A New Gravimetric Primary Standard for Natural Gas Flow Measurement at KOGAS

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Contents

- Background
- Aim
- Description of the standard facility
  - Design and operation
  - Model of measurement
  - Effects of an overlap diverter
- Inter-laboratory comparison results
- Conclusion

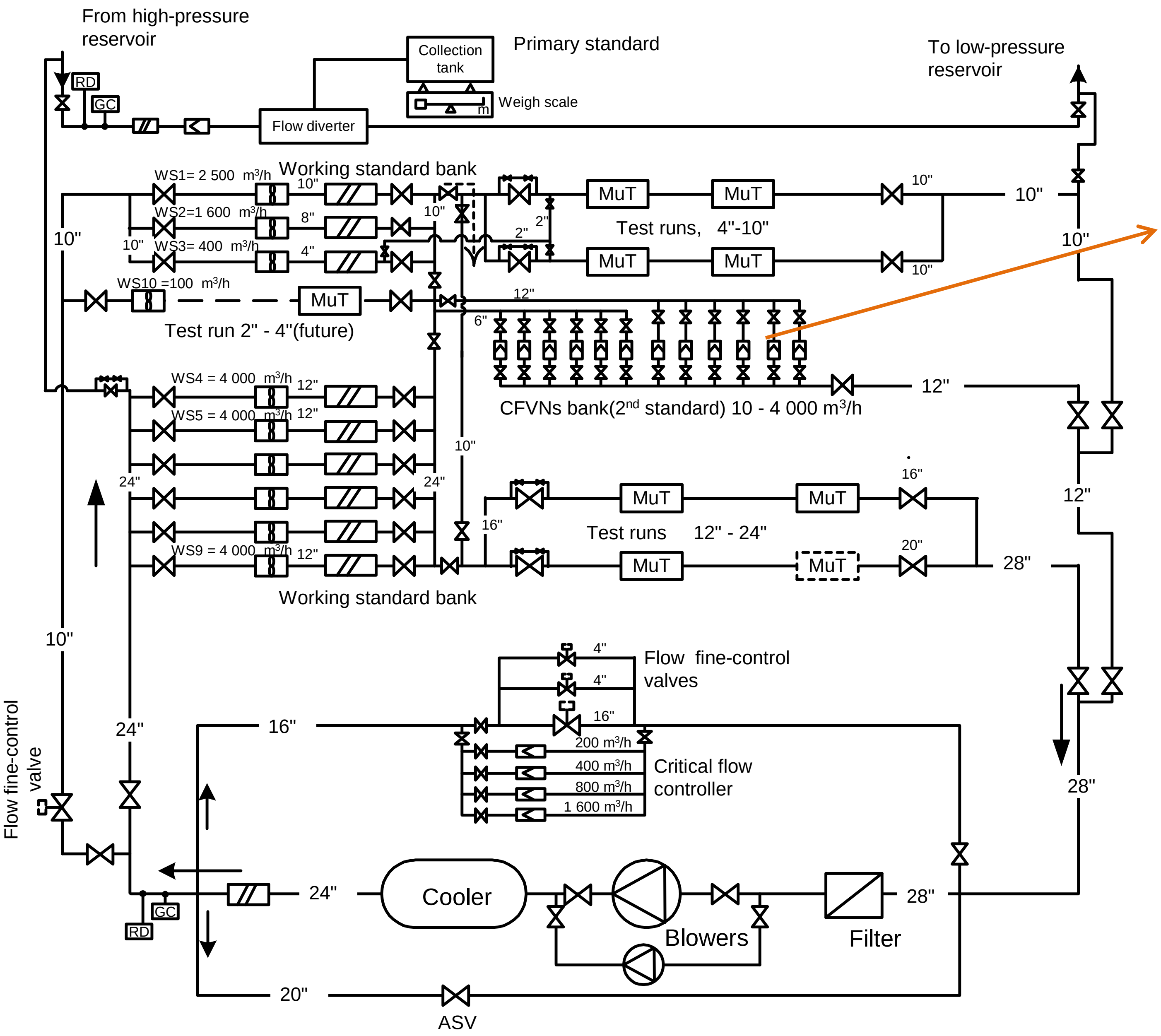
Background

- A new static gravimetric primary standard facility, which was constructed at Incheon LNG terminal of Korea Gas Corporation (KOGAS) in 2017, is currently operated at pressures up to 5 MPa

- KOGAS HP calibration facility (closed loop type) :

  20 – 24 000 m^3/h at 1 – 5 MPa (Medium: Regasified LNG, N_2)

KOGAS HP Calibration Facility (closed loop type)



2nd Standard

CFVN-bank

10 – 4000 m³/h

KOGAS HP Calibration Facility (KFCC)

- Number test runs : 4 (4 - 24 inch)
- Max. length of test runs: 40 m

HP Calibration Lab

Blower: 2.0 MW

Background

- A new static gravimetric primary standard facility, which was constructed at Incheon LNG terminal of Korea Gas Corporation (KOGAS), is currently operated at pressures up to 5 MPa
- KOGAS HP calibration facility (closed loop type) :

  20 – 24 000 m³/h at 1 – 5 MPa (Medium: Regasified LNG, N_2)

- KRISS (Korea NMI) already has the primary air-flow standard:

  The max. pressure is 4 MPa, which is **3 MPa** in terms of Reynolds number under choked flow conditions.

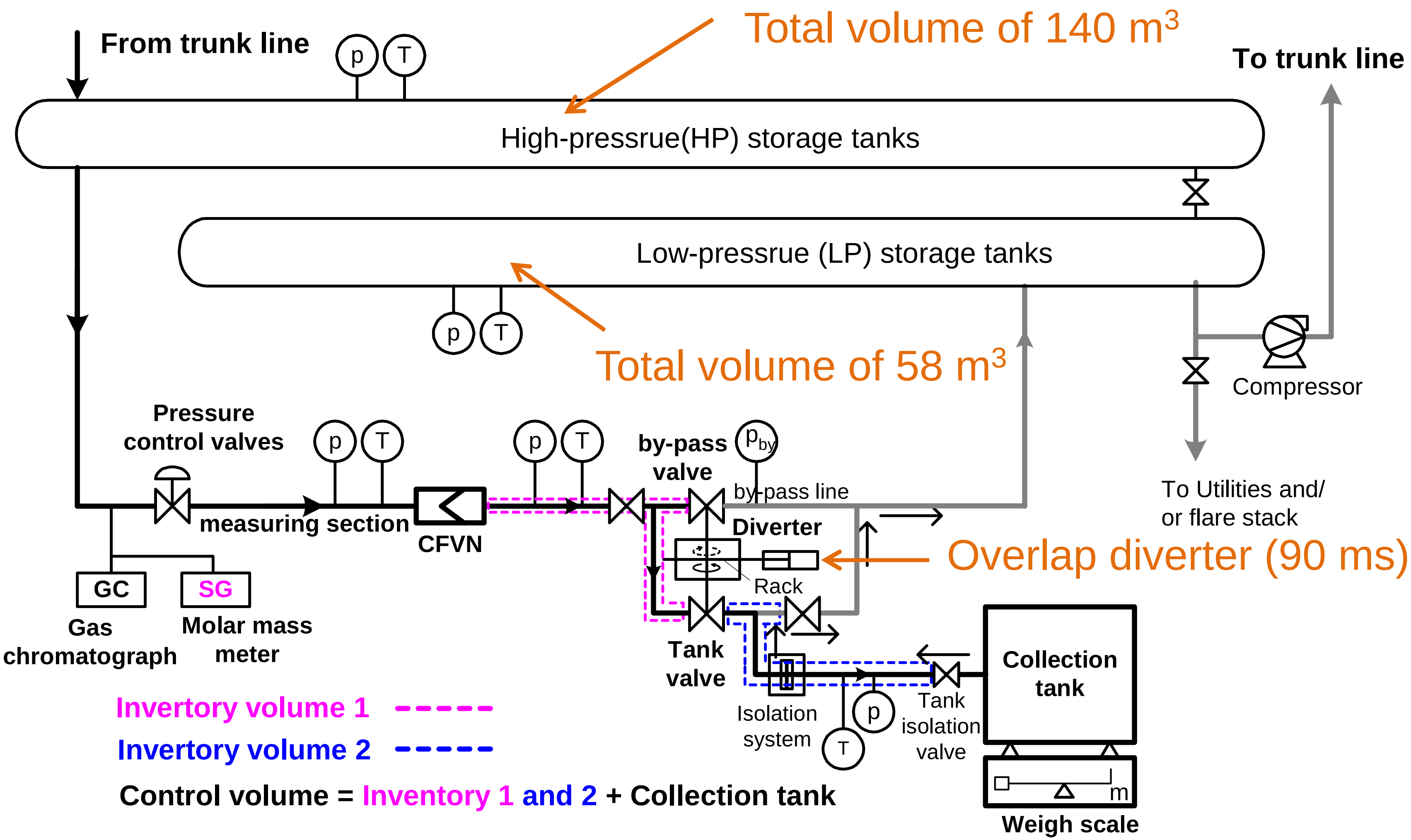
- For this reason, KOGAS has built a new NG-flow primary standard.

Aim

- To prove the accuracy of the new gravimetric primary standard facility at KOGAS.
- To achieve this aim:
  1) the effects of **an overlap diverter**, especially **for the systematic error** were estimated for this facility;
  2) an **inter-laboratory comparison between KOGAS and KRISS** was performed using 5 CFVNs in 2018.

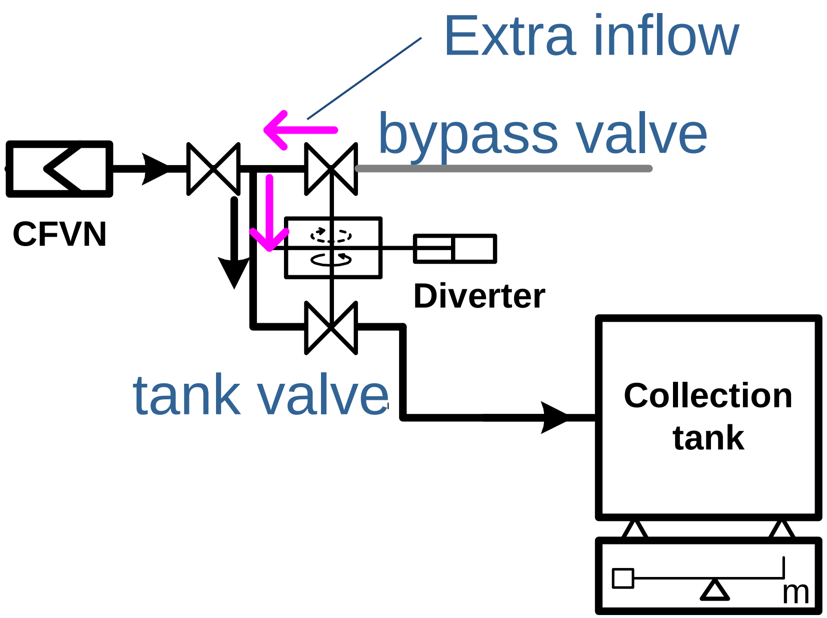
KOGAS

Schematic of the standard facility

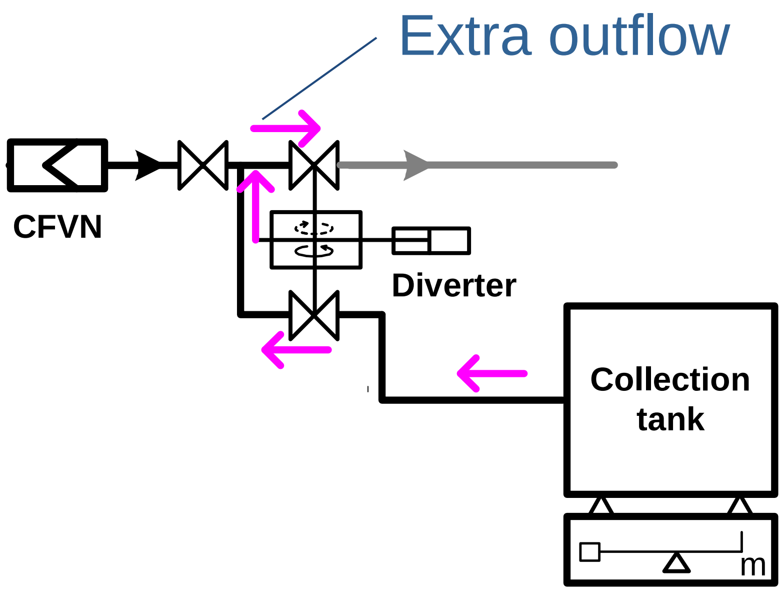


Effects of overlap diverter

- With an overlap flow diverter, **non-negligible lost mass and/or extra mass** can occur during diversions if the diverter operating time is not very short.



Initial diversion



Final diversion

Model of measurement

$$\overline{q_{m,cfvn}} = \frac{1}{t}\left[m + V_{inv1}\left(\rho_{inv2,2} - \rho_{inv1,1}\right) + V_{inv2}\left(\rho_{inv2,2} - \rho_{inv2,1}\right)\right] + C_{buoy}$$

$$+ \frac{1}{t} C_s\, p_{by,1} \sqrt{1 - \left(\frac{p_{tk,1}}{p_{by,1}}\right)^2}\, \Delta t_{div,1}$$

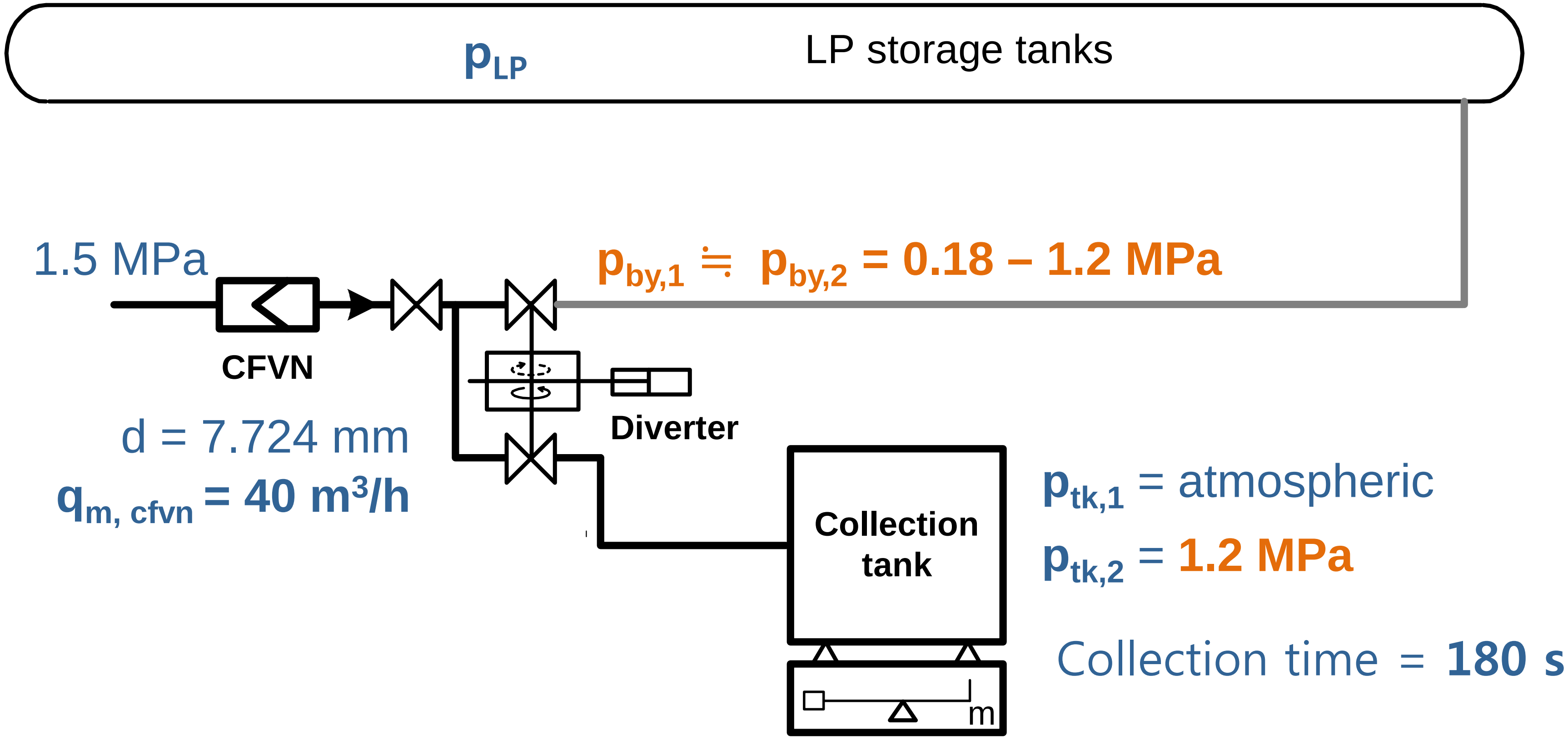
Extra inflow

$$- \frac{1}{t} C_e C\, q_{m,cfvn} \cdot (t + t_{atm}) \sqrt{1 - \left(\frac{p_{\mathrm{by},2}}{C\, q_{m,cfvn} \cdot (t + t_{atm})}\right)^2}\, \Delta t_{div,2}$$

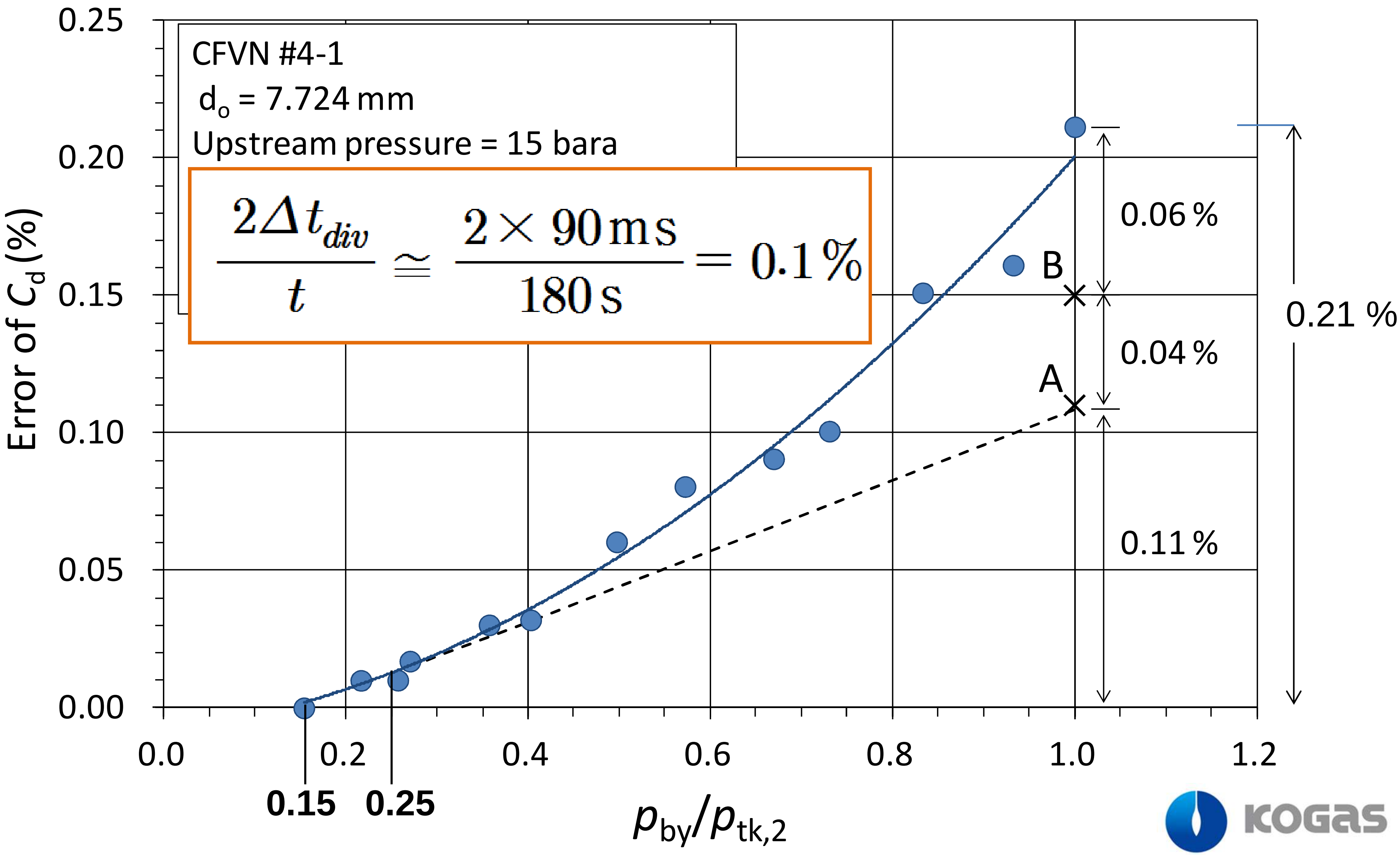
Extra outflow

Test method for evaluating the extra outflow

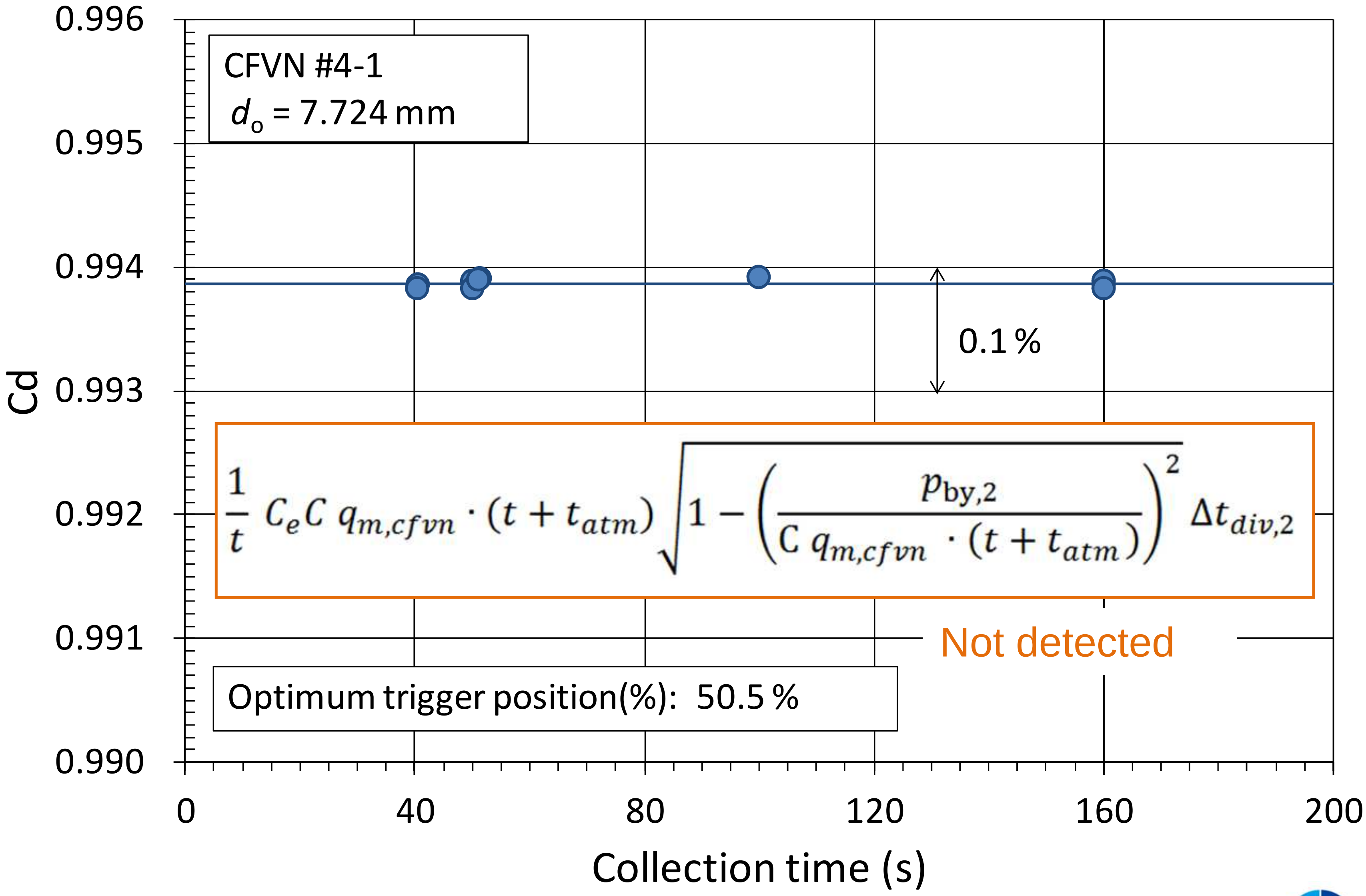
- In order to evaluate the effects of the overlap diverter somewhat quantitatively, especially **for the amount of the extra outflow** (i.e., bias), a test was performed.



Test result: effects of overlap diverter



C_d values at an optimal trigger point



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Uncertainty contribution

Uncertainty category	Uncertainty (k =1)	
	Root-sum-squared term	Add term
Weigh scale readout	0.010 %	
Weigh scale calibration	0.008 %	
Timing of diverter - optimal trigger point - overlap diverter	0.007 %	0.015 %
Stability of optical sensor of timer system (background noise effect)	0.014 %	
Gas pressure	0.021 %	
Gas temperature	0.018 %	
Total effects from gas composition	0.013 %	
Critical flow function	0.024 %	
Mass of inventory	0.005 %	
Repeatability	0.010 %	
Gas leakage	0.010 %	
Combined standard uncertainty	0.061 %	
Extended uncertainty (k = 2)	0.12 %	

0.014 % (k=2)

0.03 % (k=2)

The inter-laboratory comparison

- In 2018, an inter-laboratory comparison between KOGAS and KRISS was carried out using 5 toroidal-throat CFVNs.

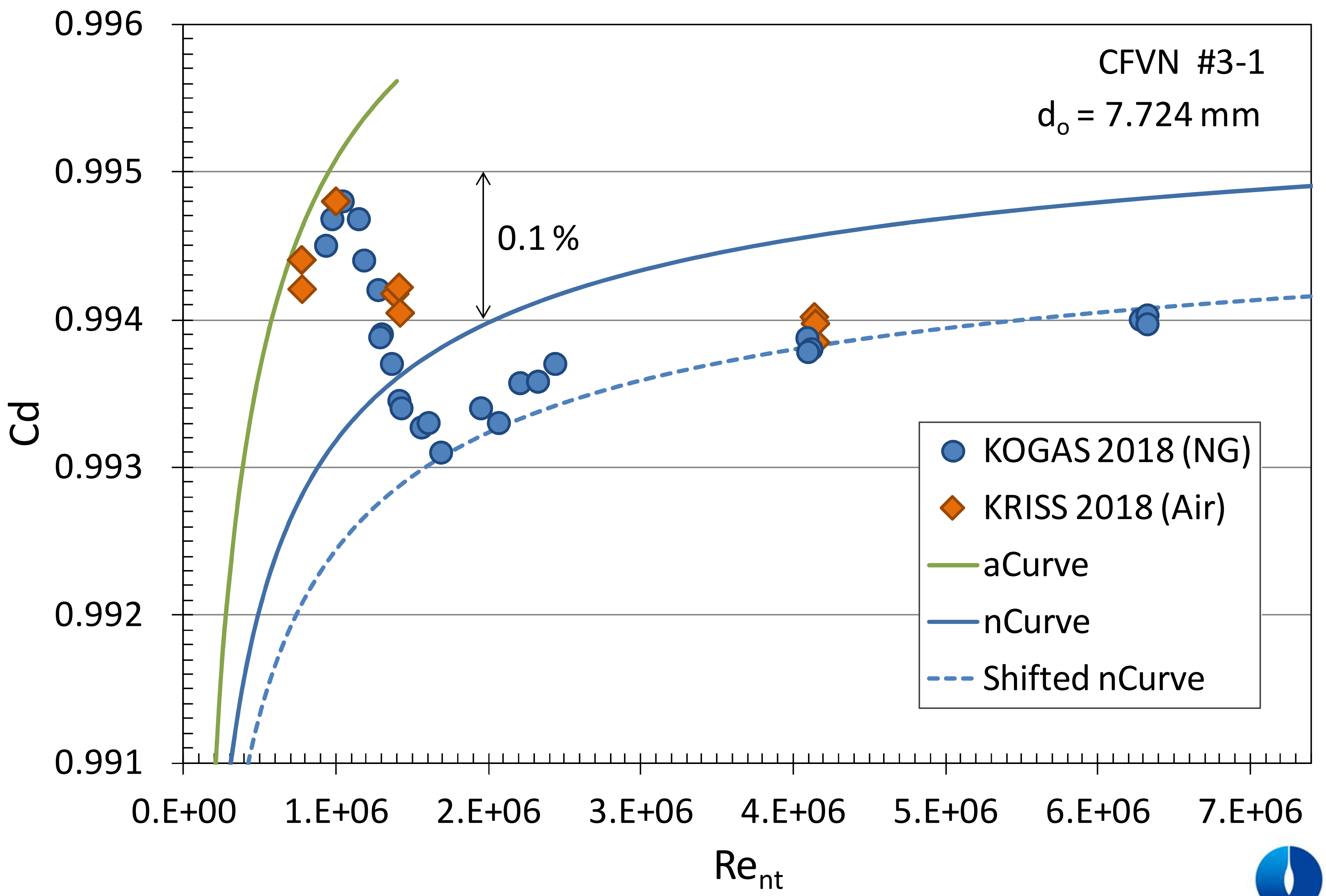
- The goal of the comparison was to prove the equivalence of the primary standards of KRISS and KOGAS using pressurized air (KRISS) and NG (KOGAS) at pressures of 0.9 MPa (≒ 1 MPa) and 3 MPa.

The calibration pressures of KOGAS's CFVNs: 1, 3, 5 MPa

- Maximum pressure of the KOGAS primary NG-flow standard is 5 MPa, but the upper pressure was limited to 3 MPa.

  Max. press. of the KRISS air-flow standard is 4 MPa (≒ **3 MPa** in terms of Re under choked flow conditions).

The inter-laboratory comparison results (1)



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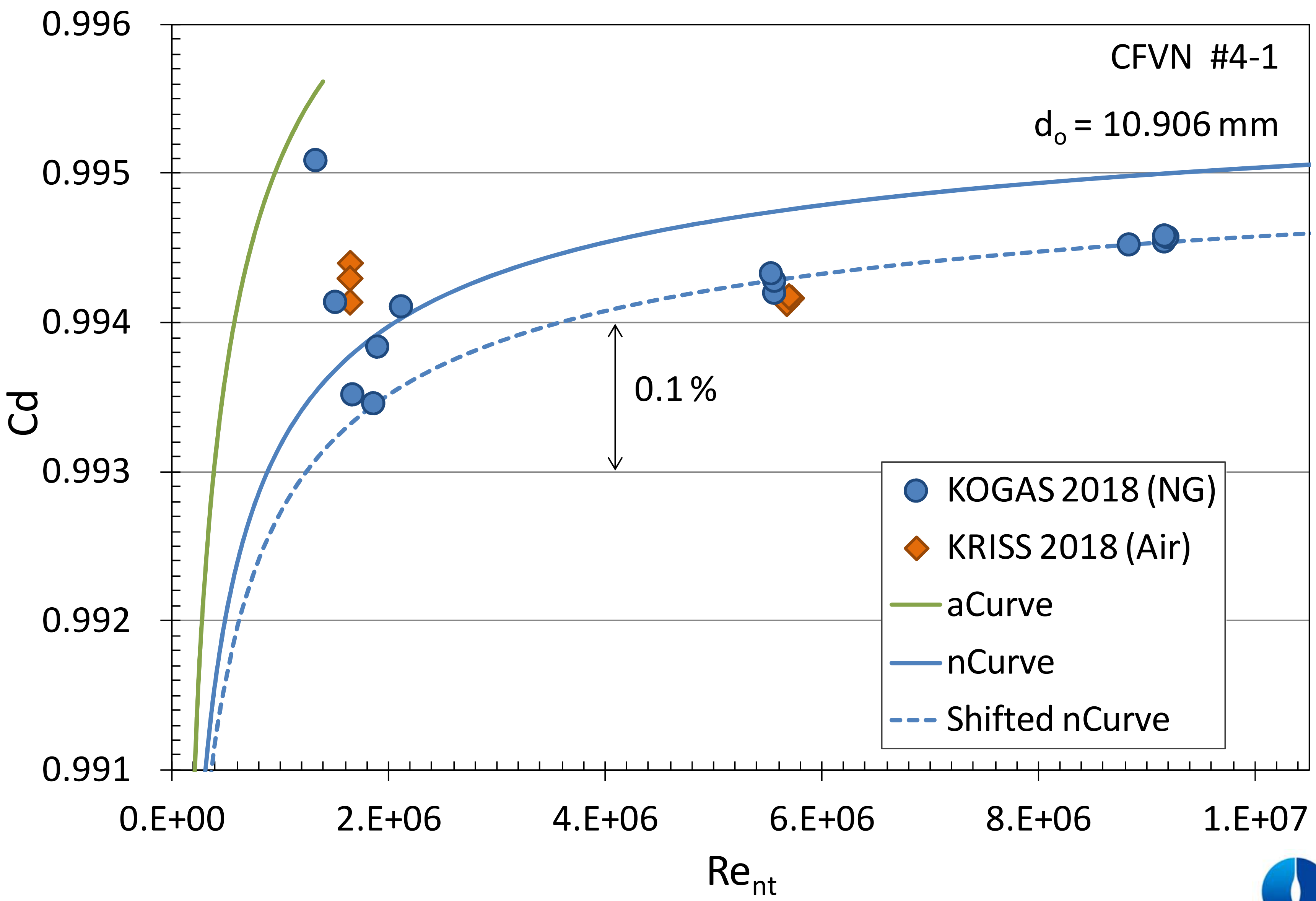
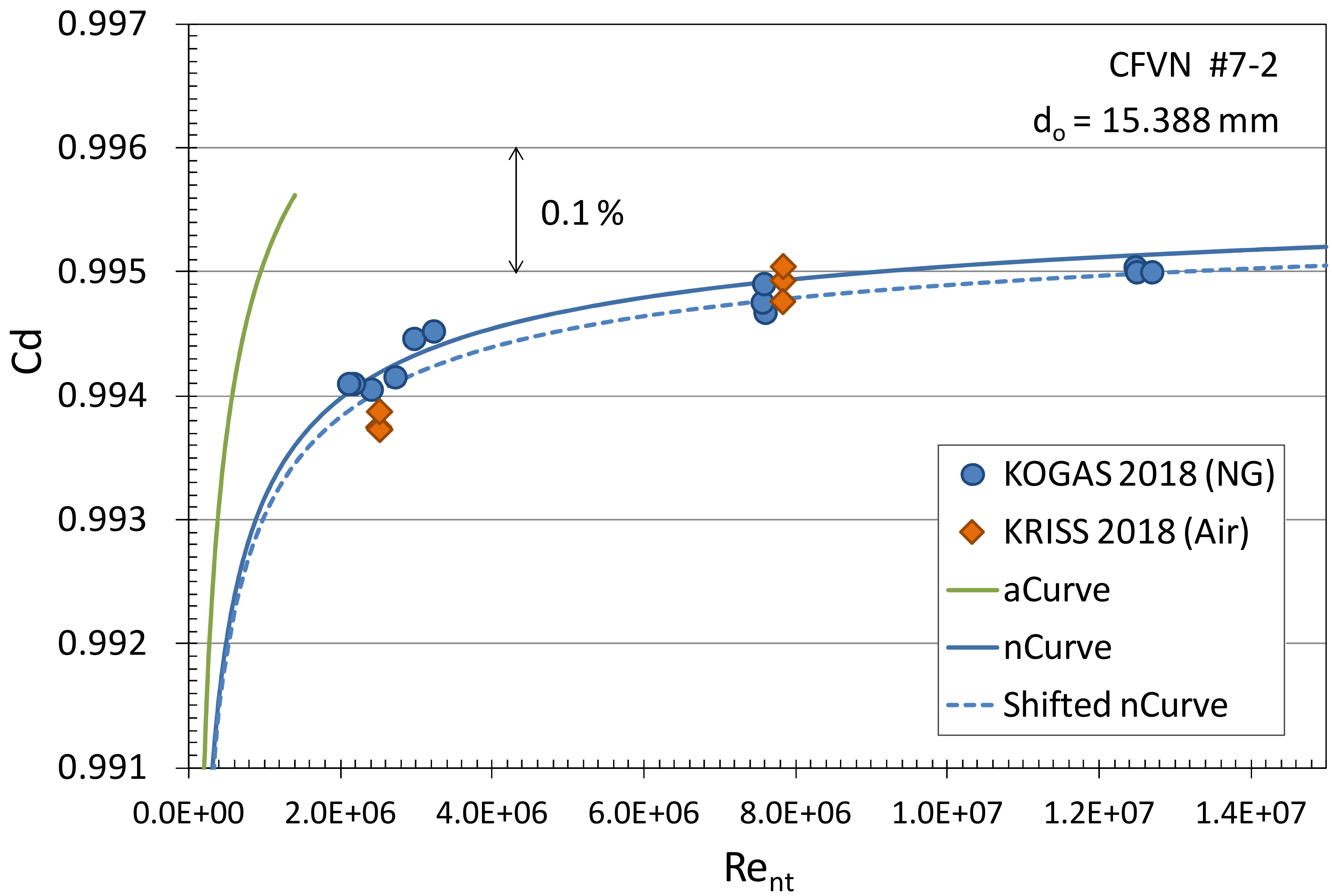
The inter-laboratory comparison results (2)



The inter-laboratory comparison results (3)



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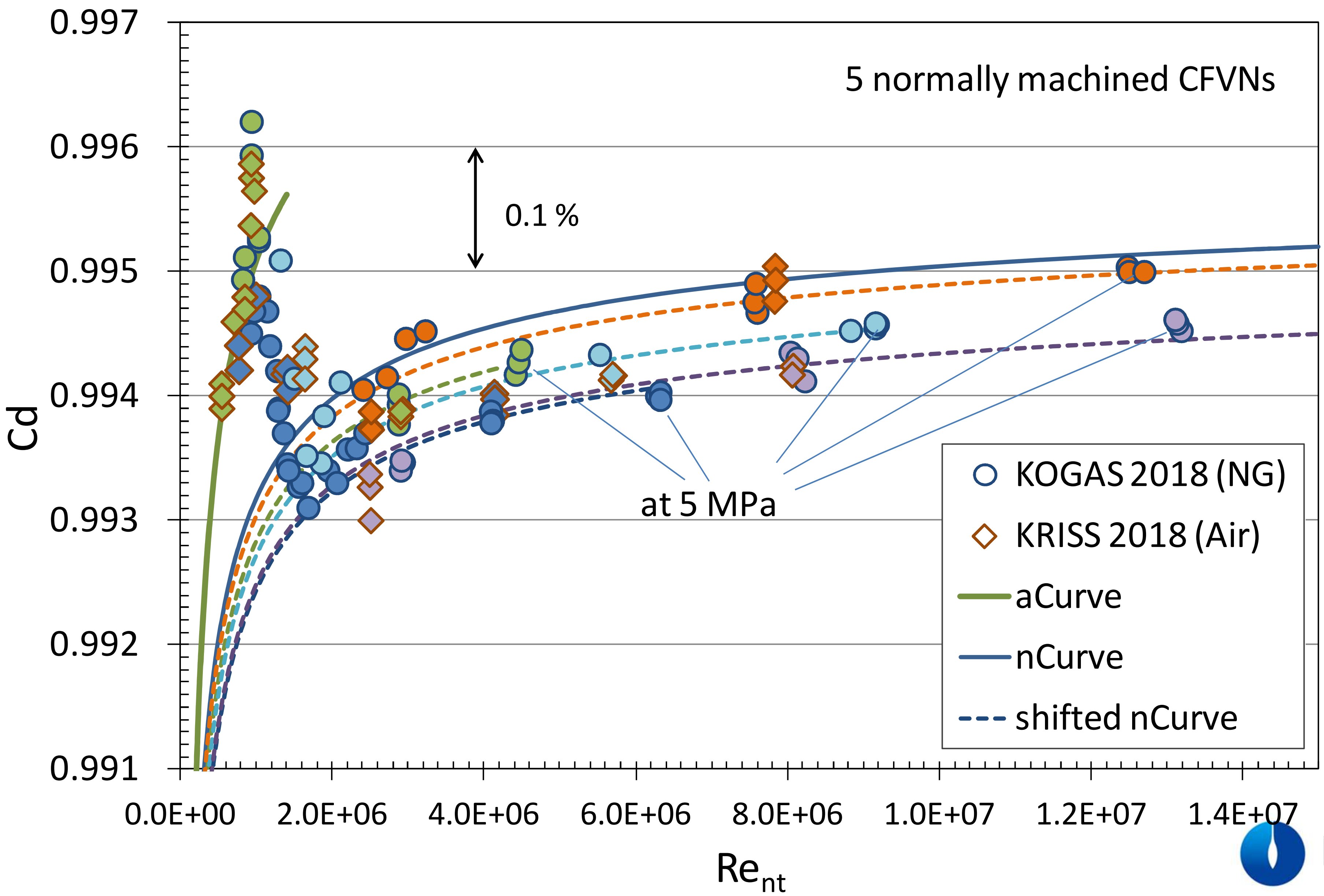
The inter-laboratory comparison results (4)



The inter-laboratory comparison results (5)

- The degrees of equivalence between KOGAS and KRISS at pressures of 1 MPa and 3 MPa evaluated to be within ±0.23 and ±0.14, respectively.

$$E_{N,KOGAS,KRISS} = \frac{C_{d,KOGAS} - C_{d,KRISS}}{\sqrt{U_{CMC,KOGAS}^2 + U_{CMC,KRISS}^2}}$$

$U_{CMC,\ KOGAS}$ (k =2) : 0.12 %

$U_{CMC,\ KRISS}$ (k =2) : 0.18 % (actual CMC 0.11 % for d ≤ 16 mm)

Conclusion

- To prove the accuracy of the new gravimetric primary standard facility at KOGAS, the systematic error, which occurred due to an overlap diverter and has not yet been identified, was estimated for this facility, and an inter-laboratory comparison between KOGAS and KRISS was performed in 2018.
- The systematic error due to the overlap diverter was of this standard system was estimated to be about 0.06 %;
- the degrees of equivalence between KOGAS and KRISS at pressures of 1 MPa and 3 MPa evaluated to be within 0.23 and 0.14, respectively.
- This primary standard is now used to calibrate the secondary standards of KOGAS HP calibration facility and is expected to become the national standard in the near future for HP gas flow that KRISS can not cover.

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That’s it !

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