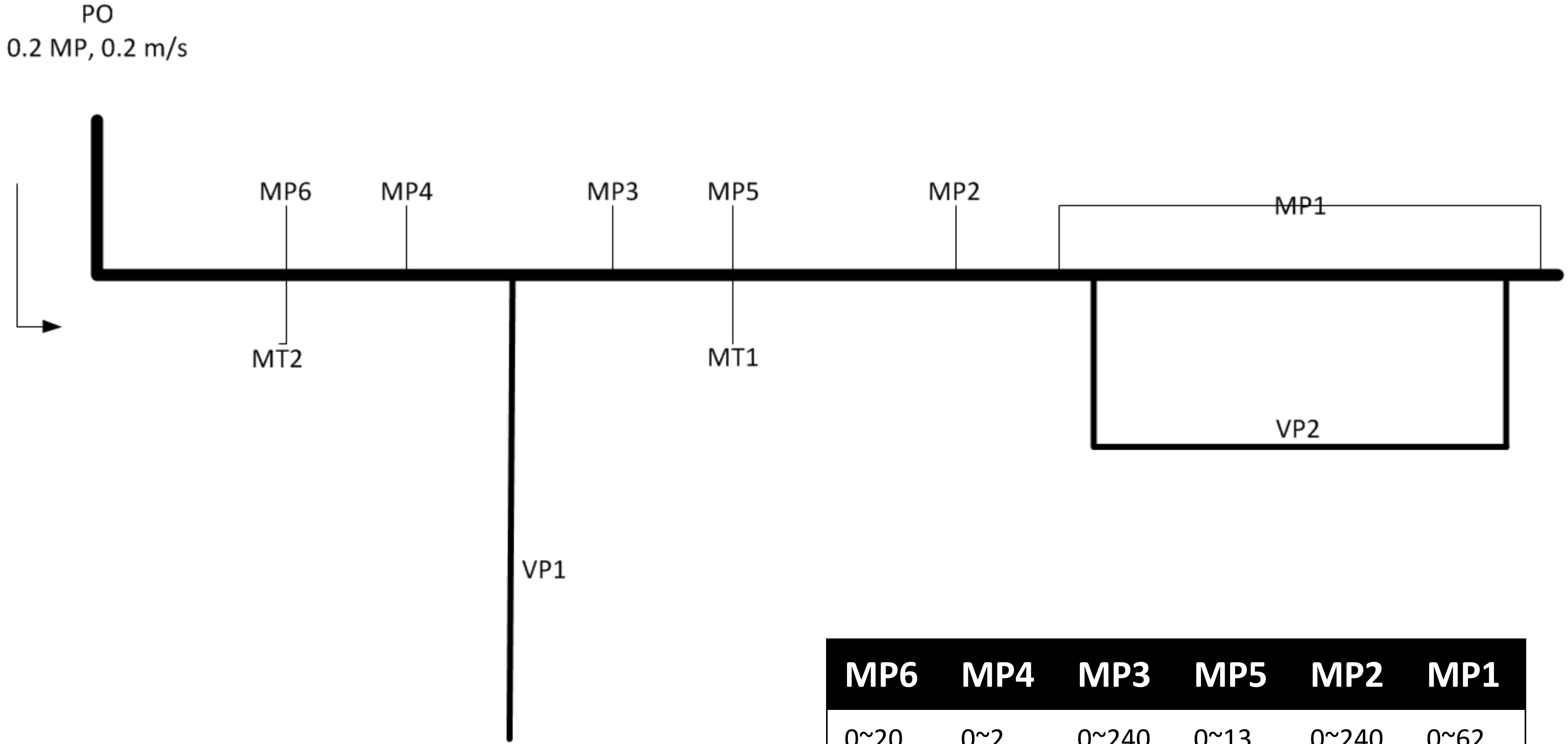
[Add flowchart here]

```
[START: Setup Parameters]
        |
        ▼
[1. Pre-Leak Baseline]
 └── Establish initial linear pressure gradient (0.2 to 0.1 MPa)
        |
        ▼
[2. Transient Trigger (t = 0.3s)]
 └── Calculate wave arrival delays to sensors based on sonic speed (1200 m/s)
        |
        ▼
[3. Macro Base Generation]
 └── Apply Sigmoid function to model smooth, macro-scale pressure drops
        |
        ▼
[4. Micro Noise Modulation]
 ├── Pre-Leak: Apply uniform Gaussian White Noise to both sensors
 └── Post-Leak (Asymmetric Shift):
      ├── Upstream (mp6): Boost amplitude + keep high frequencies (turbulent flow)
      └── Downstream (mp5): Dampen amplitude + heavy low-pass filter (energy dissipa
        |
        ▼
[5. Final Signal Output]
 └── Superposition: P(t) = Base Pressure + Modulated Noise
        |
        ▼
[6. Verification & Analytics]
 └── Extract detrended noise components and compute PSD via FFT
        |
        ▼
[END: High-Contrast Evaluation Plot]
```

3.3 Results


DN50 Pipeline Tee Leakage Simulation: Absolute Pressure Readings
Absolute Pressure (MPa)
0.2
0.18
0.16
0.14
0.12
Leakage Triggered (0.3s)
Upstream Sensor mp6 (0.22m)
Downstream Sensor mp5 (2.78m)
0 100 200 300 400 500 600 700 800 900 1000
Time (ms)
Transmitter Digital Fluctuations (Detrended Pure Noise Component)
×10-3
Fluctuation Amplitude (MPa)
6 4 2 0 -2 -4
mp6 Fluctuation
mp5 Fluctuation
0 100 200 300 400 500 600 700 800 900 1000
Time (ms)
Post-Leakage Steady State: Power Spectral Density (PSD) Comparison
PSD (MPa2/Hz)
10-10
10-15
mp6 (Upstream Turbulent Modulation)
mp5 (Downstream Damping Attenuation)
0 100 200 300 400 500 600 700 800 900 1000
Frequency (Hz)

4 Test



MP6	MP4	MP3	MP5	MP2	MP1
0~20 MPa	0~2 MPa	0~240 kPa 3.5~10 MPa	0~13 MPa	0~240 kPa	0~62 kPa


1.13 m
15 cm
27 cm
99 cm


1.86 m
33 cm
21 cm
cm


2810
150
110
0
316L 90E(L)
14.3*3.2


凯泉
立式单级化工泵
生产许可
型号KQH 150 - 400C
流量 160 m3/h 必需汽蚀余量 3.5 m
扬程 32 m 配套功率 22 kW
转速 1480 r/min 重量 kg
出厂编号 出厂日期 2015年 09月
许可证编号 XK06-003-00497
上海凯泉泵业(集团)有限公司
凯泉集团有限公司

5 Future Work

Threshold and Uncertainty Study

Validation

Sensor Fusion and Machine Learning

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