Experimental Analysis of Influencing Factors on Flow Stability of Water Flow Facilities

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Lisbon, 06.2019

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1. Introduction

01

Flow stability is an important **technical index** of flow standard facilities.

It is of great significance to find out the causes of the fluctuation for **improving the calibration capability** and **decreasing the uncertainty**.

02

The **buffer tank** and the **high constant water head tank** are two kinds of methods for stabilizing flow widely used in the water flow facilities, the actual effect of them was studied by the experiments in this paper.

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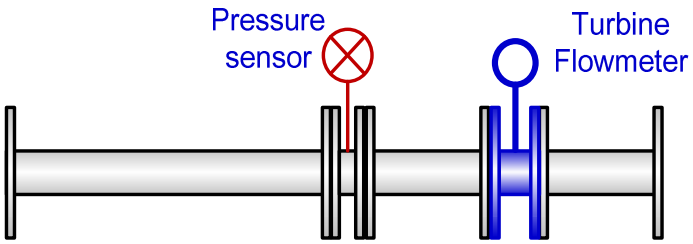
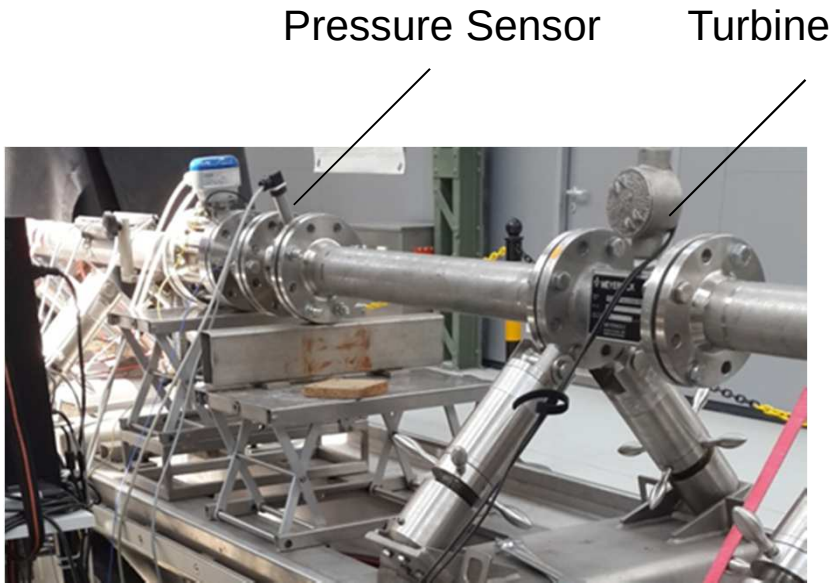
2. Measurement of flow stability

2.1 The flow stability test devices



a pressure sensor + a flow meter in series



2. Measurement of flow stability

2.2 The flow stability test system

Tao Meng, Shangchun Fan, Chi Wang, Huichao Shi，Xiaopeng Li. A flow stability evaluation method based on flow-pressure correlation. *Flow Measurement & Instrumentation*, 2018(64): 155－163.

（1）The amplitude of flow fluctuation

$$D_q = \sqrt{\frac{\sum_{i=1}^{N}\left(q_i - \bar{q}\right)^2}{N-1}} \Big/ \bar{q}$$

Standard Deviation

by flowmeter in a single flow measurement

（2）The frequency of flow fluctuation

by performing **FFT** analysis on the pressure signal

（3）The direction of fluctuations source

$$r_{qp} = \frac{\sum_{n=1}^{N} q(n)p(n+m)}{\sigma_q \sigma_p}$$

Correlation Analysis

obvious positive correlation（$0.3<r_{qp}<1$）

→ from the **upstream**

obvious negative correlation（$-1<r_{qp}<-0.3$）

→ from the **downstream**

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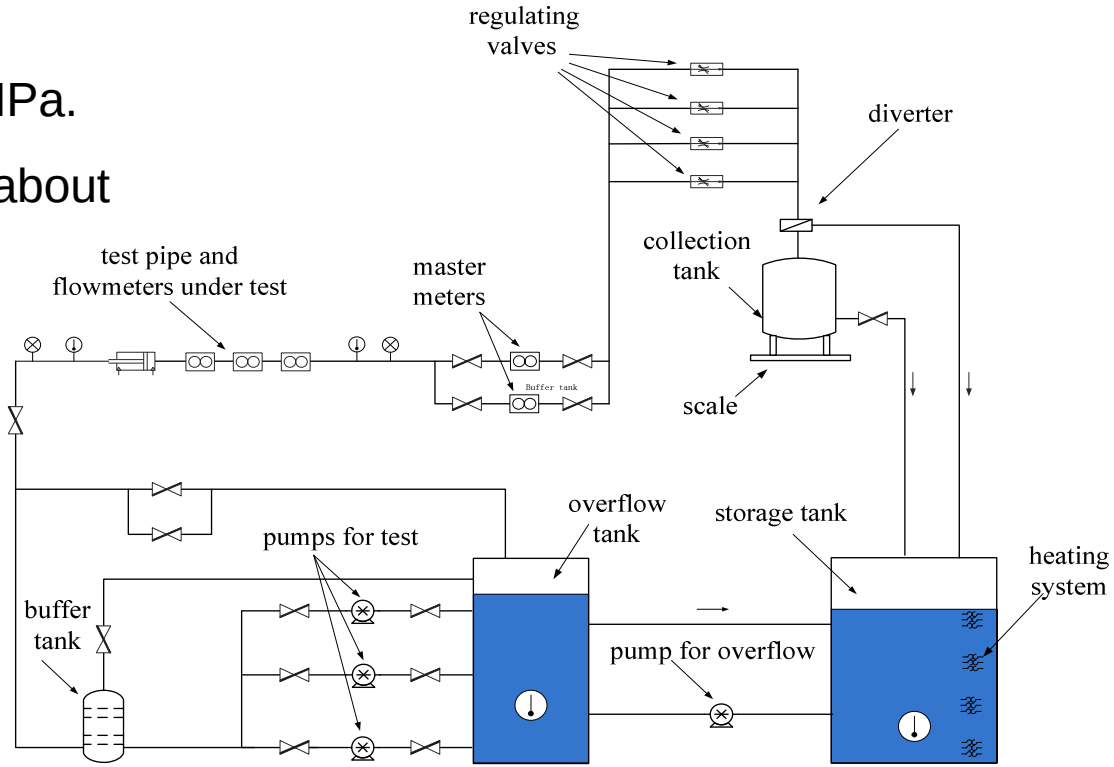
3. Experiment on buffer tank method

3.1 Experimental facility and scheme

- Pipe diameter: DN80
- Flow range: (15~120) m^3/h
- outlet pressure : (0.1~0.2) MPa.
- From $15m^3/h$, increased by about $10m^3/h$ each time

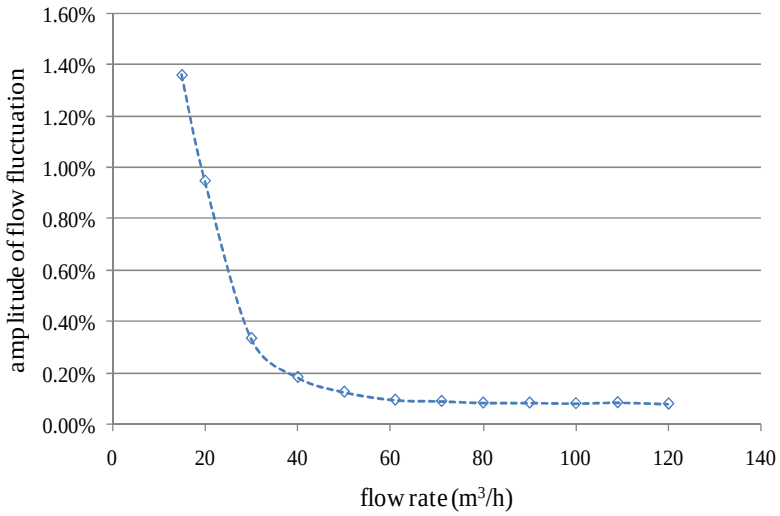
Test on 1# facility



3. Experiment on buffer tank method

3.2 Test results of 1# facility

Flow Rate (m^3/h)	Flow Fluctuation Amplitude (%)	Flow Fluctuation Frequency (Hz)	Correlation Coefficient
15	1.36	1.45	0.70
20	0.95	1.48	0.77
30	0.34	1.61	0.77
40	0.18	1.73	0.68
50	0.13	1.91	0.61
61	0.10	--	0.49
71	0.09	--	0.56
80	0.09	--	0.39
90	0.09	--	0.38
100	0.08	--	0.33
109	0.09	--	0.23
120	0.08	--	0.25



3. Experiment on buffer tank method

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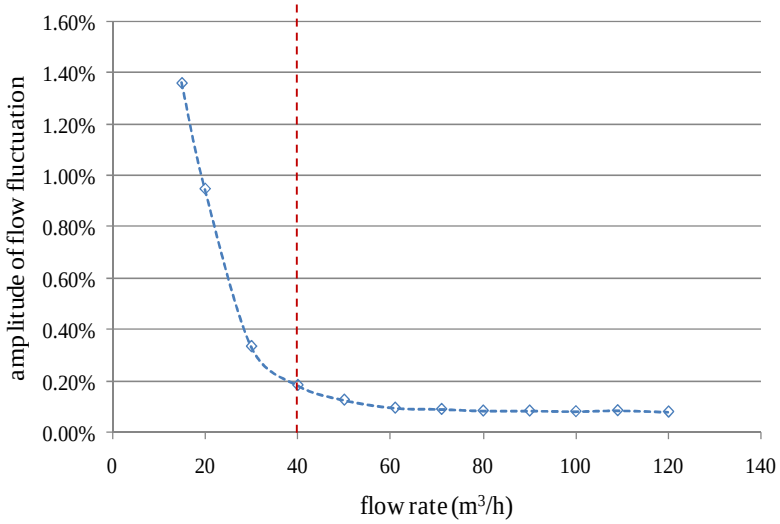
Flow Fluctuation Amplitude



The flow fluctuation amplitude showed a trend of rapid decrease with the increase of flowrate

3. Experiment on buffer tank method

3.2 Test results of 1# facility

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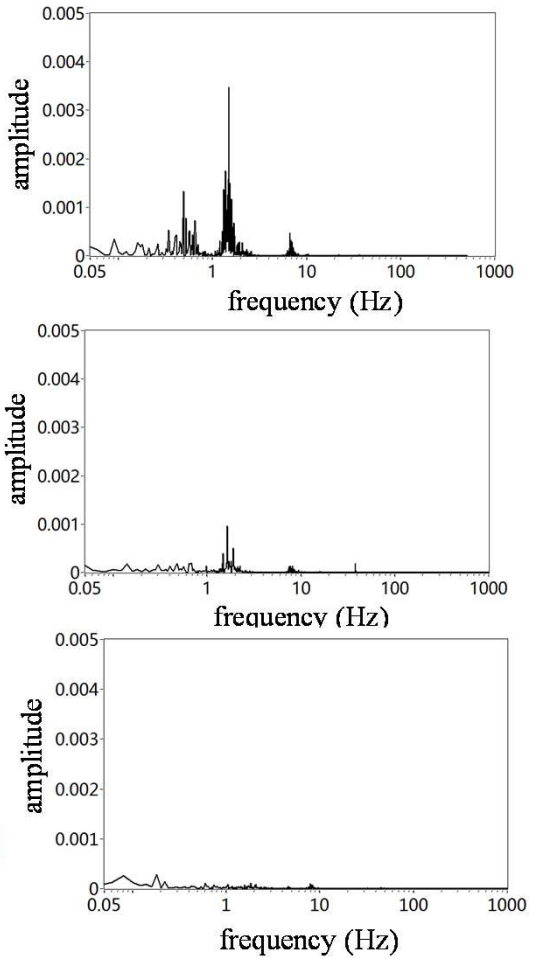
In terms of the characteristics of fluctuation frequency, the main fluctuation frequency was about 1.5Hz in the **low-flow rate area**. However, when the flow rate is **greater than 60m³/h**, there was no obvious characteristic frequency.

Flow Fluctuation Frequency



q=15m³/h

q=40m³/h

q=60m³/h

FFT spectrum analysis

3. Experiment on buffer tank method

3.2 Test results of 1# facility

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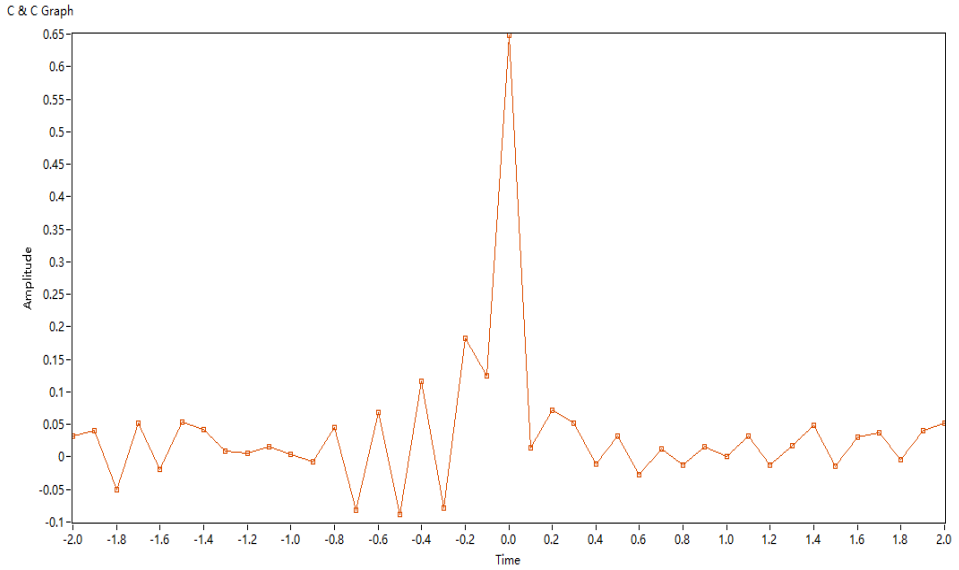
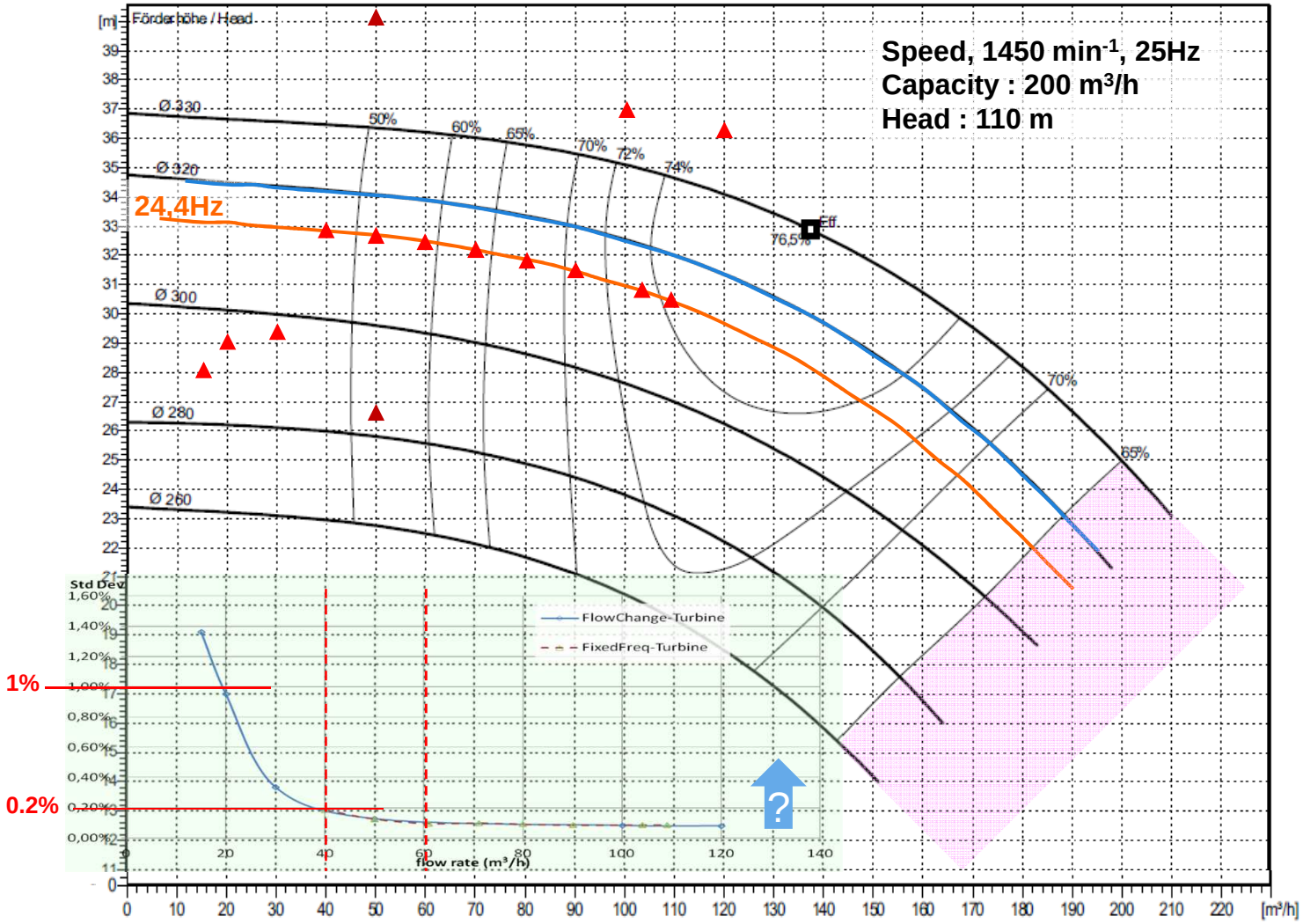
Correlation analysis of pressure and flow signals



It was an obvious **positive** correlation ($0.6<r_{pq}<0.8$) between flow and pressure, and it can be inferred that the fluctuation source mainly was at the **upstream** of the measurement system.

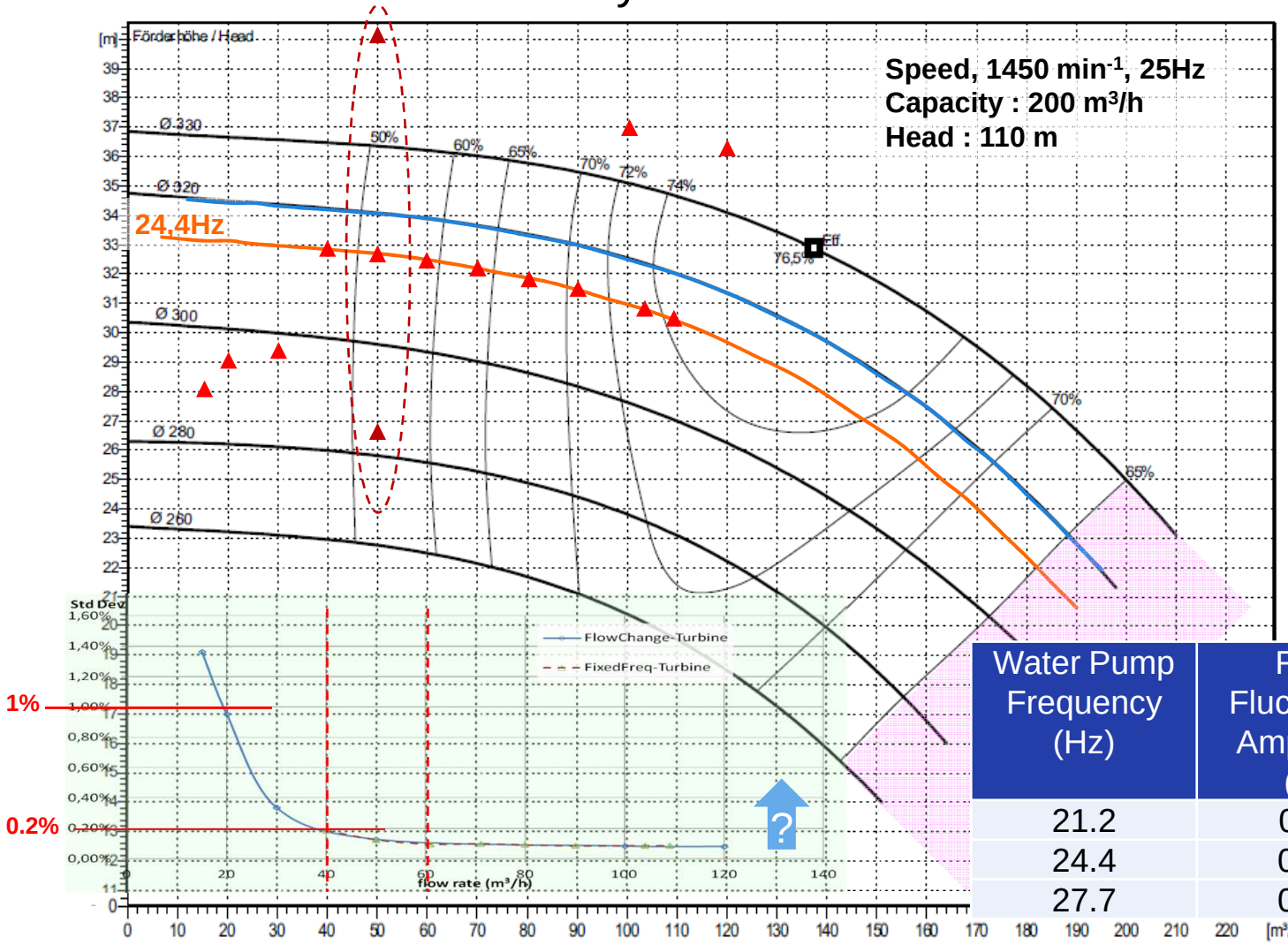
3. Experiment on buffer tank method

3.2 Test results of 1# facility



3. Experiment on buffer tank method

3.2 Test results of 1# facility



Water Pump Frequency (Hz)	Flow Fluctuation Amplitude (%)	Flow Fluctuation Frequency (Hz)
21.2	0.11	1.9
24.4	0.13	1.9
27.7	0.14	2.0

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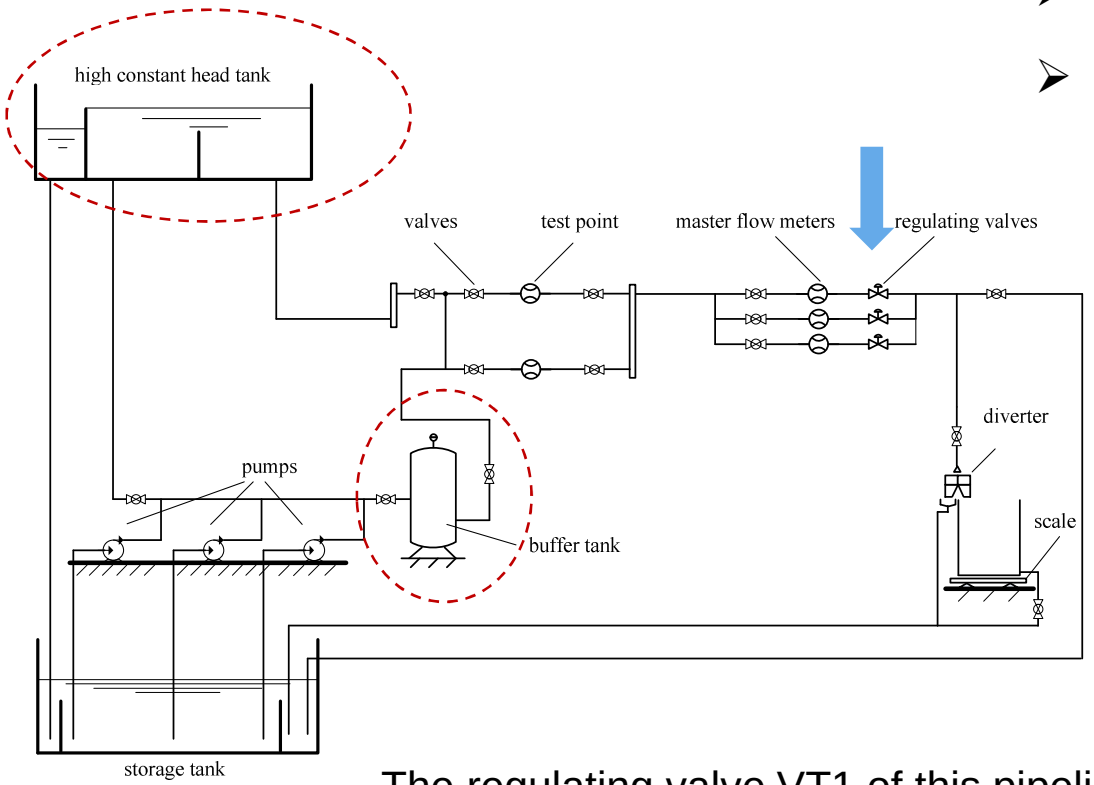
4. Experiment on high constant water head tank method

4.1 Experimental facility and scheme

- Pipe diameter: DN100
- Flow range: (30~120) m^3/h
- outlet pressure : (0.1~0.3) MPa.



Two different methods for flow stabilization:

(1) High constant water head tank.

(2) Buffer tank

The regulating valve VT1 of this pipeline was a linear ball valve, and its flow adjustment range was (30~200) m^3/h.

4. Experiment on buffer tank method

4.2 Test results of 2# facility

Experimental Group	Experiment Number	Stabilizing Pressure Method and Working Condition	Flow Rate (m^3/h)	Fluctuation Amplitude (%)	Pipeline Pressure (kPa)	Valve Opening (%)
Group 1	H-01	constant head tank	30	0.52	175	28
	H-02		50	0.36	171	40
	H-03		120	0.22	143	70
Group 2	H-04	buffer tank, mid-pressure	30	0.50	175	29
	H-05		50	0.38	172	40
	H-06		120	0.22	164	66
Group 3	H-07	buffer tank, high-pressure	50	0.47	299	31
	H-08		120	0.31	289	54
Group 4	H-09	buffer tank, low-pressure	50	0.20	39	100
	H-10		120	0.18	99	100

4. Experiment on buffer tank method

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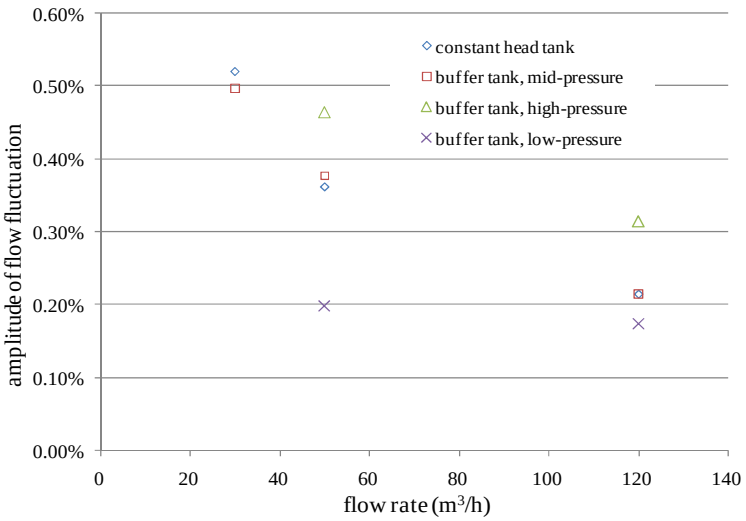

Compared with the result of Group 1 and Group 2, it can be found that the fluctuation amplitude of the two stabilizing flow methods were very close at different flow rate.

4. Experiment on buffer tank method

4.2 Test results of 2# facility

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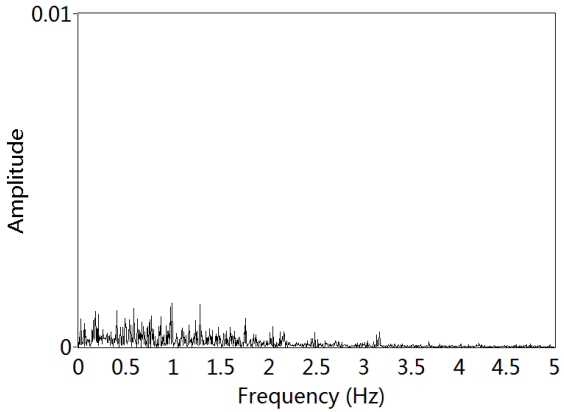
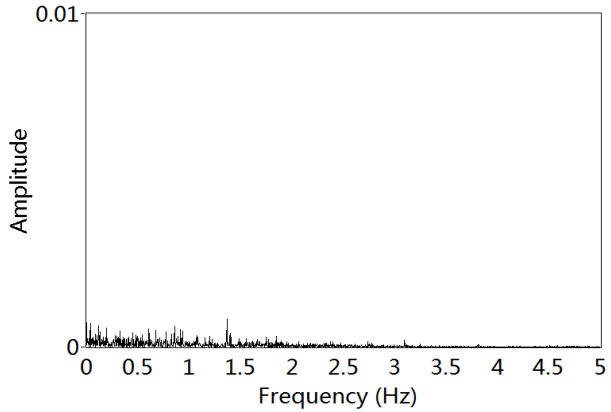


experiment H-01 (water tower)



experiment H-04 (buffer tank)

Only some weak signals were found around 1Hz

4. Experiment on buffer tank method

4.2 Test results of 2# facility

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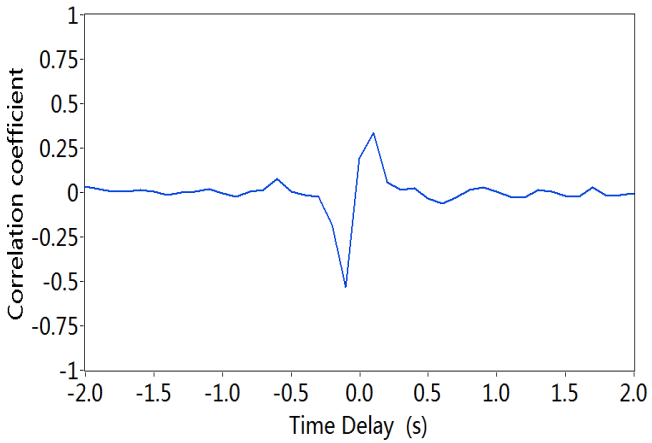

Correlation analysis of pressure and flow signals

Fluctuation Source

negative correlation

downstream of the measuring point

4. Experiment on buffer tank method

4.2 Test results of 2# facility

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	H-02	
	H-03	
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	H-05	
	H-06	
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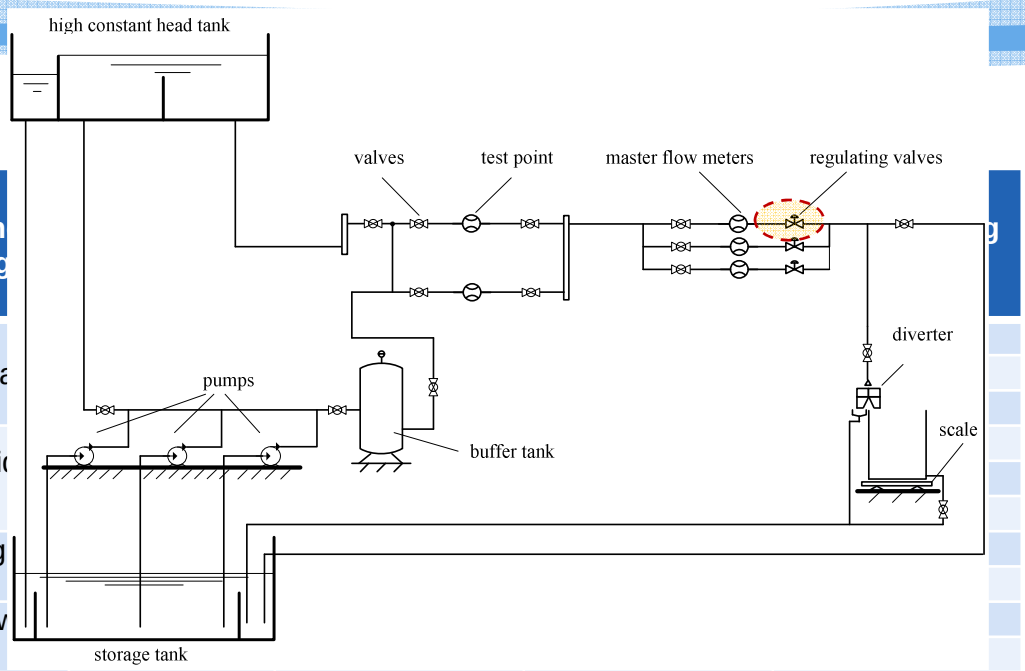
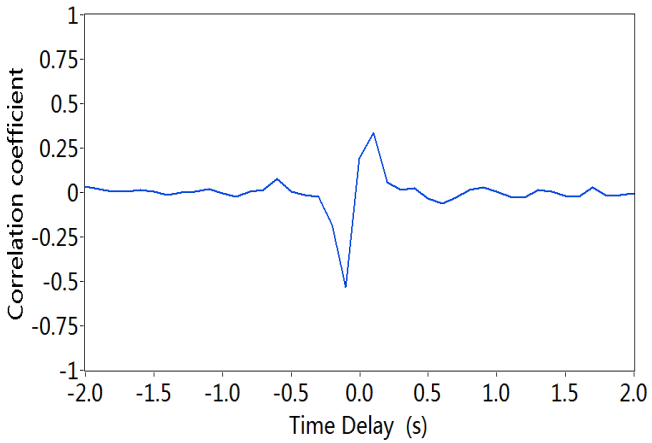
	H-08	
Group 4	H-09	buffer tank, lov pressure
	H-10	





Correlation analysis of pressure and flow signals

Fluctuation Source

negative correlation

downstream of the measuring point

regulating valve VT1

4. Experiment on buffer tank method

4.2 Test results of 2# facility

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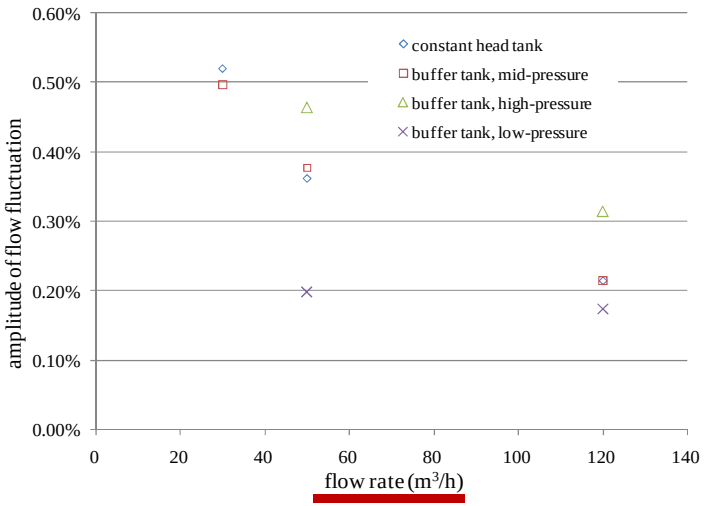

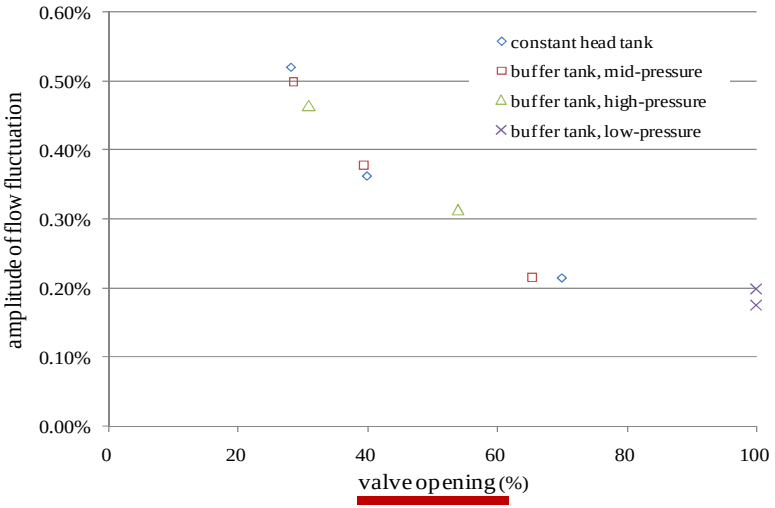

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5. Conclusions

01

The amplitude and frequency of flow fluctuation are not only the technical indicators to represent the flow stability of the facility, through the analysis of the direction of the fluctuation source and the change rule of flow stability at different working conditions, the causes of the fluctuation can be effectively found.

02

For flow facilities with the **buffer tank**, working in **low-efficiency areas of pumps** should be avoided; and for facilities with the **high constant water head tank**, the reasonable regulating valve groups should be designed to avoid **excessive local pressure loss**, so as to obtain good flow stability.


Thank You !