Uncertainty Analysis of Stack Gas Flowrate Measurement with the S-Type Pitot Tube for Estimating Greenhouse Gases Emission

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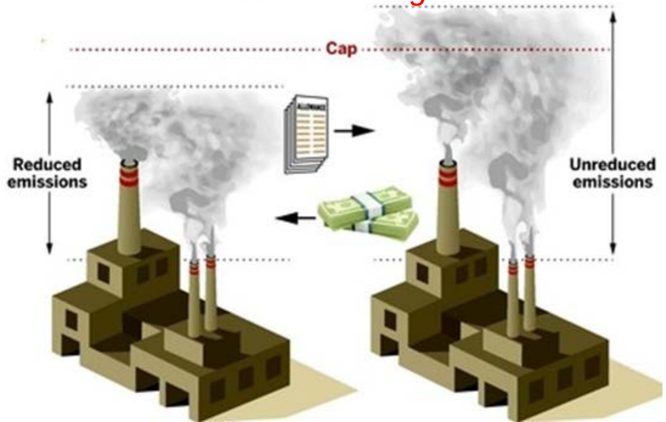
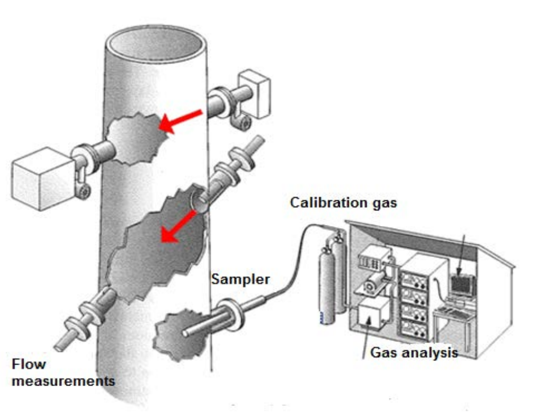
Korea Greenhouse Gas Emission

- Top 10 countries of GHG Emissions in 2010, High proportion of GHGs emissions arising from the energy and industrial fields
- Korea Emission Trading Scheme have been implemented with allocation of emission cap for each company in 2015
- Continuous Emission Monitoring System(CEMS) measure GHG emissions by monitoring concentrations and volumetric flow rate at exhaust stack gas with higher quality tier
- First necessary to carry out accurate and reliable GHGs emission estimate with proper uncertainties

Korea Emission Trading Scheme



Continuous Emission Monitoring



On-site measurement for CEMS

CEMS

$$\underbrace{E_{CEM}}_{\text{GHGs Emission}} = \sum_{i=1}^{N} E_{5\min,i} = \sum_{i=1}^{N} \Big(\underbrace{\bar{C}_i}_{\text{Concentration}} \times Q_{5\min,i} \times \frac{MW_{gas}}{22.4L} \Big)$$

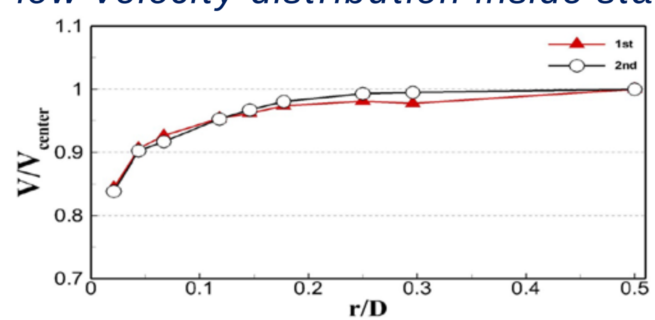
Flow Rate

$$\underbrace{Q}_{\text{Volumetric Flow rate}} = \underbrace{V}_{\text{Velocity}} \times \underbrace{A}_{\text{Area}} \times \frac{T_{std}}{T_s} \times \frac{P_s}{P_{std}} \times (1 - \underbrace{X_w}_{\text{Water Content}}) \times 300$$

Combined Heat and Power Plant, KOREA

S-type Pitot installation at the stack

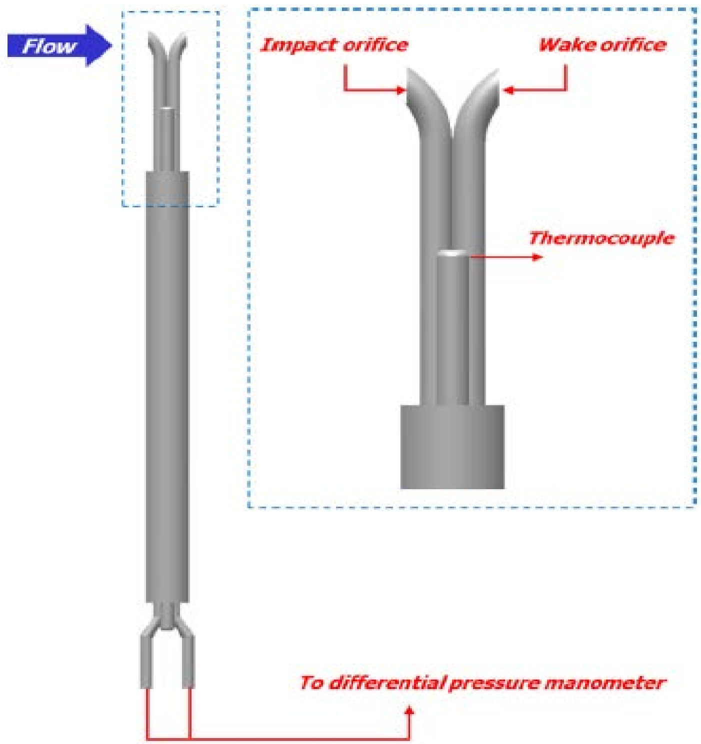
Flow velocity distribution inside stack

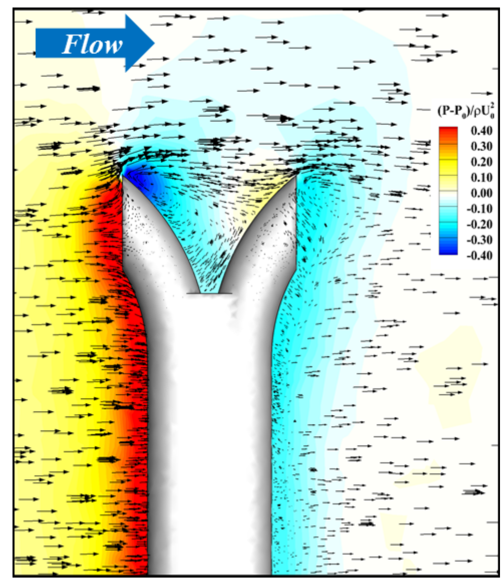


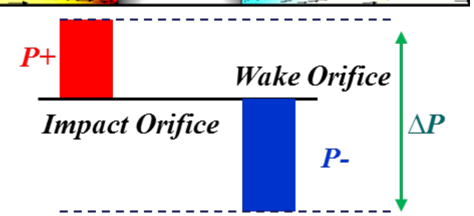
KRISS

S-Type Pitot tube

- S-type Pitot tube is mainly used in on-site measurements for GHGs in Korea emission (S-type Pitot :56%, Thermal Flowmeter:23%, Ultrasonic : 11%)
- Large pressure orifices(Φ=5~10mm) & Strong tubes for high dust environments like industry stack (ISO 10780, KS M9429, EPA method2)
- Measurement differential pressure between an impact(total pressure) and wake orifice(static pressure) based on Bernoulli equation







$$V = C_{P,S}\sqrt{\frac{2\Delta P}{\rho}}$$

V : flow velocity in the stack gas(m/s)
ΔP : differential pressure (Pa)
ρ : density of the stack gas (kg/m^3)
$C_{P,S}$: S type Pitot tube coefficient

Uncertainty Evaluation

$$\frac{u_c^2(Q)}{Q} = \frac{u^2(C_p)}{C_P^2} + \frac{1}{4}\frac{u^2(\Delta P)}{\Delta P^2} + \frac{1}{4}\frac{u^2(\rho)}{\rho^2} + 4\frac{u^2(D)}{D^2} + \frac{u^2(P_s)}{P_s^2} + \frac{u^2(T_s)}{T_s^2} + \frac{u^2(1-X_w)}{(1-X_w)^2}$$

Symbol	Value	unit	Uncertainty component		Sensitivity coefficient	Combined uncertainty contribution
			Type A %	Type B %		
C_p	0.826	-	-	0.55	1	0.55 %
ΔP	136.4	Pa	0.80	1.09	0.5	0.68 %
ρ	1.33	kg/m^3	0.0054	1.05	0.5	0.53 %
D	2500	mm	-	0.23	2	0.46 %
P_s	756	mmHg	0.0019	0.13	1	0.13 %
T_s	409	K	0.0046	0.24	1	0.25 %
$1\text{-}X_w$	91.5	%	0.0016	0.30	1	0.30 %
ΔV_D	14.8	m/s	1.54	-	1	1.54 %
Q	12972.5	m^3/min (5min)				
Combined uncertainty of the flow rate measurement						1.94 %
95 % confidence level, k=						2
Expanded Uncertainty, U =						3.88 %

- Uncertainty analysis of stack flow rate measurements with traceability to NMI
- Research for accurate average velocity measurements in the stack by used instruments (S-type Pitot tube, Ultrasonic meter, Thermal flowmeter)