Experimental Study on Flow Rate Measurement Downstream of an Elbow Pipe using the Clamp-on ultrasonic Flowmeter

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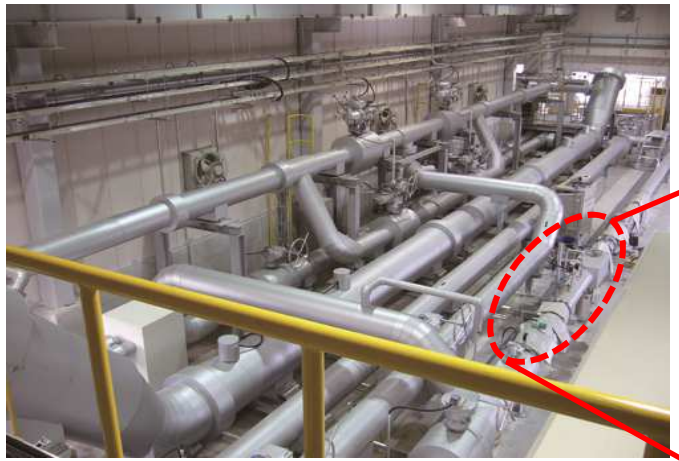
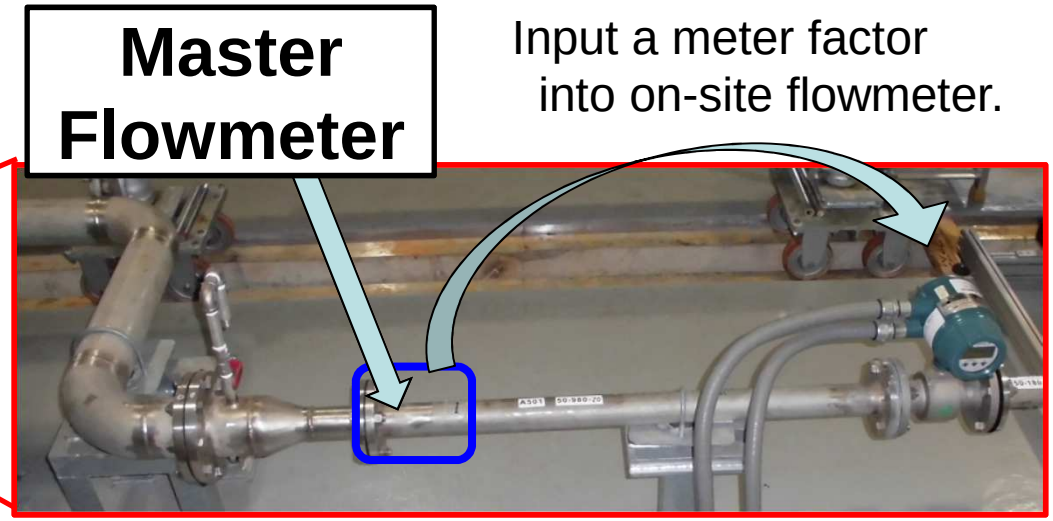
Purpose of this study

- Meter factor is required for a conventional flowmeter.
  (obtained in a calibration facility)
- Meter factor depends on a velocity profile in a pipe.
  (Downstream of elbow, valve…)

- **On-site calibration without modification of existing pipe**



On-site Facility



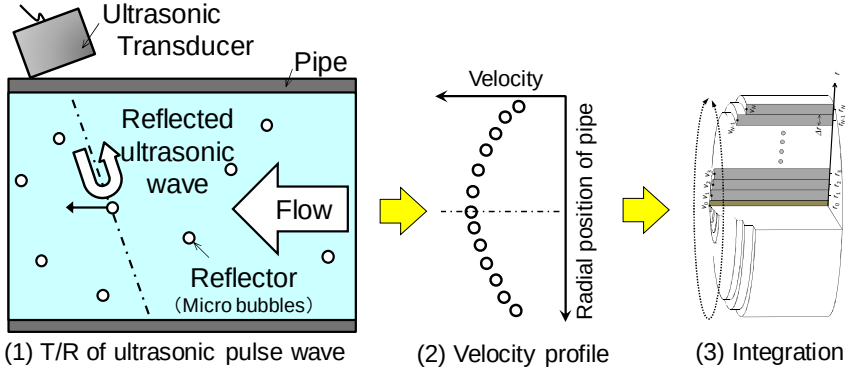
Calibration using a Master Flowmeter

Purpose of this study

Requirement

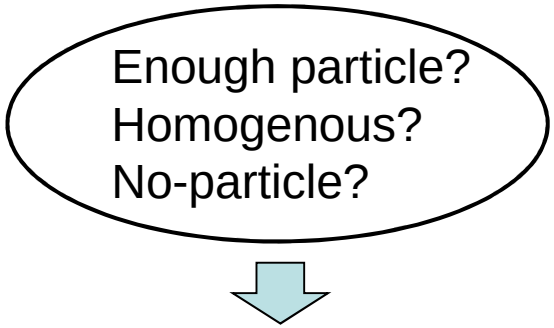
1. Velocity profile measurement
2. Clamp-on

Ultrasonic flowmeter
based on Doppler method



- Fundamental Uncertainty Analysis of Flowrate Measurement using the Ultrasonic Doppler Velocity Profile Method, Furuichi, N., Flow Measurement and Instrumentation, 30, 2013, pp.202-211
- S. Wada, N. Furuichi, Influence of obstacle plates on flowrate measurement uncertainty based on ultrasonic Doppler velocity profile method, Flow Measurement and Instrumentation, 48, 2016, pp.81-89
- S. Wada, N. Furuichi, T. Shimada, Development of ultrasound pulse-train Doppler method for velocity profile and flowrate measurement, Measurement and Science Technology, 27, 2016, 115302
- S. Wada, N. Furuichi and T. Shimada, “Application of partial inversion pulse to ultrasonic time-domain correlation method to measure the flow rate in a pipe”, Measurement and Science Technology, 28, 2017, 115302

Purpose of this study



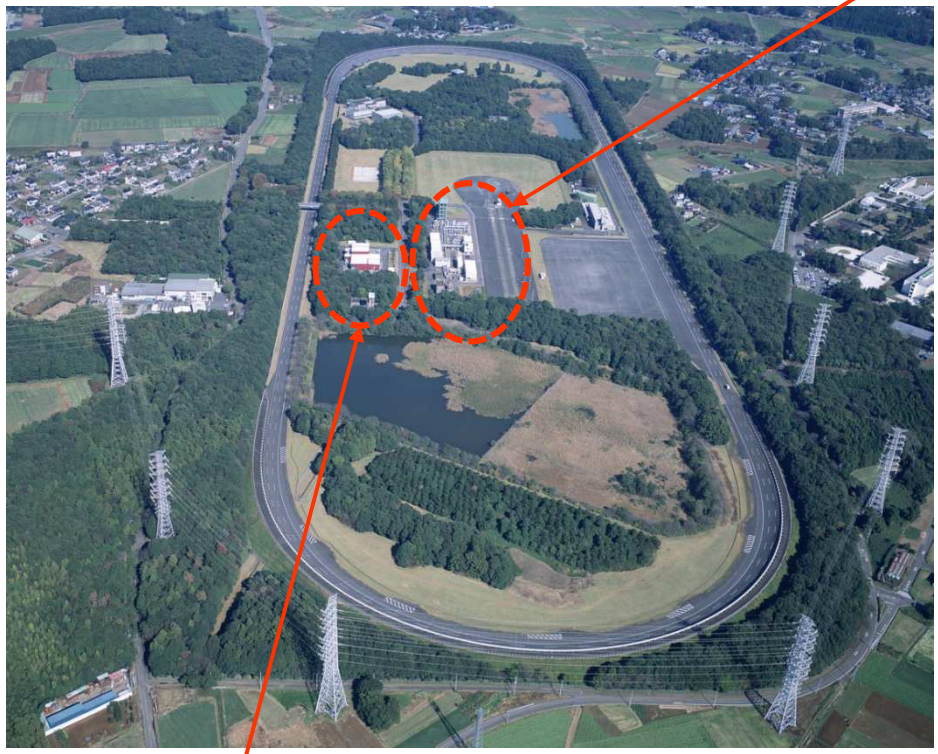
Return to the origin

Clamp-On transit-time ultrasonic

To evaluate of an uncertainty of flow rate measurement using the clamp-on ultrasonic flowmeter, experiments were carried out at the national standard calibration facility of water flow rate in Japan, as a first step toward an on-site calibration.

Liquid flow calibration facility

AIST, Tsukuba North Site



Water flow calibration facility

High Reynolds number facility
Comparison method
BMC 0.08%
750~12000m³/h
20~70°C
400A~600A

High Reynolds number facility

50t system
Weighing tank method
BMC 0.06%
30~3000m³/h
15A~400A

Prover system
BMC 0.08%
100~800m³/h
20~70°C
100A~200A

5t, 500kg weighing system

5t system
Weighing tank method
BMC 0.04%
5~300m³/h
15A~400A

500kg system
Weighing tank method
BMC 0.04%
0.3~30m³/h
15A~400A

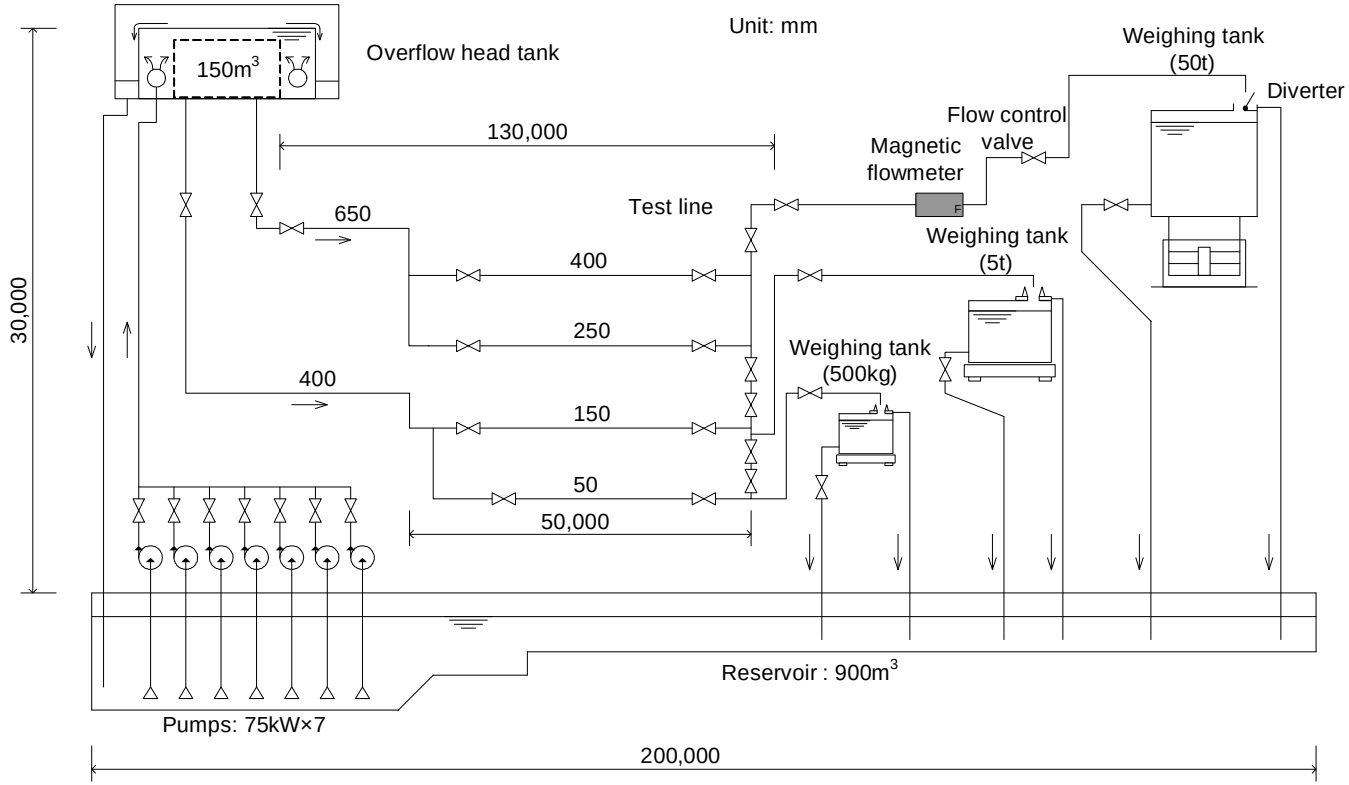
10kg system
Weighing tank method
BMC 0.04%
0.005~1.2m³/h
~25A

Prover system

Flowrate m³/h

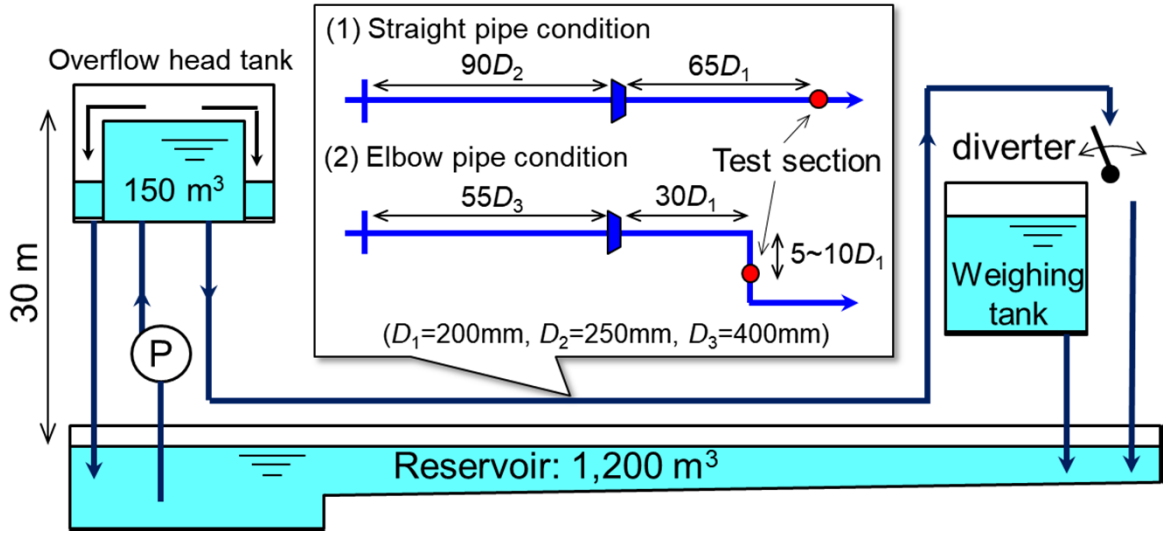
10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4}

Water flow calibration facility (50t, 5t, 500kg tank system)

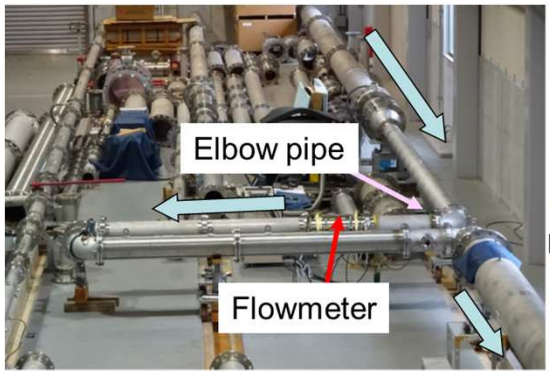


Flowrate : 0.3 m^3/h – 3000 m^3/h
Temperature : ambient, ±1 °C/day

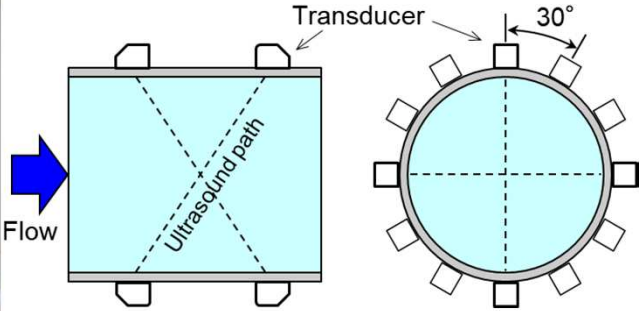
Experimental apparatus and conditions



Experimental facility



Elbow pipe setting



Transducers setting

【Parameters】

Flow rate:

Q = 100 ~ 700 m³/h

Pipe condition (test section):

Outer diameter: D_1 = 216.3 mm

Thickness: t_1 = 6.5 mm

Material: Stainless steel

Upstream condition:

・Straight pipe condition:

Length of straight pipe

$L_S = 65D_1$

・Elbow pipe condition:

Length from elbow outlet

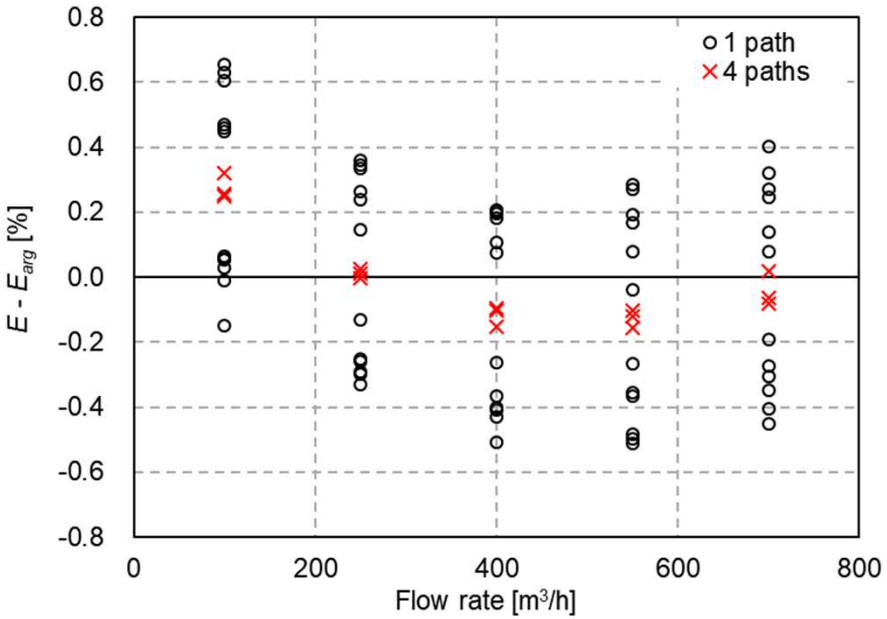
$L_E = 5D_1$, $10D_1$

Transducer setting:

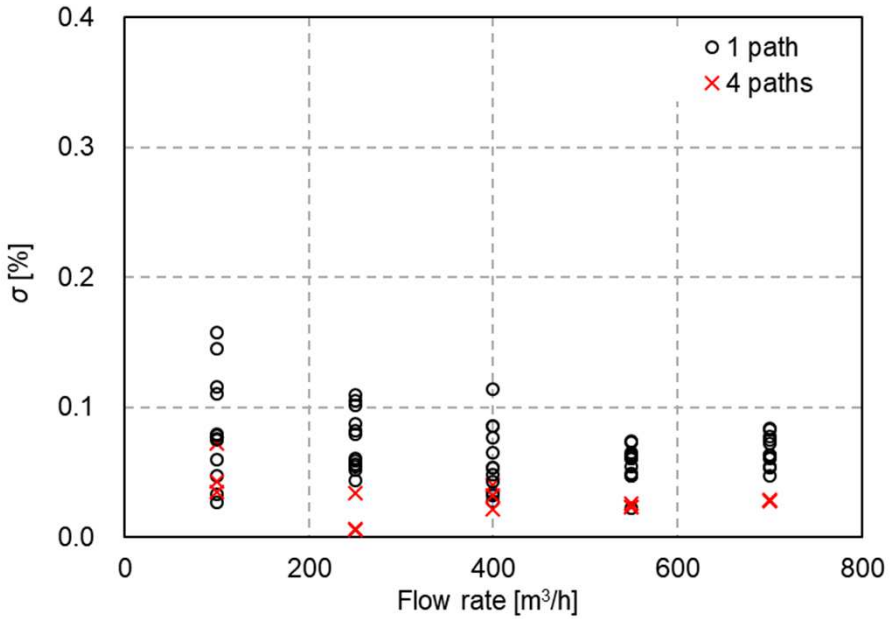
Interval: α = 30°

Number of path N_P= 1 ~ 4

Results (downstream of the long straight pipe)



Errors of flow rate measurement



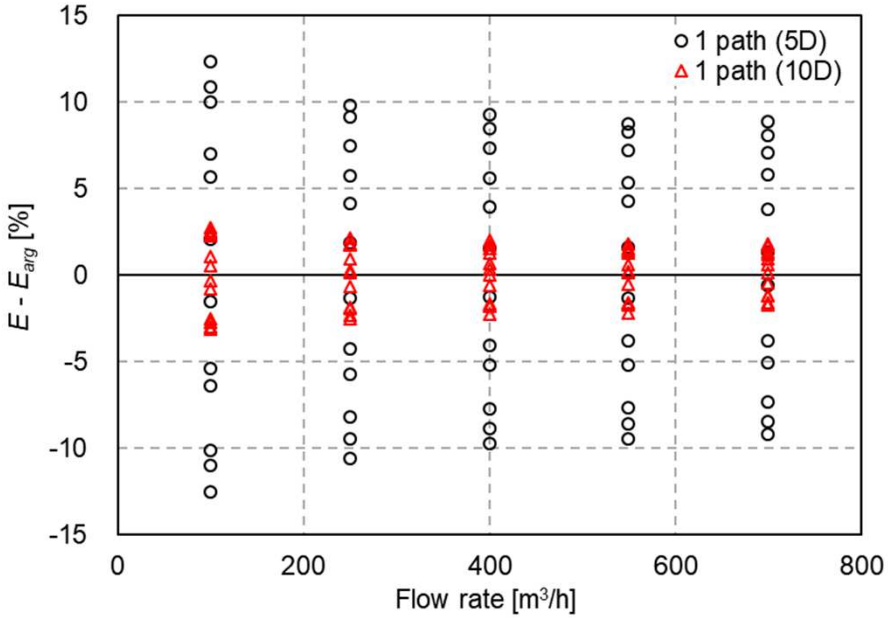
Standard deviations

- These results indicate clearly that 4 paths can measure the flow rate accurately compared with 1 path, even though downstream of the long straight pipe.

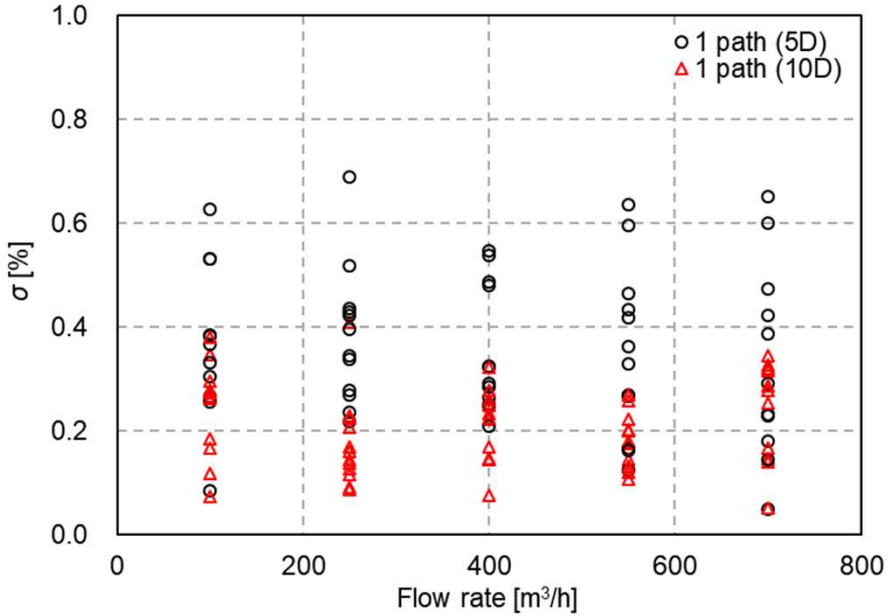
$$E = \frac{Q_u}{Q_w} - 1$$

Where, Q_u and Q_w are the flow rate measured by the ultrasonic flowmeter and the weighing tank system, respectively. E_{arg} is the average value of all measured E.

Results (downstream of an elbow : 1 path mode)



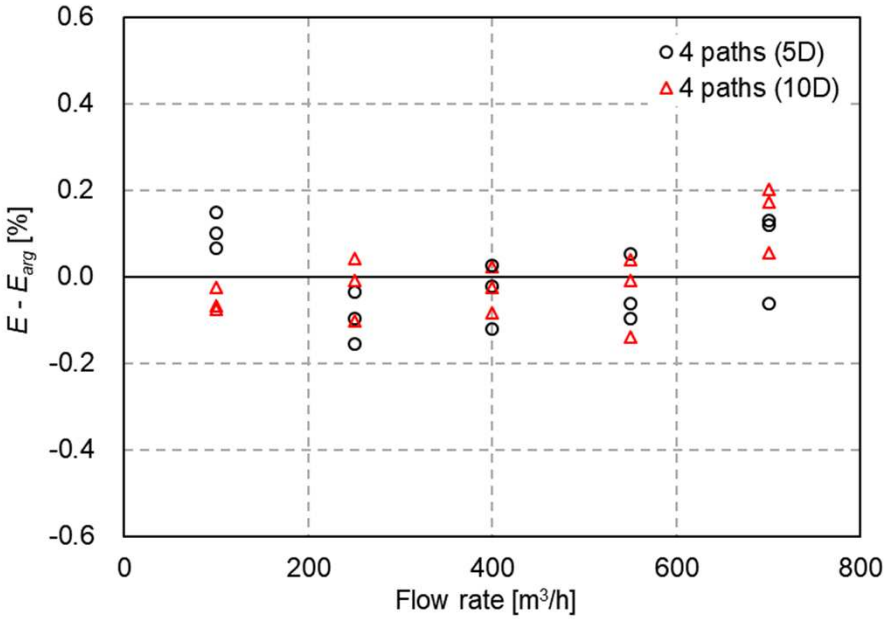
Errors of flow rate measurement



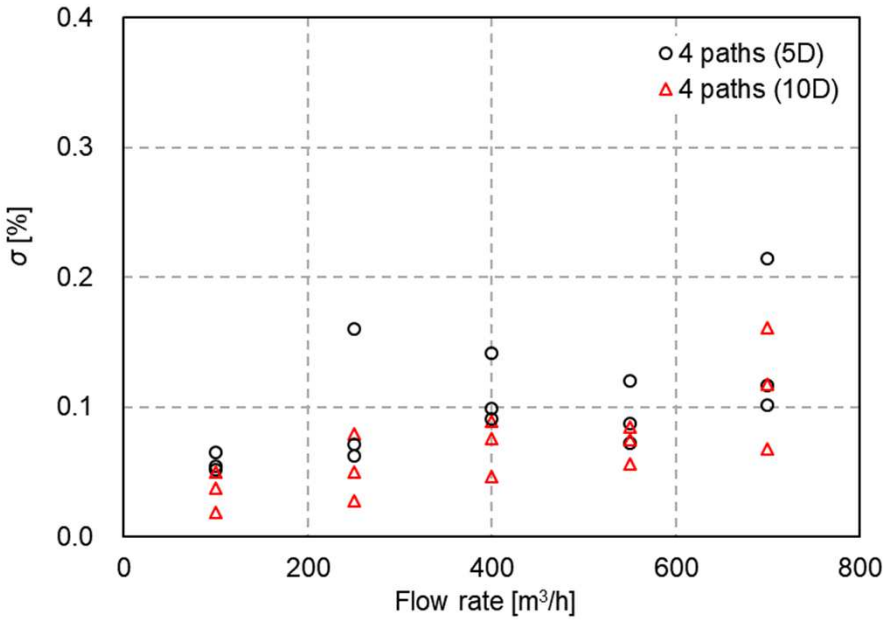
Standard deviations

- These results indicate that the accuracy of flow rate measurement depends on the circumferential position of transducer because of the strongly disturbed flow by the elbow.

Results (downstream of an elbow : 4 paths mode)



Errors of flow rate measurement



Standard deviations

- The errors and standard deviations of flow rate measurement are almost equivalent to the errors downstream of the long straight pipe condition, when using the 4 paths mode.

Conclusion

- The clamp-on ultrasonic flowmeter using 4 paths can measure the flow rate accurately compared with 1 path downstream of the long straight pipe.
- The errors and standard deviations measured downstream of the elbow pipe using 4 paths are equivalent to the case of the long straight pipe, even if the velocity profiles are disturbed strongly by the upstream elbow pipe.
- Questions for s.wada@aist.go.jp ?