QdotFlow

Time varying gas flow meter

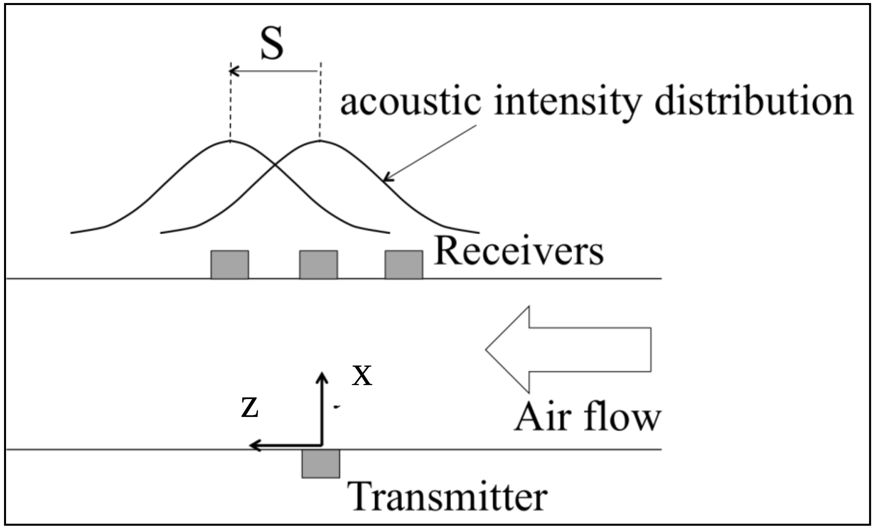
$$Q = \int_A f u dA$$

Flow rate measurement by Shift Method

FlowBiz

Working Principle:

Flying pulse is transported by flow



Working principle

Ultrasonic wave flying in the fluid is transported by flow itself to the flow direction and the path of sharp beam is distorted from straight line. The position of the wave on the opposite surface is shifted from the right opposite by amount Z (displacement or shift). The amount of shift reflects the magnitude of the volumetric flow rate, and it is obtained by line integral of the velocity distribution in the flowing channel. In the cross section of the channel, x is a direction of US flight, z a direction of flow and y is orthogonal to x. Whatever the shape of cross section, the amount of shift S depends on the location of y, S(y). Integrating S to y direction gives an areal integral of velocity distribution U(x,y), which corresponds to the flow rate Q.
Thus, flow rate can be obtained, by measuring the Shift distribution.

General geometry

Volume flow rate, *Q*, is defined as

$$Q = \iint U(x,y)\,dxdy$$

Magnitude of Shift, *S*

$$S(y) = \int \frac{U(x,y)}{c}dx$$

By integrating *S*,

$$\int S(y)dy = \iint \frac{U(x,y)}{c}dxdy$$

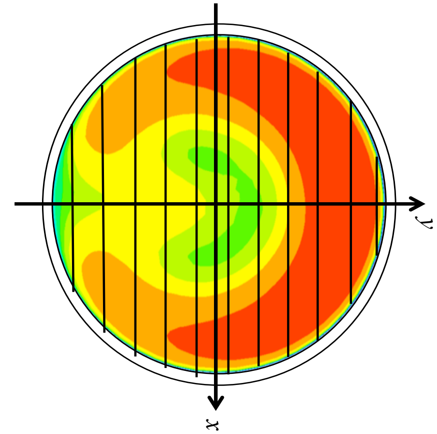
Q is obtained by S distribution

$$Q = c\int S(y)dy$$

Flow rate measurement by Shift Method

Shift of acoustic intensity at y, *S*
= line integral of velocity distribution
(local Mach number)

$$S(y) = \int \frac{U(x,y)}{c} dx$$

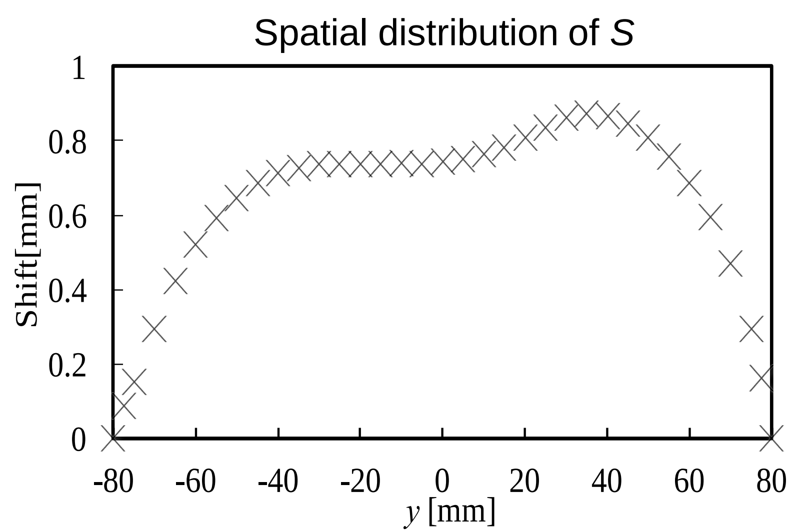


Secondary flow after bend

<u>Expected magnitude of Shift, *S*</u>

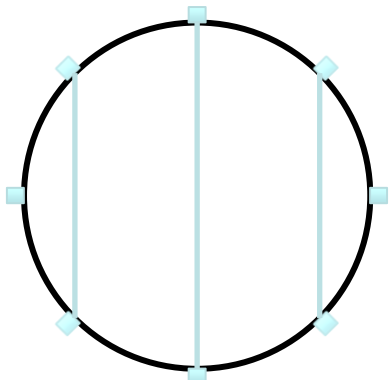
Air(100kPa, 298K)
c = 350 m/s, *D* = 0.05 m

Q_m[kg/h]	*Q*	*u*	*S* [mm]
4.5	0.0005	0.27	0.039
60	0.007	3.61	0.52
900	0.106	54.1	7.7

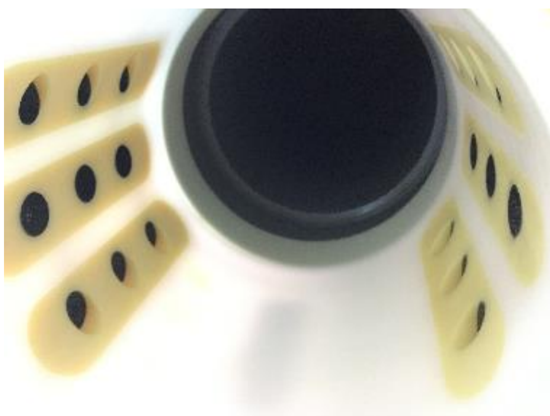


Verification test at straight pipe

- Pipe diameter 160 mm
- Flow rate：0.03~0.18m³/s Re: 20,000~85,000

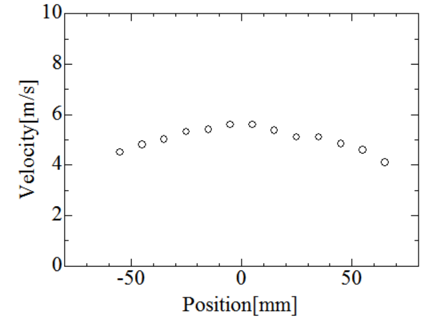


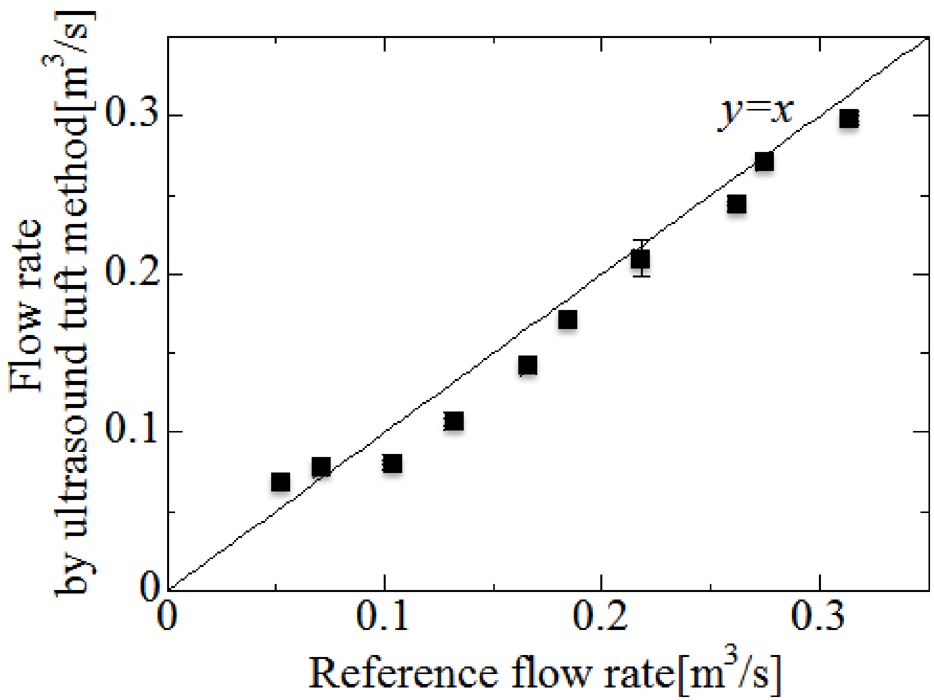
Parallel beam alignment



Test section

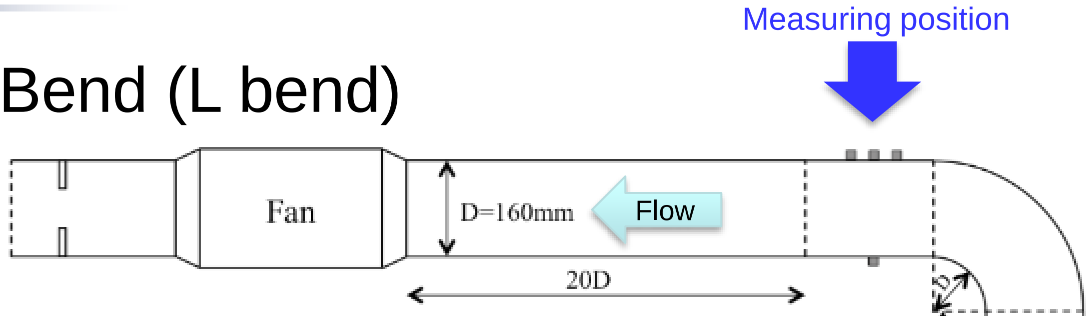
Test for Axisymmetric flow

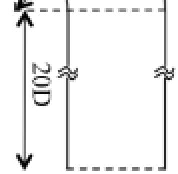


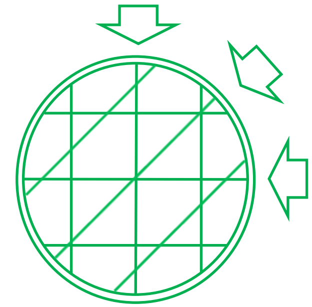


Schematics of pipes

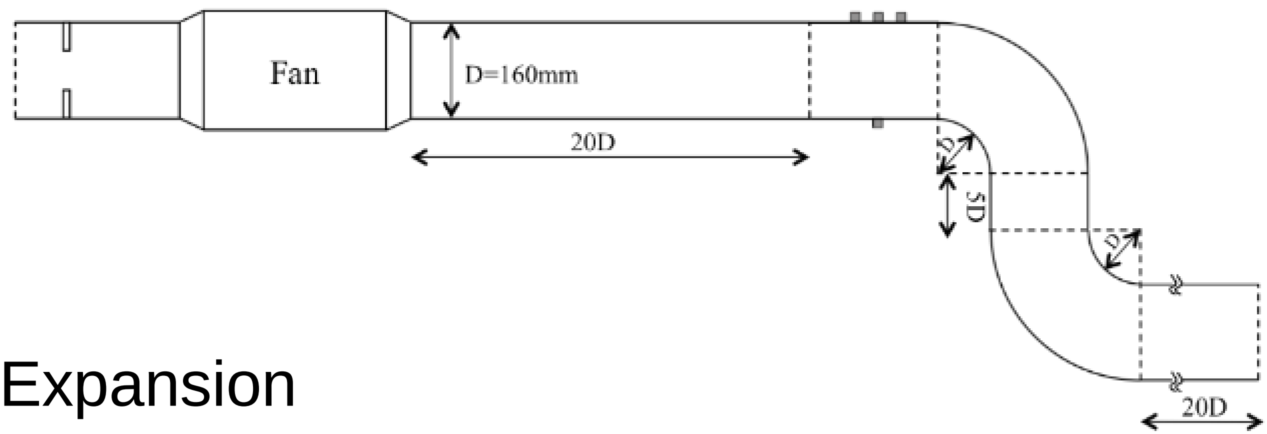
- Bend (L bend)



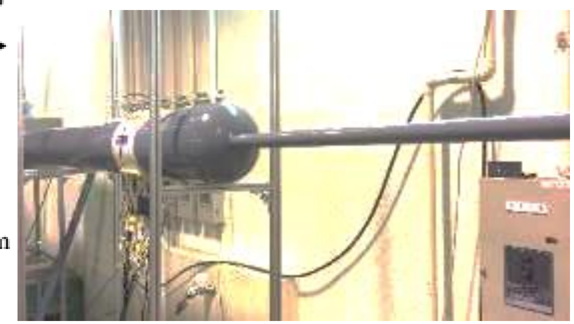


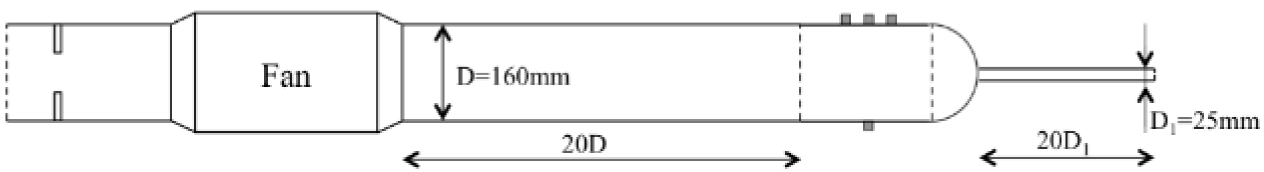


- Double bend (Z bend)



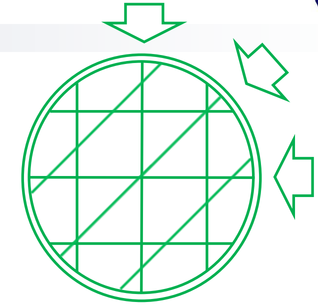
- Expansion



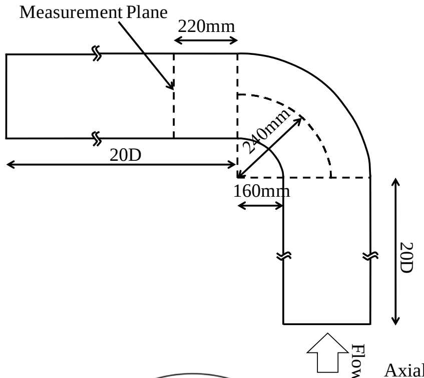


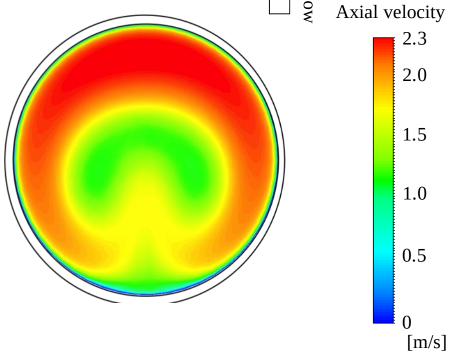
CDF prediction of axial velocity distribution

- Software : ANSYS Fluent, *k–ε* model
- Inlet B.C: const. *U* = 4.9 m/s
- Outlet B.C.: const. *P*



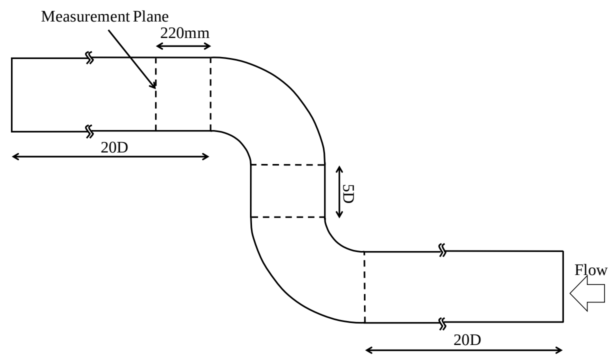
Bend

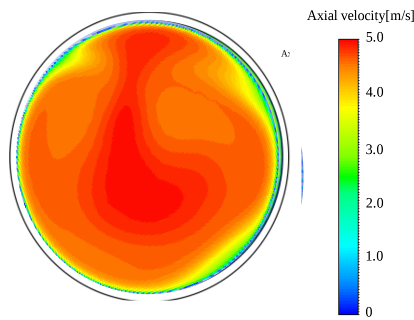




Symmetric, but Non-axisymmetric

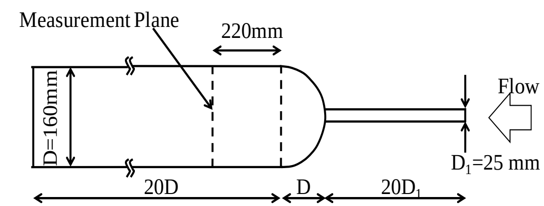
Double bends

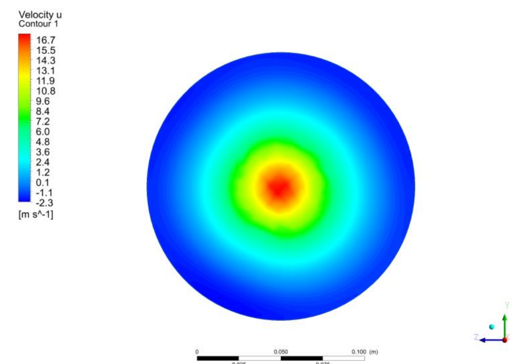




Fully distorted

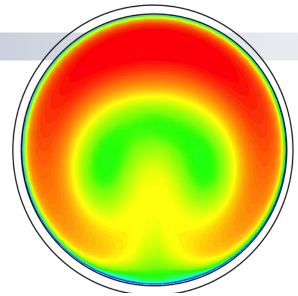
Expansion

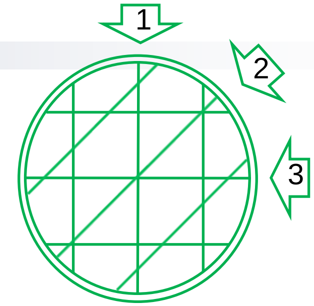




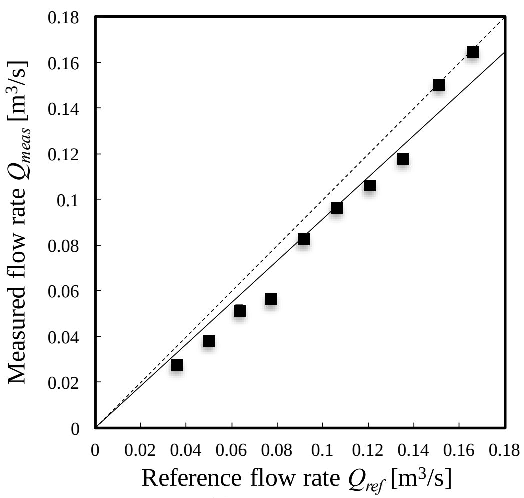
Inverse flow

Flow rate(Single bend)



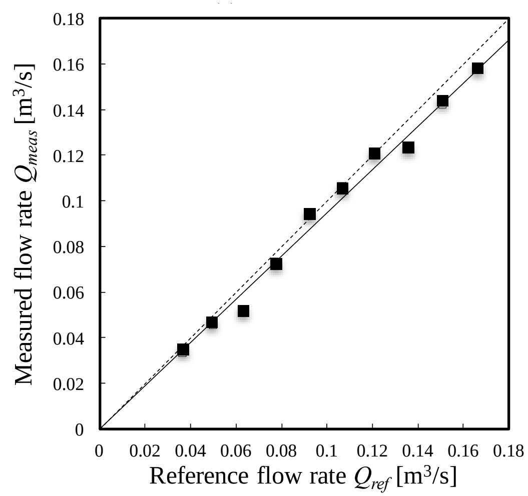


Direction 1



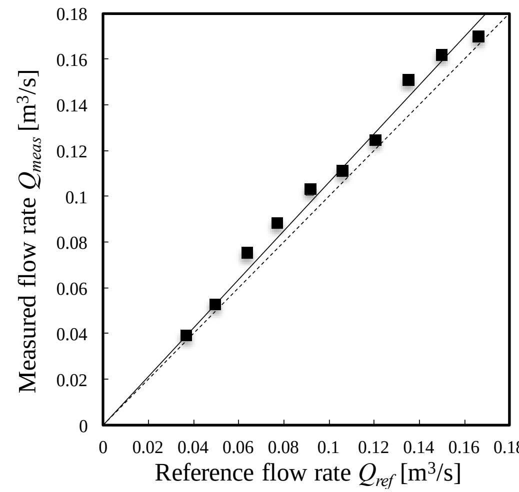
slope : 0.91
stdev : 0.00812
max error : 16%

Direction 2



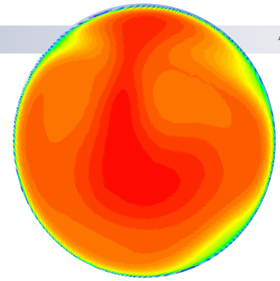
slope : 0.95
stdev : 0.00451
max error : -13%

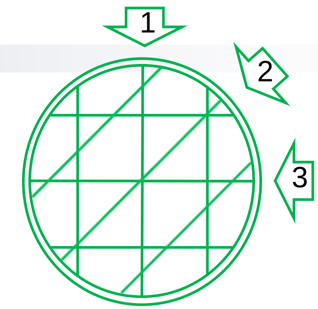
Direction 3



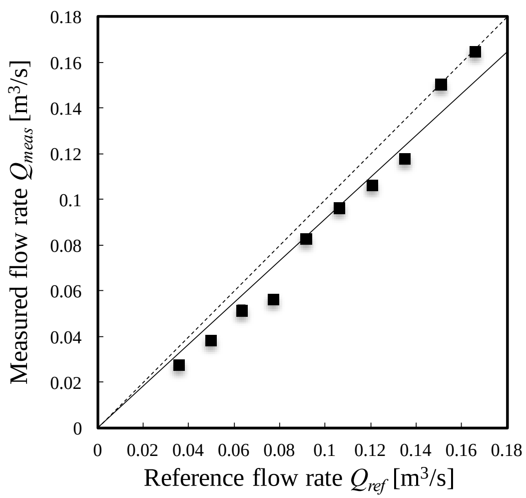
slope : 1.06
stdev : 0.00475
max error : 11%

Flow rate (Double bend)

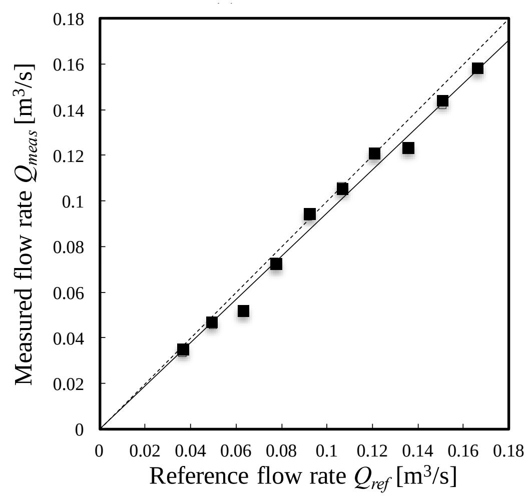




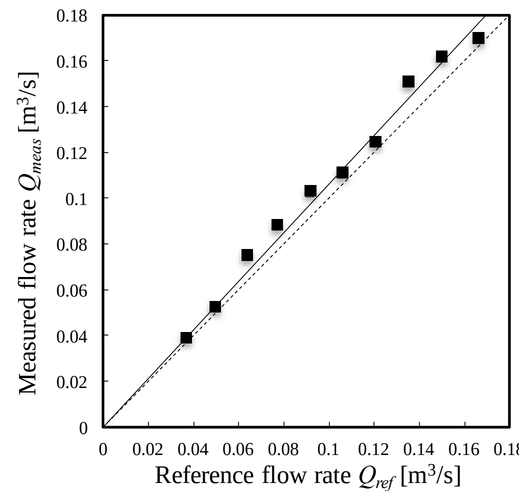
Direction 1



Direction 2



Direction 3

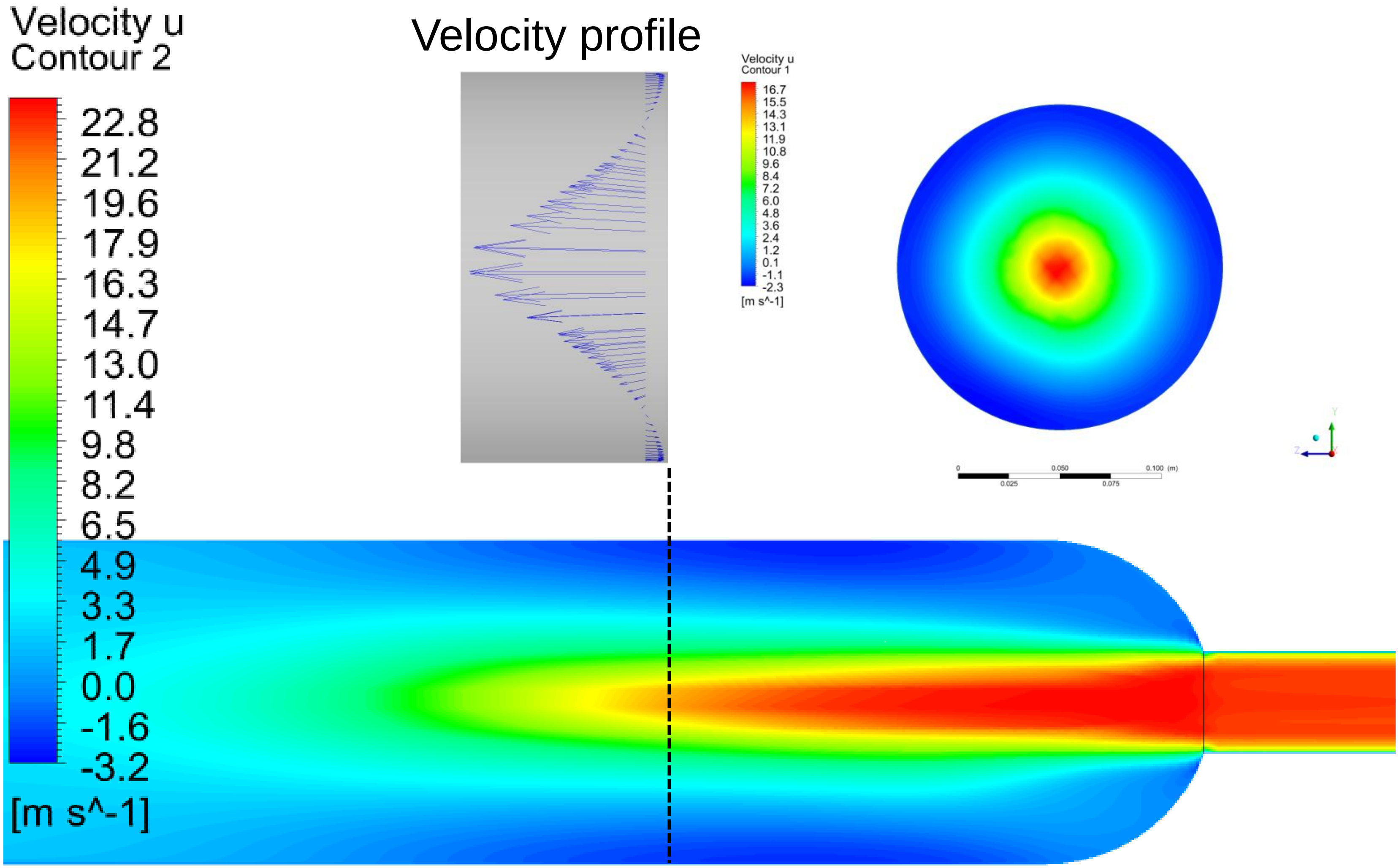


slope : 1.058
stdev : 0.00810
max error : 12%

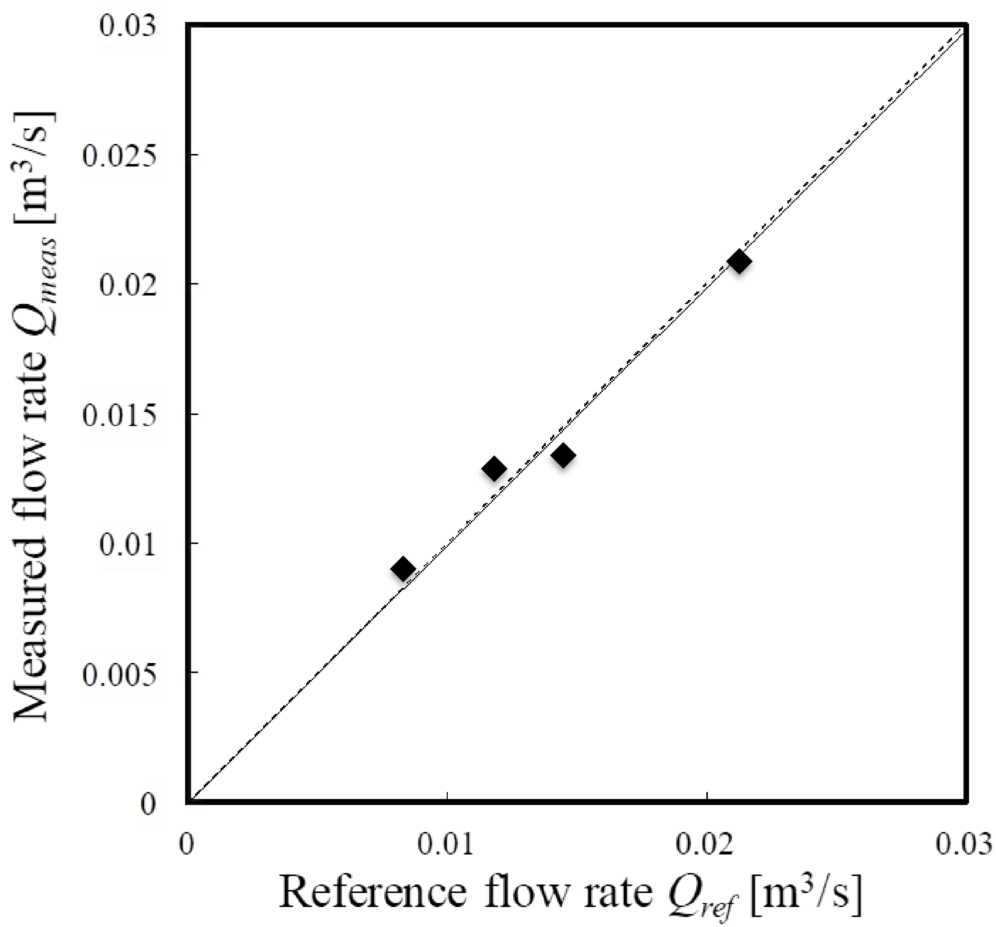
slope : 1.05
stdev : 0.0103
max. error : 19%

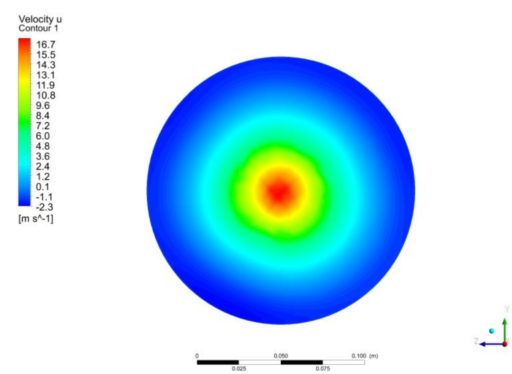
slope : 0.95
stdev : 0.0719
max. error : -12%

Expansion section(CFD)



Flow rate (Expansion)





特　許　証

(CERTIFICATE OF PATENT)

特許第６３２１３１６号

(PATENT NUMBER)

発明の名称 (TITLE OF THE INVENTION)	超音波流量測定装置及び超音波流量測定方法
特許権者 (PATENTEE)	東京都練馬区西大泉一丁目３２番１３号 有限会社フロウビズ・リサーチ
発明者 (INVENTOR)	武田　靖
出願番号 (APPLICATION NUMBER)	特願２０１８－５０６６４４
出願日 (FILING DATE)	平成２９年１１月１４日(November 14, 2017)
登録日 (REGISTRATION DATE)	平成３０年　４月１３日(April 13, 2018)

この発明は、特許するものと確定し、特許原簿に登録されたことを証する。
(THIS IS TO CERTIFY THAT THE PATENT IS REGISTERED ON THE REGISTER OF THE JAPAN PATENT OFFICE.)

平成３０年　４月１３日(April 13, 2018)

特許庁長官
(COMMISSIONER, JAPAN PATENT OFFICE)

宗像直子

US011280648B2

(12) **United States Patent**
Takeda

(10) **Patent No.:** **US 11,280,648 B2**
(45) **Date of Patent:** **Mar. 22, 2022**

(54) **ULTRASONIC FLOW-RATE MEASUREMENT DEVICE AND ULTRASONIC FLOW-RATE MEASUREMENT METHOD**

(71) Applicant: **Flowbiz Research INC.**, Tokyo (JP)

(72) Inventor: **Yasushi Takeda**, Sendai (JP)

(73) Assignee: **FLOWBIZ RESEARCH INC.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 20 days.

(21) Appl. No.: **16/763,898**

(22) PCT Filed: **Nov. 14, 2017**

(86) PCT No.: **PCT/JP2017/040918**
§ 371 (c)(1),
(2) Date: **May 13, 2020**

(87) PCT Pub. No.: **WO2019/097570**
PCT Pub. Date: **May 23, 2019**

(65) **Prior Publication Data**
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(51) **Int. Cl.**
G01F 1/66 (2006.01)
G01F 1/663 (2022.01)

(52) **U.S. Cl.**
CPC *G01F 1/663* (2013.01)

(58) **Field of Classification Search**
CPC G01F 1/663
(Continued)

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Primary Examiner — Nathaniel T Woodward
(74) *Attorney, Agent, or Firm* — Rabin & Berdo, P.C.

(57) **ABSTRACT**

An ultrasonic flow-rate measurement device and an ultrasonic flow-rate measurement method capable of accurately measuring a flow rate of a fluid to be measured with a simple configuration are obtained. A reference-sound-pressure distribution waveform holding unit **(60)** holds a reference sound pressure distribution waveform based on an ultrasonic pulse emitted from a transmitter **(10)** and incident on at least three receivers **(20)** in a state where a flow velocity of a fluid (G) to be measured in the pipe **(5)** is zero. A variable-sound-pressure distribution waveform acquisition unit **(70)** acquires a variable sound pressure distribution waveform based on the ultrasonic pulse emitted from the transmitter **(10)** and incident on the at least three receivers **(20)** in a state where the flow velocity of the fluid (G) to be measured in the pipe **(5)** is not zero. A flow-rate calculation unit **(80)** obtains a shift amount (S), which is a difference between the reference sound pressure distribution waveform and the variable sound pressure distribution waveform, and integrates the shift amount (S), thereby calculating a flow rate of the fluid (G) to be measured in the pipe **(5)**.

3 Claims, 9 Drawing Sheets

$\dot{Q}$**flow** : Ultrasonic Transient Gas Flow Meter

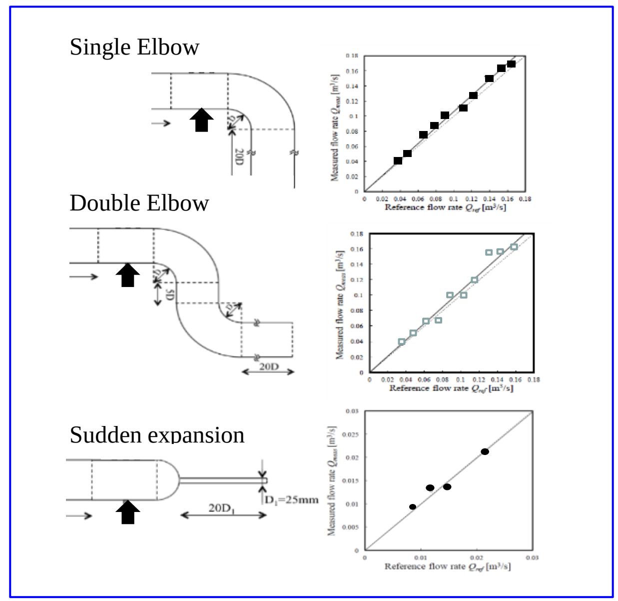
We have successfully confirmed a new principle of gas flow metering having high precision by knowing a behavior of ultrasonic pulse in flowing gas (pipe flow). Tested configuration is a ∅160 pipe and the installation of the meter is possible at various locations after bent or expansion, where conventional flow meter cannot be applied. Moreover, sampling speed as well as time resolution is as high as 10Hz and transient flow measurement has become feasible. We plan to adapt a Clamp-on technology so that the meter might be applied to wider variety of measurement point.

Advantages

- ■ Flow rate by integrating velocity distribution
  - ● No developed flow is conditioned.
  - ● Short entry length at upstream.
  - ● High precision is attained independent of flow regime.
- ■ Asymmetric flow is overcome.
  - ● Highly angular-dependent flow.
  - ● Complexed geometrical channel flow.
- ■ Fast response
  - ● Transient flow is measured.
  - ● Synchronized with external equipment.

Gas flow configurations or cases expected

- ◆ Exhaust gas from combustion engines
- ◆ Exhaust gas of automobiles
- ◆ Fuel gas pipe line
- ◆ Exhaust of factory chimney
- ◆ Intake and out-fumes of heating facility
- ◆ Equipment using expensive gas



Next step :
Prototype unit will be made for a target configuration.

We seek for collaboration organizations or companies.
Please contact us.

This method uses a granted patent and additional patent has been filed.

Contact:
FlowBiz Research Inc.
Mail : kt@flowbiz.jp