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Leading Innovation >>>

Effect of number concentration of aerosol in flue gas upstream of the absorber on mist based emissions from a PCC plant

TOSHIBA Corporation

Koshito Fujita, Yasuhiro Kato, Tetsuya Kaseda, Satoshi Saito, Hideo Kitamura, Mitsuru Udatsu, Daigo Muraoka, Yusuke Handa

Birmingham, Alabama, 7th Sept. 2017

Outline

- **Background of the Project**
- **Experimental**
- **Results and Discussions**
  - Investigate the ratio of mist based amine emissions
  - What substances affect on mist based amine emissions

    CO_2, aerosol, and SO_3
- **Researching countermeasures against mist**
- **Schedule of CO_2 Capture Demonstration Plant (>500t/d)**
- **Summary**

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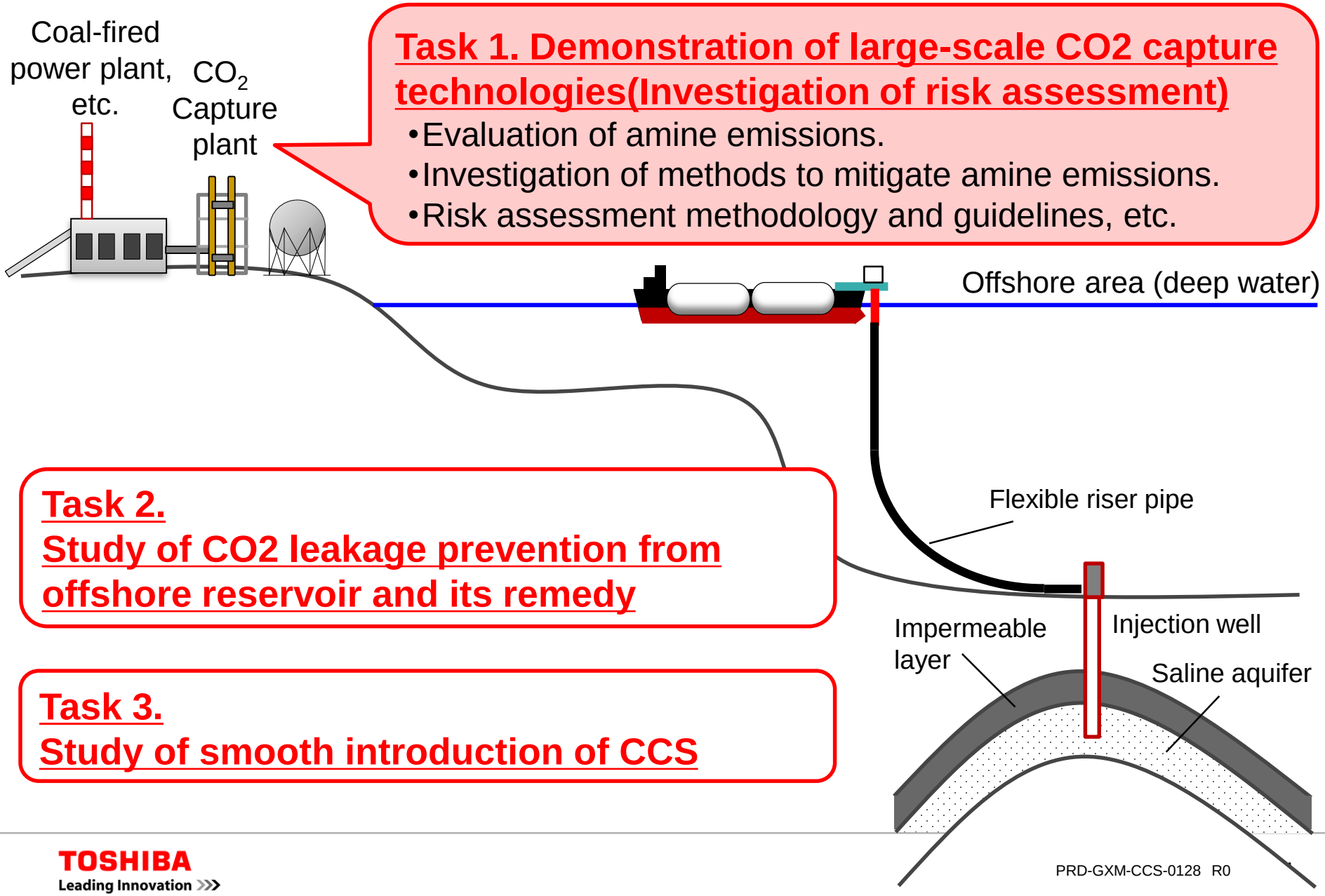
MoE “Sustainable CCS Project” Outline



Task 1. Demonstration of large-scale CO2 capture technologies(Investigation of risk assessment)

- Evaluation of amine emissions.
- Investigation of methods to mitigate amine emissions.
- Risk assessment methodology and guidelines, etc.

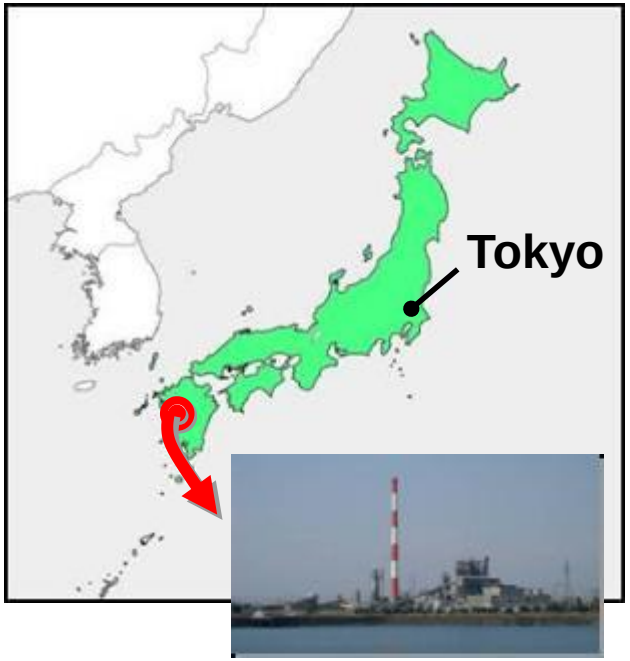
Task 2.
Study of CO2 leakage prevention from offshore reservoir and its remedy

Task 3.
Study of smooth introduction of CCS

Toshiba PCC Pilot Plant at Mikawa

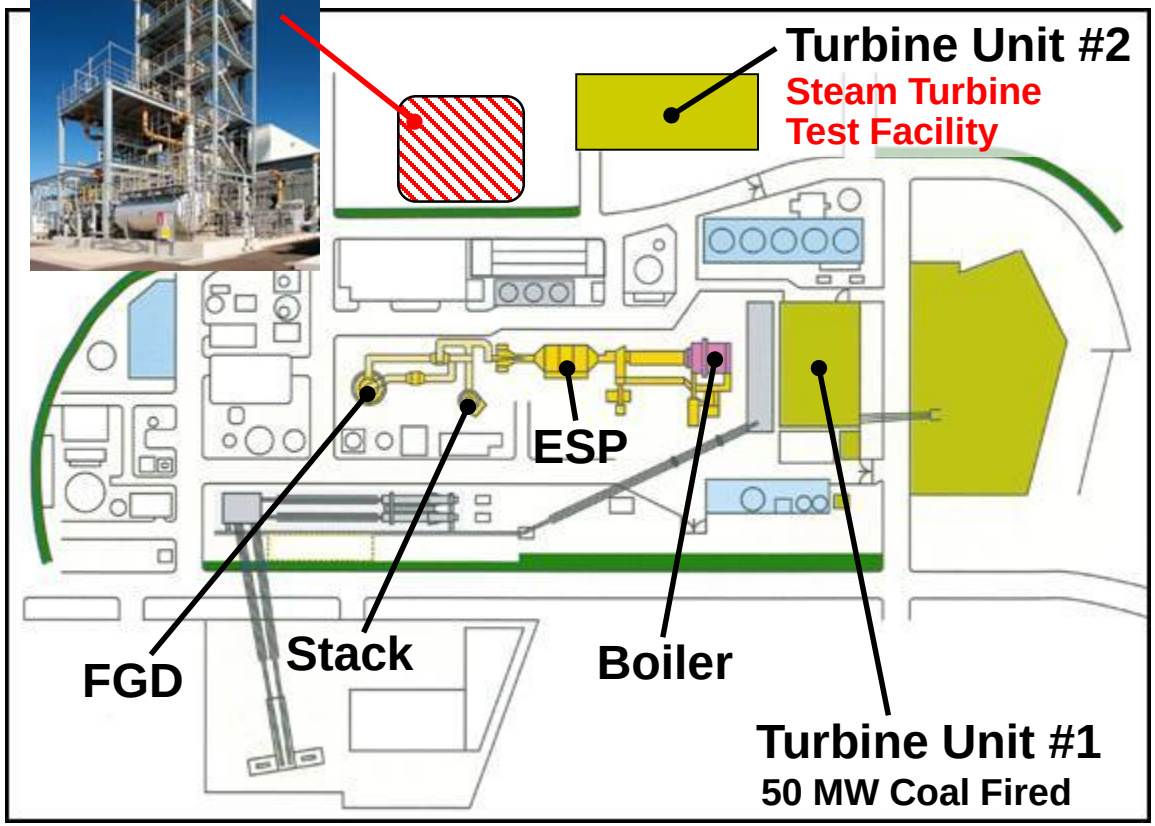
PCC Pilot Plant

Location:



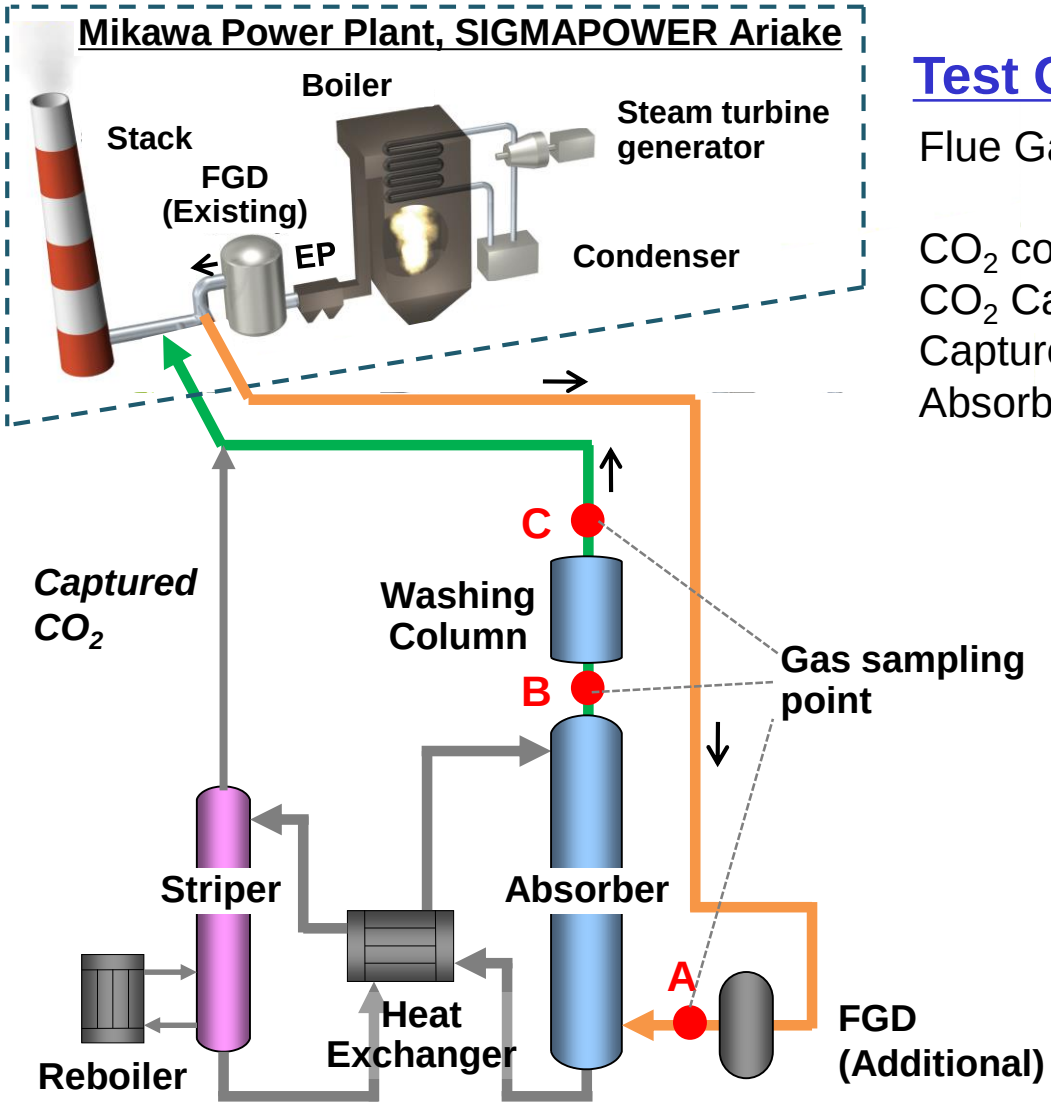
Sigma Power Ariake Co., Ltd.
Mikawa Power Plant
Omuta City, Fukuoka, Japan

Plot Plan:



Mikawa: Toshiba's Showcase of Low Emission Thermal Power Technology

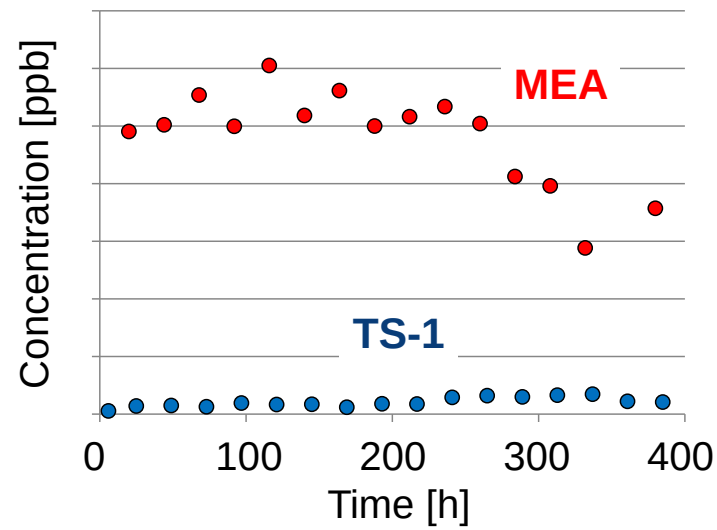
Amine emissions test Outline



Test Outline

Flue Gas Flow:	2100 Nm^3 / hour (from Coal Fired Power Plant)
CO_2 concentration:	Approx.12vol%
CO_2 Capture Ratio:	90%
Capture Capacity:	10 ton-CO_2 / day
Absorbent:	MEA (600h operation) TS-1 (400h operation) (Toshiba Solvent-1)

Amine concentration at the sampling point B



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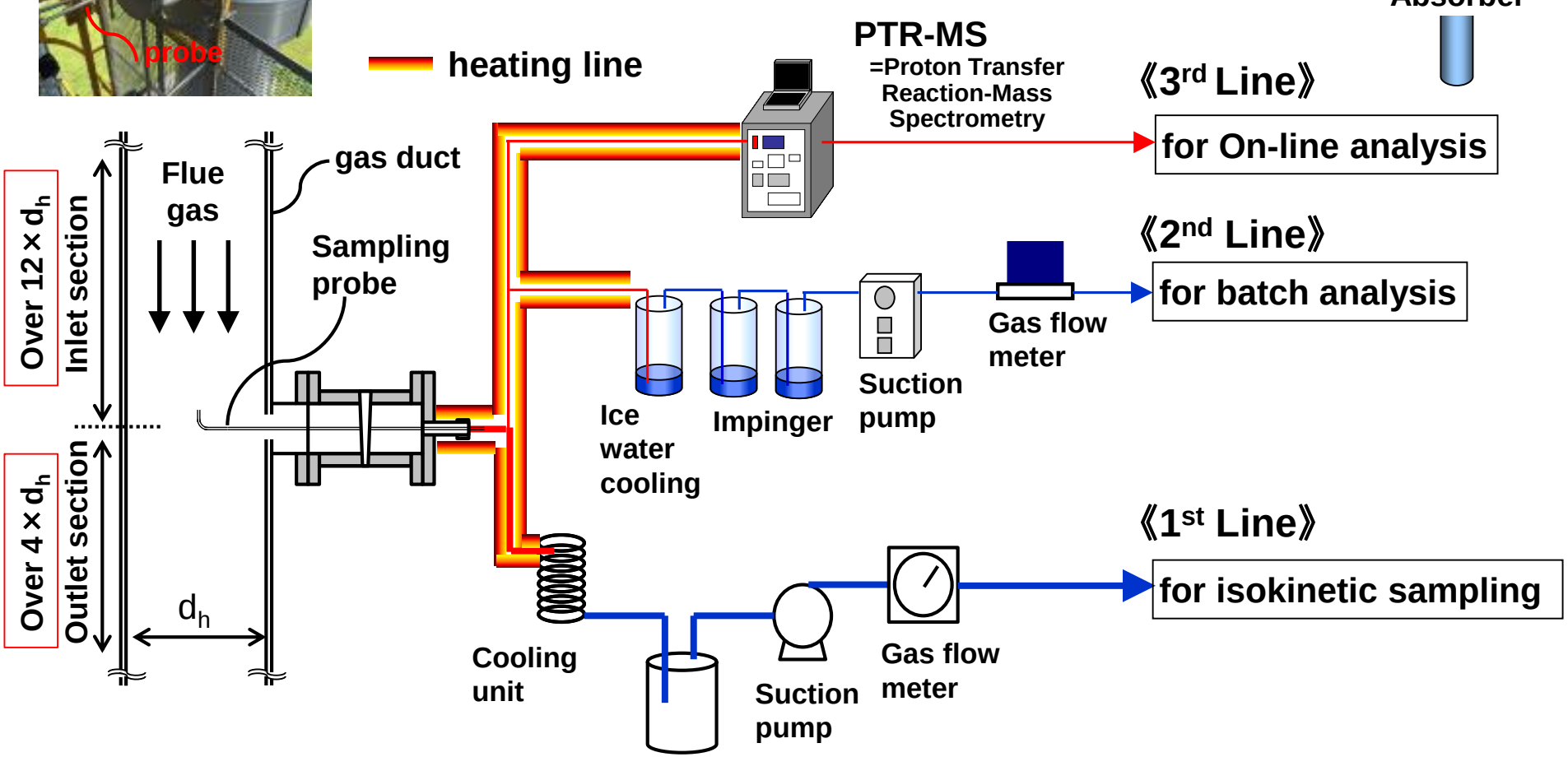
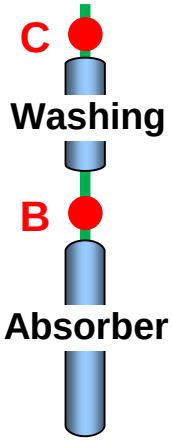
Measurement; Amine concentrations

On-line and Batch analytical methods to measure amine concentrations

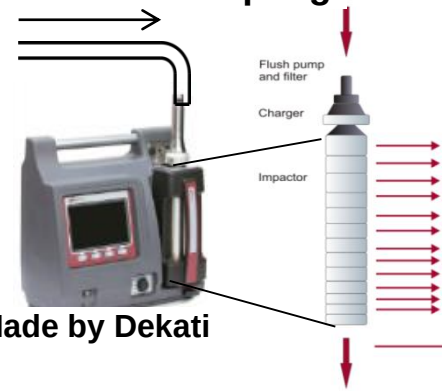


Measurement; Amine mist, Aerosol, and SO_3

Amine mist



Isokinetic sampling



Made by Dekati

ELPI+ =Electrostatic Low Pressure Impactor

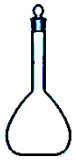
Stage1-15
:
1.62-2.46μm
0.94-1.62μm
0.6-0.94μm
:

Stage8 to 15 (0.38-10μm)

Collected on each stage

Stage

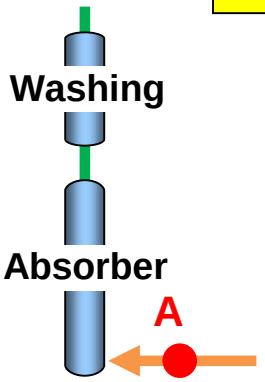
Collecting in measuring flask



Quantitative analysis

LC/MS/MS

Aerosol



Made by TSI

SMPS =Scanning Mobility Particle Sizer

Particle size:10-487nm
Concentration:10E2-10E7

SO_3

Made by PENTOL

Detection limit:0.1ppm

SO_3 Analyzer

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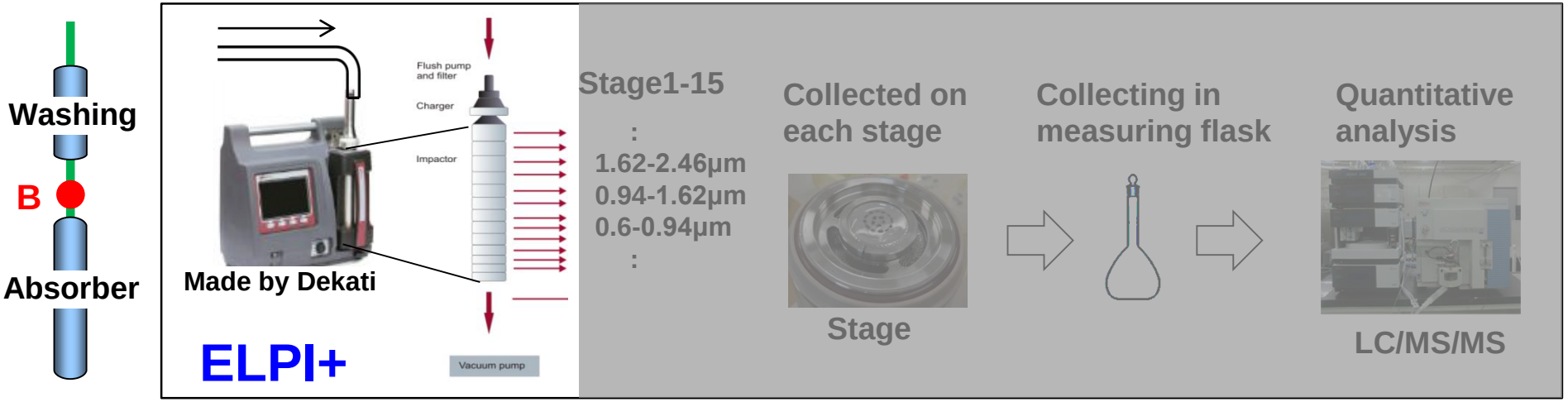
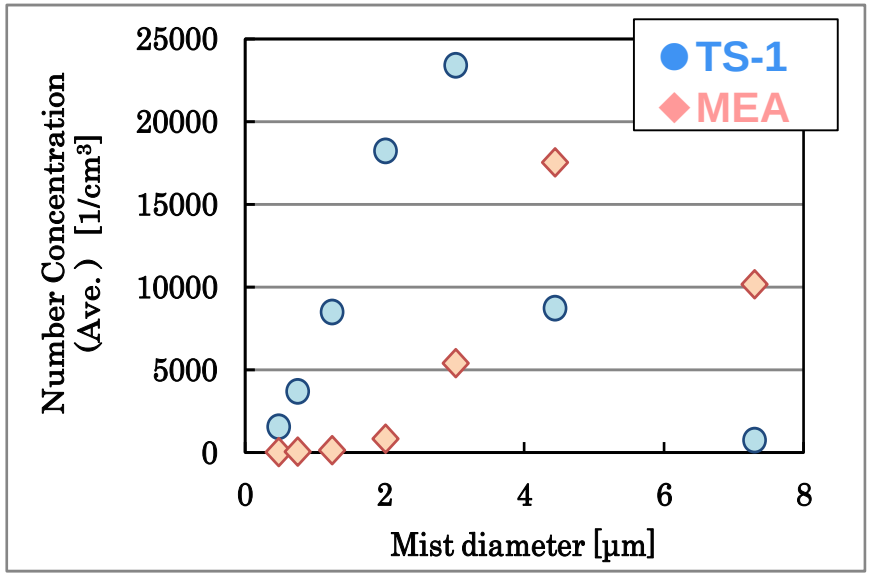
Mist particle distribution



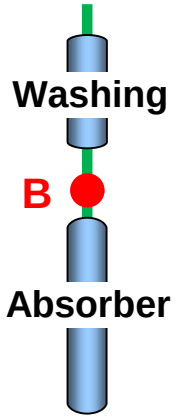
Number Concentration of mist at sampling point: B

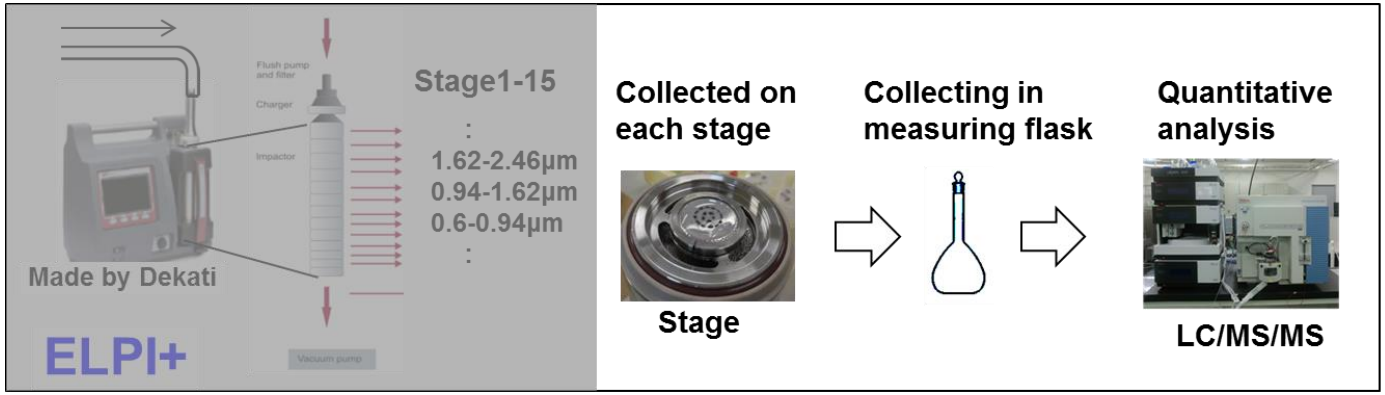


under basic condition
TS-1:9/5,2016
MEA:10/10,2016

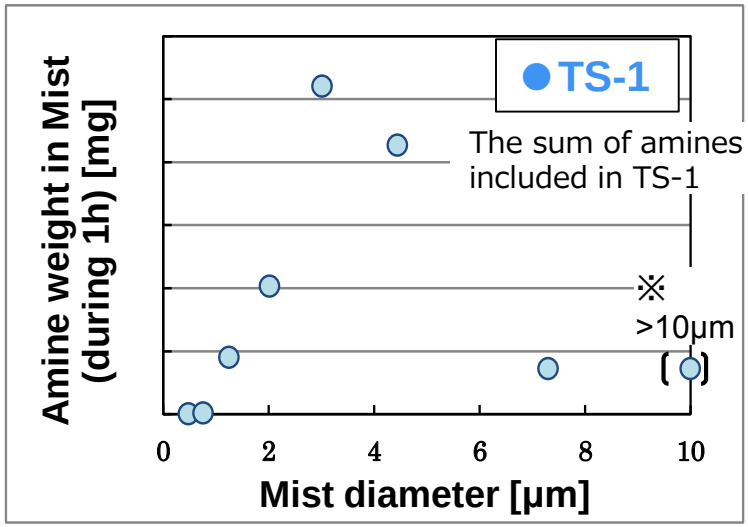
Mist diameter derived from MEA is larger than that of TS-1

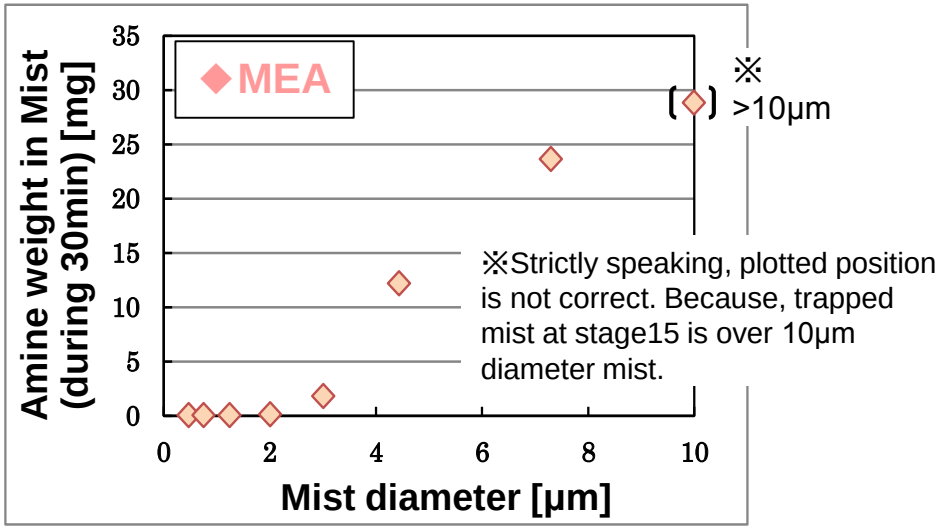
The net amount of Amine weight in Mist particle





The net amount of Amine weight depending on mist particle size



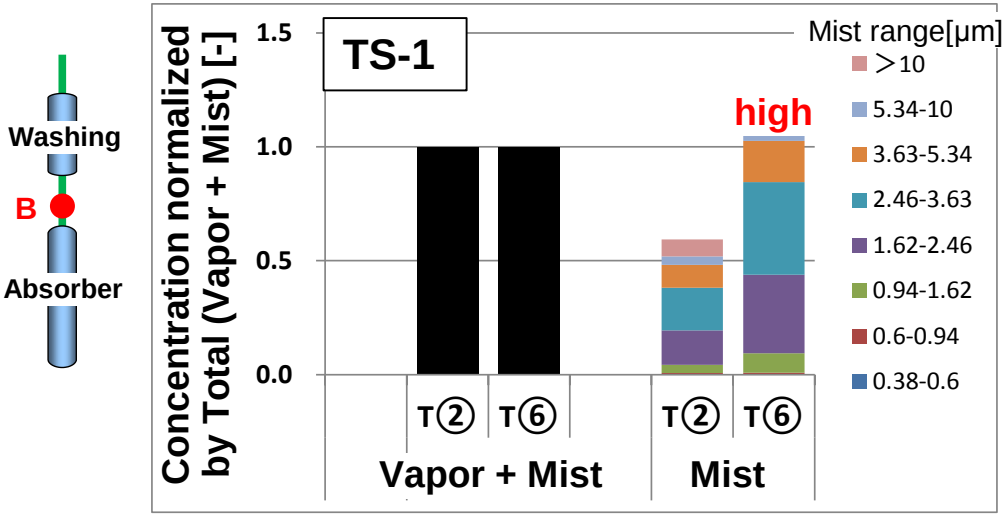


A large part of mist based emissions is emitted by TS-1; several micro diameter
MEA; over 10 micro diameter

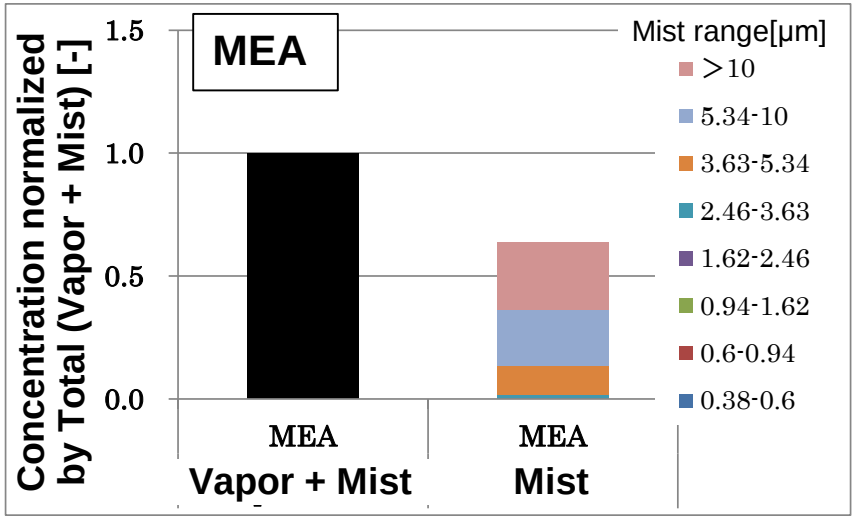
Ratio of mist based amine emissions

Compared between "total concentration (Vapor + Mist)" and "Mist" to investigate the ratio of mist based amine emissions

The ratio of mist based amine emissions



under basic condition on 9/5



under basic condition on 10/10

- **Mist based amine emissions of MEA occupy over 50%.**
- **The ratio of T⑥ tended to be more than 90%.**
- **the ratio of mist based amine emissions depends on amine properties such as amine vapor pressure.**

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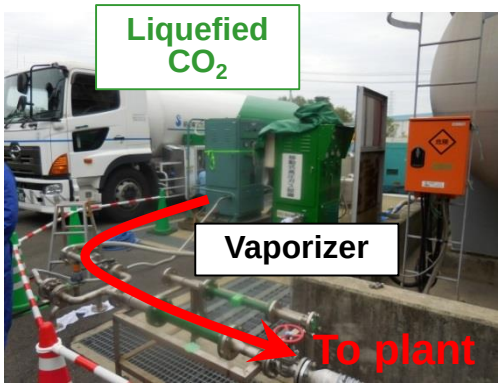
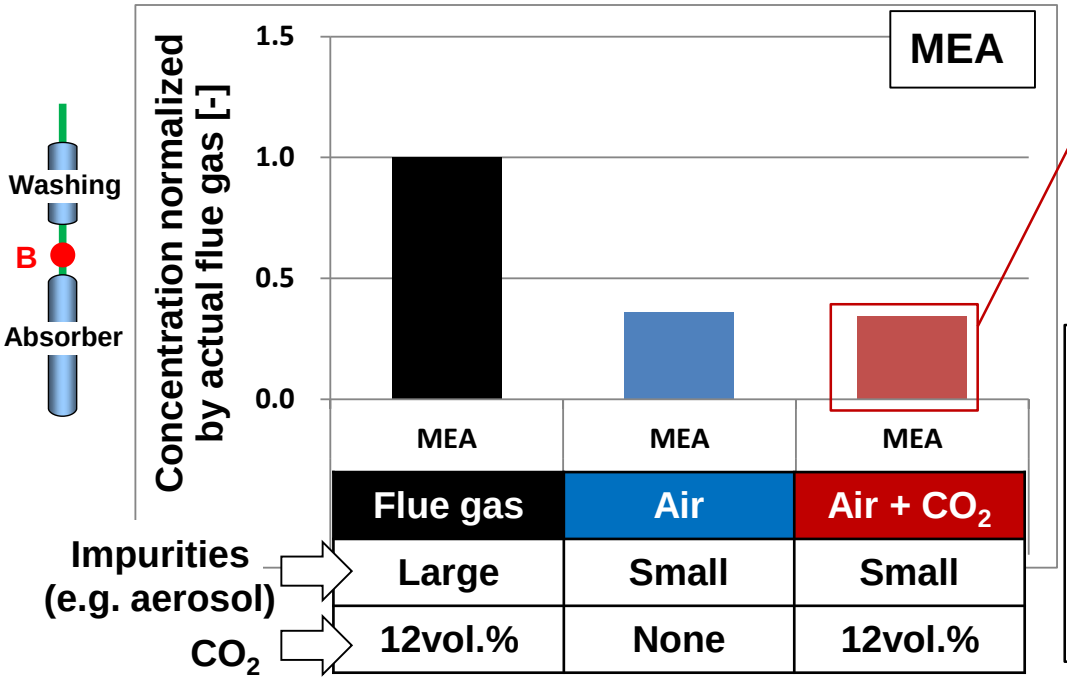
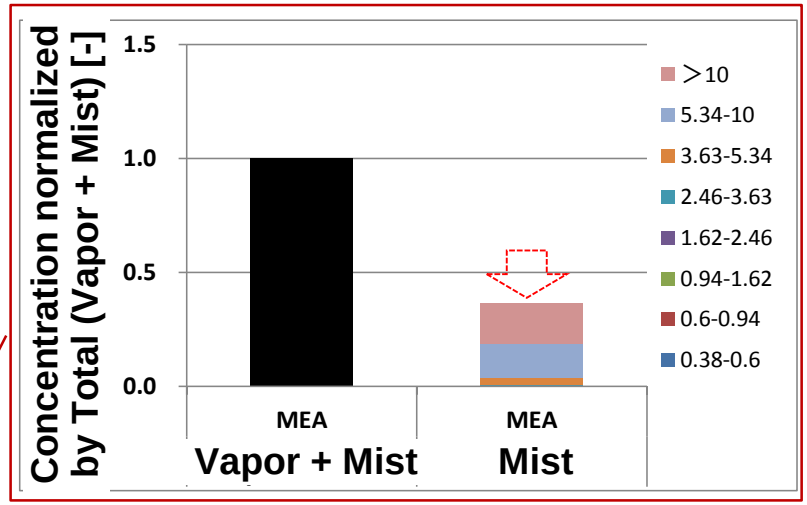
How CO_2 affects (mist based) amine emissions?

《Air + CO_2》



Conducted emissions test with artificial flue gas, to evaluate the effect of CO_2 and other impurities contained in actual flue gas

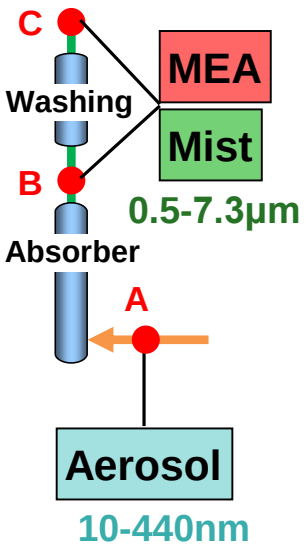




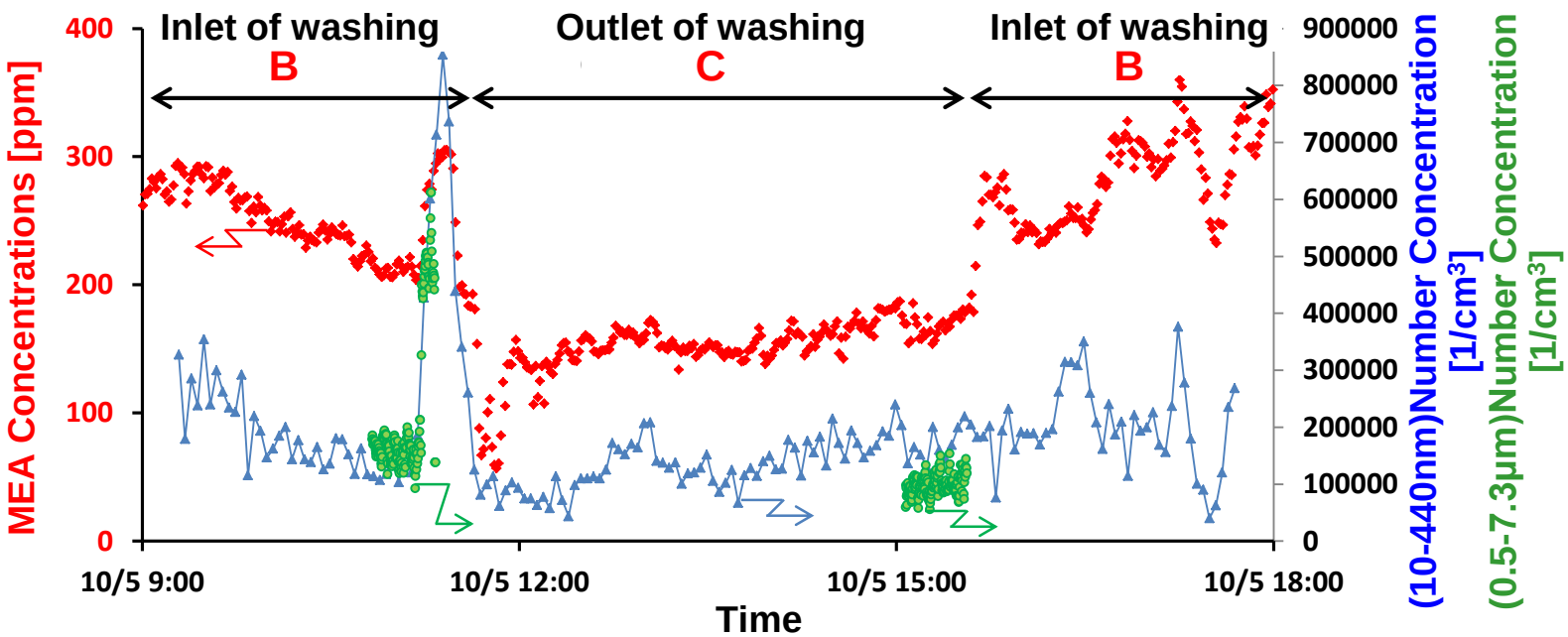
- CO_2 is less likely to contribute amine emissions.
- It was also confirmed that the ratio of mist based emission decreased in artificial flue gas test compared to actual flue gas test

How aerosol affects mist based amine emissions?

On-line Measuring for aerosol, amine mist, and amine concentration was simultaneously measured to evaluate the role of aerosol for mist formation



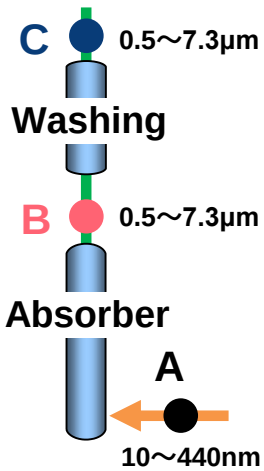
Relation of aerosol, mist and amine concentrations

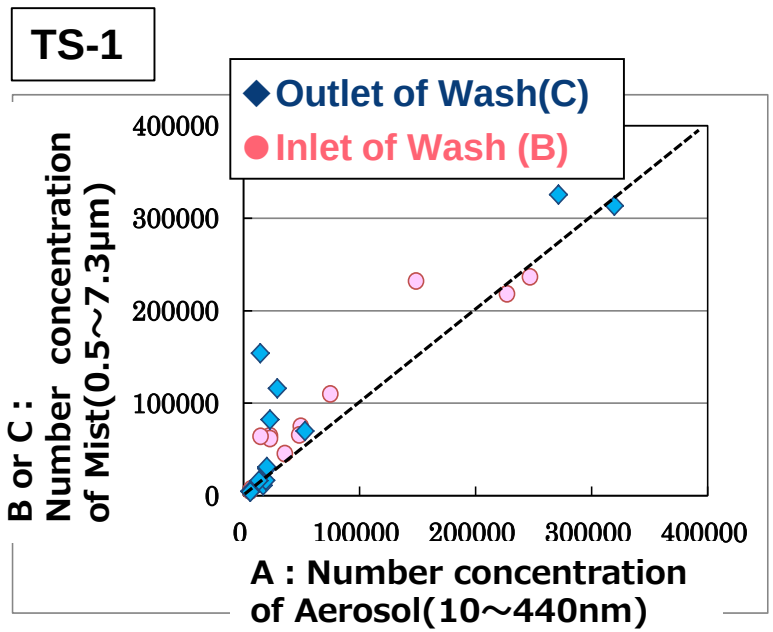


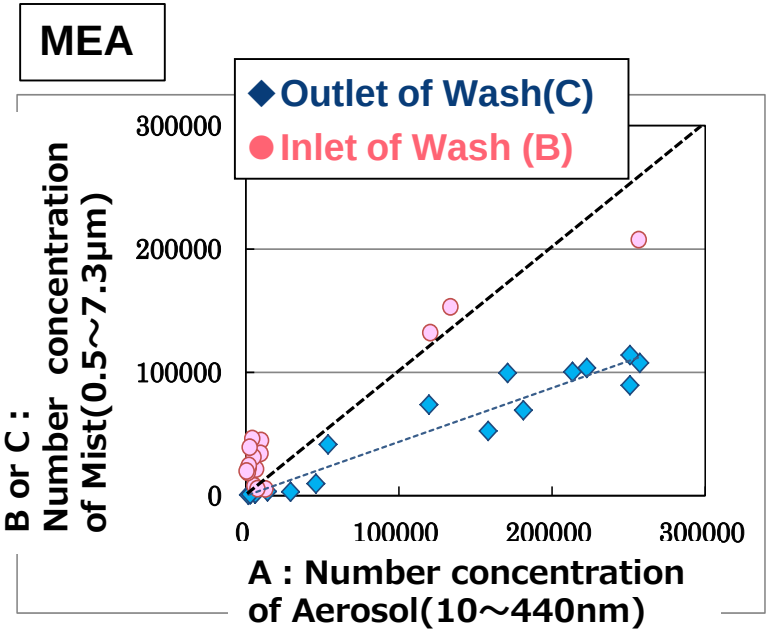
- Remarkable increase in the number concentration of the amine mist at the sampling point B was observed depending on the increase of aerosol number concentration. In addition, amine concentration was simultaneously increased.
- Amine concentration was likely to be fluctuated by a variation of aerosol.

Role of aerosol for amine mist formation

To clarify the relation between aerosol in the flue gas and amine mist at sampling point B&C, comparison results of both number concentration are confirmed in the following.



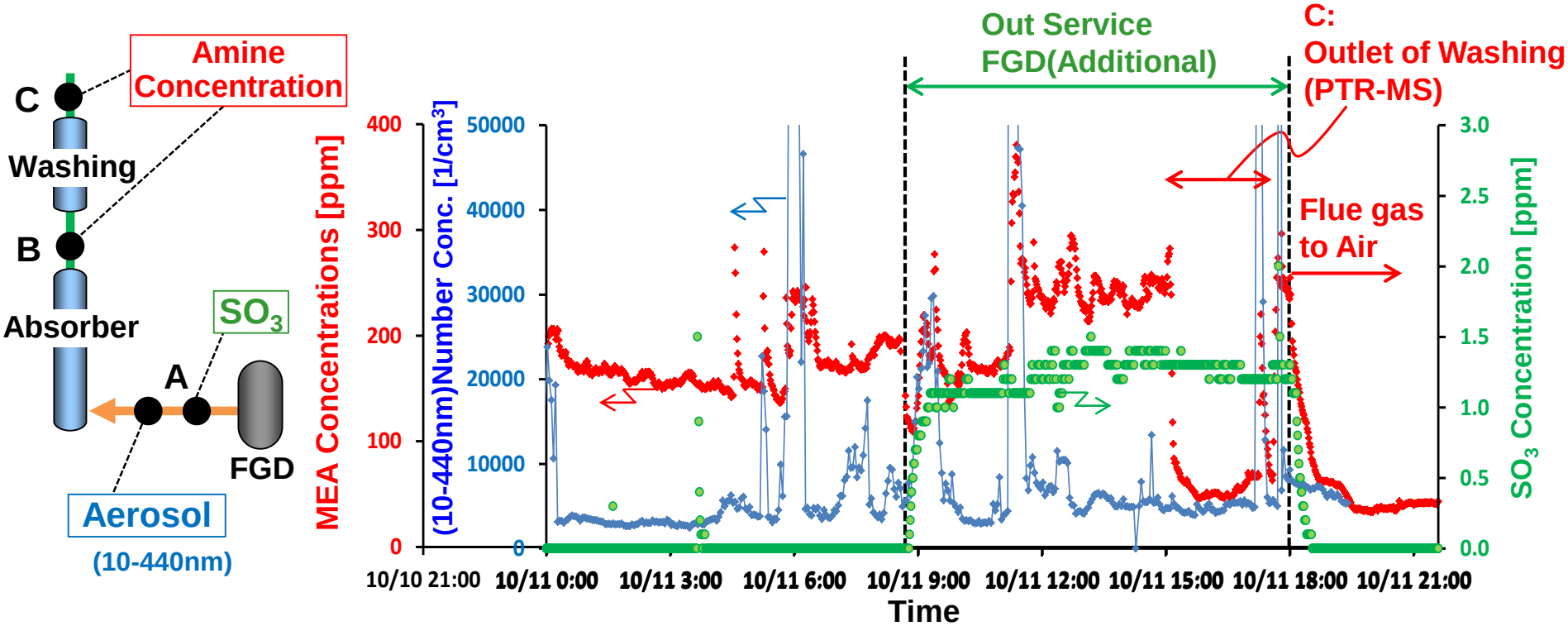




- **The number of aerosol at the inlet of the absorber matched the number of amine mist at the outlet of the absorber, regardless of size difference.**
- **The aerosol acts as a source of amine mist nuclei and enhances amine mist growth in the CO_2 absorber. In addition, it seems to be difficult for common washing systems to capture the mist derived from TS-1.**

How SO_3 affects (mist based) amine emissions?

Studied the effect of SO_3 for amine emissions by switching FGD service



When the additional FGD was out of service, SO_3 concentration raised to 1.2ppm; however, clear trends were not observed in terms of amine concentration.

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Researching countermeasures against mist

have researched effective countermeasures to mitigate amine emissions, especially against mist of amine using bench-scale plant, shown as follows.

Bench-scale plant

research

- Demister
- Gas velocity
- Novel washing methods
- Washing process
- Washing configuration

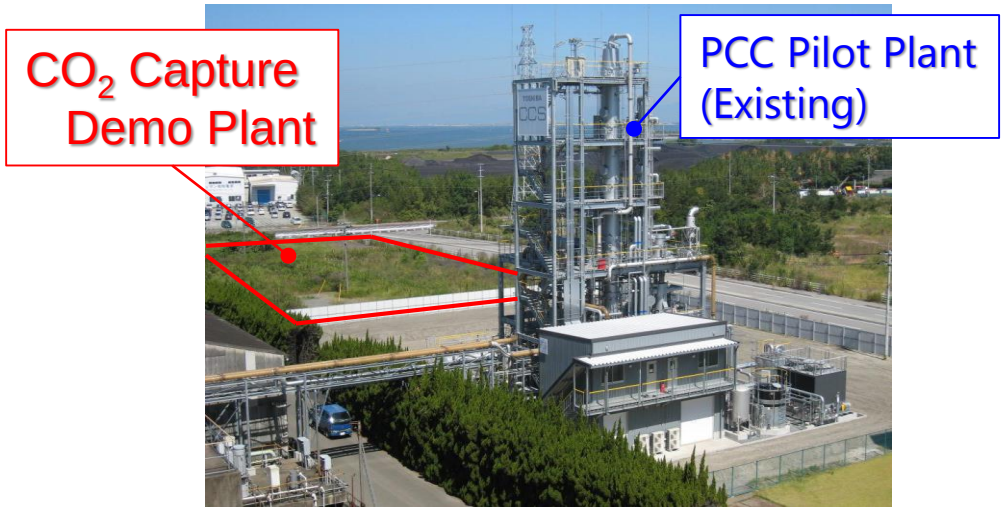
Novel washing methods have been evaluated and revealed that washing efficiency is over 99%. That methods will be utilized for demonstration plant.

Schedule of CO2 Capture Demonstration Plant

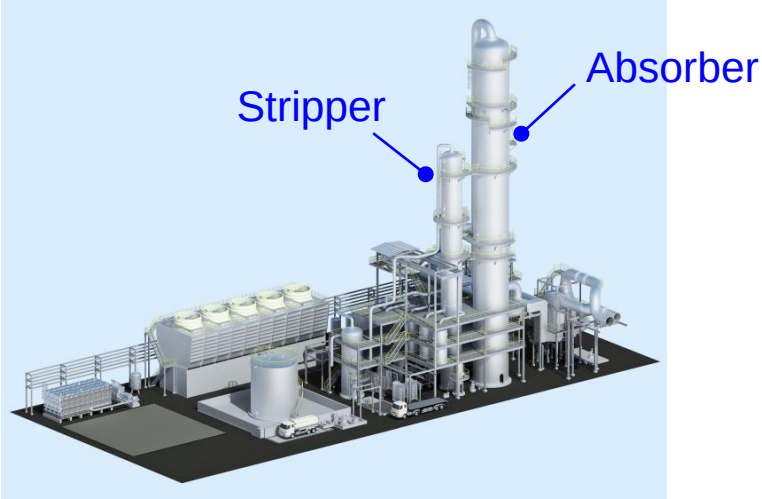
Demonstration plant will be designed and built to capture more than 500 t-CO_2/day

	FY2016	FY2017	FY2018	FY2019	FY2020
CO_2 Capture Plant Construction & Demonstration	Detailed Design of Capture Plant	Design of Existing Power Plant Modification			
	Permitting & Securing Land for Construction		Demo Plant Construction & Integration to Power Plant	Plant Commissioning & Demonstration	

Planned Location of the CO_2 Capture Demo Plant



Planned Layout of CO_2 Capture Demo Plant



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Summary

- **investigated the ratio of mist based amine emissions in total amine concentration.**
  - ・MEA; mist accounts for over 50%
  - ・TS-1; mist of “T⑥” accounts for near 100%, mist of “T②” accounts for 50%

- **Conducted a comparison test using actual flue gas, air and artificial flue gas(air + industrial CO_2).**
  - ・the aerosol acts as a source of amine mist nuclei and enhances amine mist growth in the CO_2 absorber. On the other hand, CO_2 is less likely to contribute amine emissions.

- **Investigated the effect of additional FGD by switching IN/OUT servicing.**
  - ・when FGD was OUT servicing, SO_3 concentration raised to 1.2ppm. In this concentration, however, it was not clear how much SO_3 contributes amine emissions .

- **Demonstration plants to capture more than 500t-CO_2/day will be constructed by 2020 and be evaluated emission mitigation methods.**

Acknowledgements

This work was carried out as part of the project funded by Ministry of the Environment, Government of Japan.

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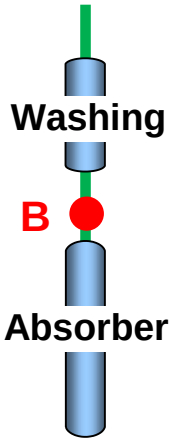
Measurement; Amine concentrations

Detected chemical species at sampling point: B at 400h operation of MEA test



Chemical substance	Abbreviation	CAS No.	Amine concentration at the outlet of absorber (ppb)
Monoethanolamine	MEA	141-35-5	52000
Diethanolamine	DEA	111-42-2	3
N-(2-hydroxyethyl)formamide	HEF	693-06-1	15
N-Nitrosodiethanolamine	NDELA	1116-54-7	N.D.(<0.4)
Pyrazine	PY	290-37-9	N.D.(<5)
Methylpyrazine	MePY	109-08-0	N.D.(<0.1)
N-(2-hydroxyethyl)imidazole	HEI	1615-14-1	2
2-Oxazolidinone	OZD	497-25-6	N.D.(<6)
N-(2-hydroxyethyl)acetamide	HEA	142-26-7	2
N-(2-hydroxyethyl)lactamide	HELA	5422-34-4	N.D.(<0.1)
N-(2-hydroxyethyl)glycine	HEGly	5835-28-9	5
1-hydroxyethl-2-piperainone	HEPO	23936-04-1	N.D.(<0.4)
N-(2-hydroxyethyl)imidazolidinone	HEIA	3699-54-5	N.D.(<0.03)

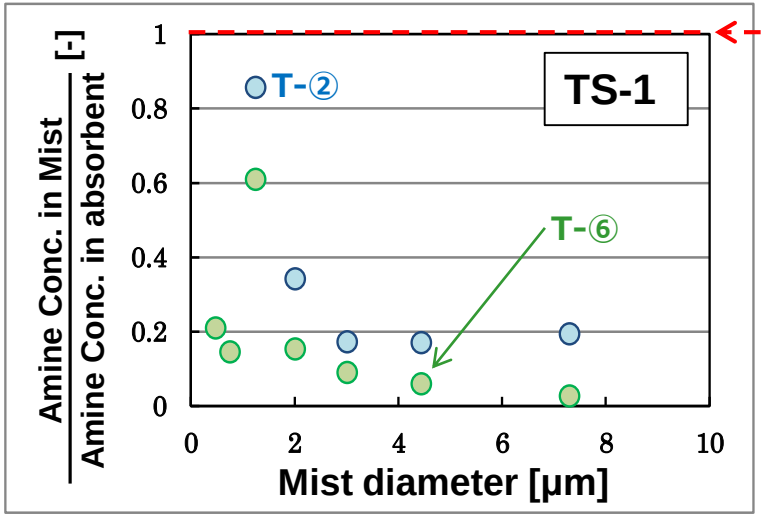
Amine mass concentration in Mist particle

《Measurement data》 Each stage

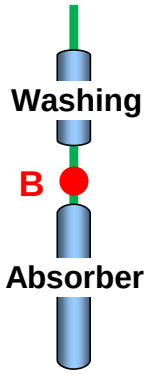
Number Concentration ($1/m^3$) → Mist weight (mg) → amine concentration in mist $\left(\frac{\text{Amine weight}}{\text{mist weight}}\right)$ ← LC/MS/MS Analysis Amine weight (mg) ← 《Analysis data》

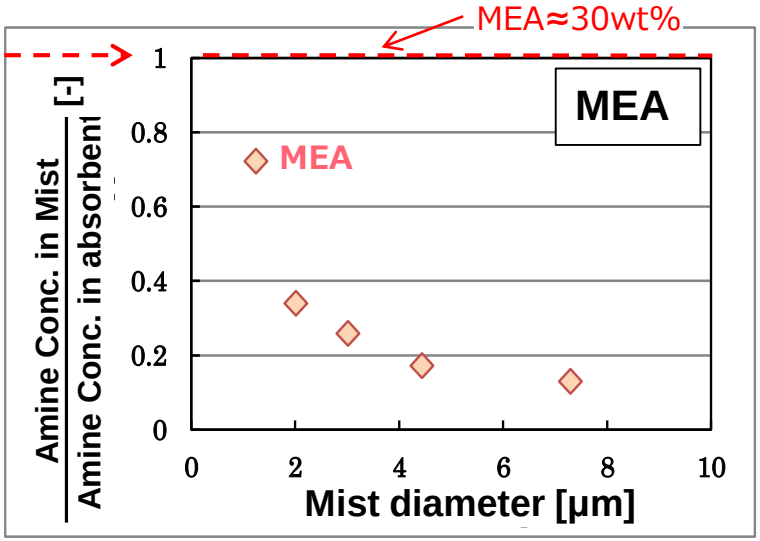
Stage

Amine concentration in mist standardized by concentration in absorbent



Amine concentration in absorbent (Standardized)

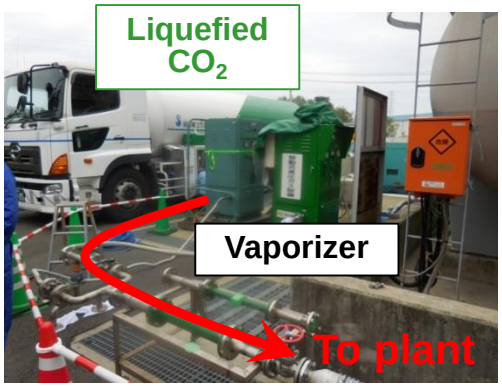




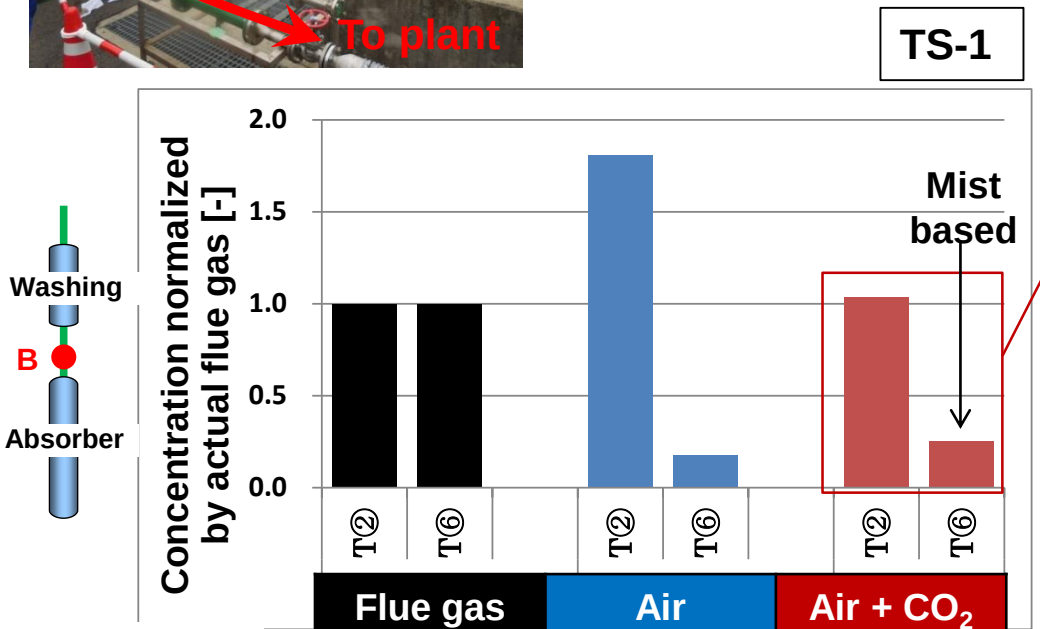
The lager mist become, the less amine concentration in mist was regardless of amine kinds; however, the ratio of concentration against absorbent is different depending on amine kinds.

How CO_2 affects (mist based) amine emissions?

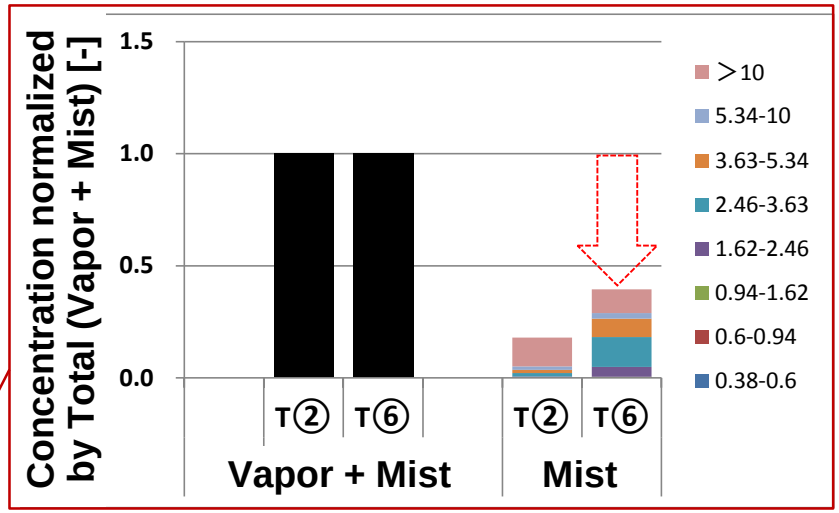
《Air + CO2》



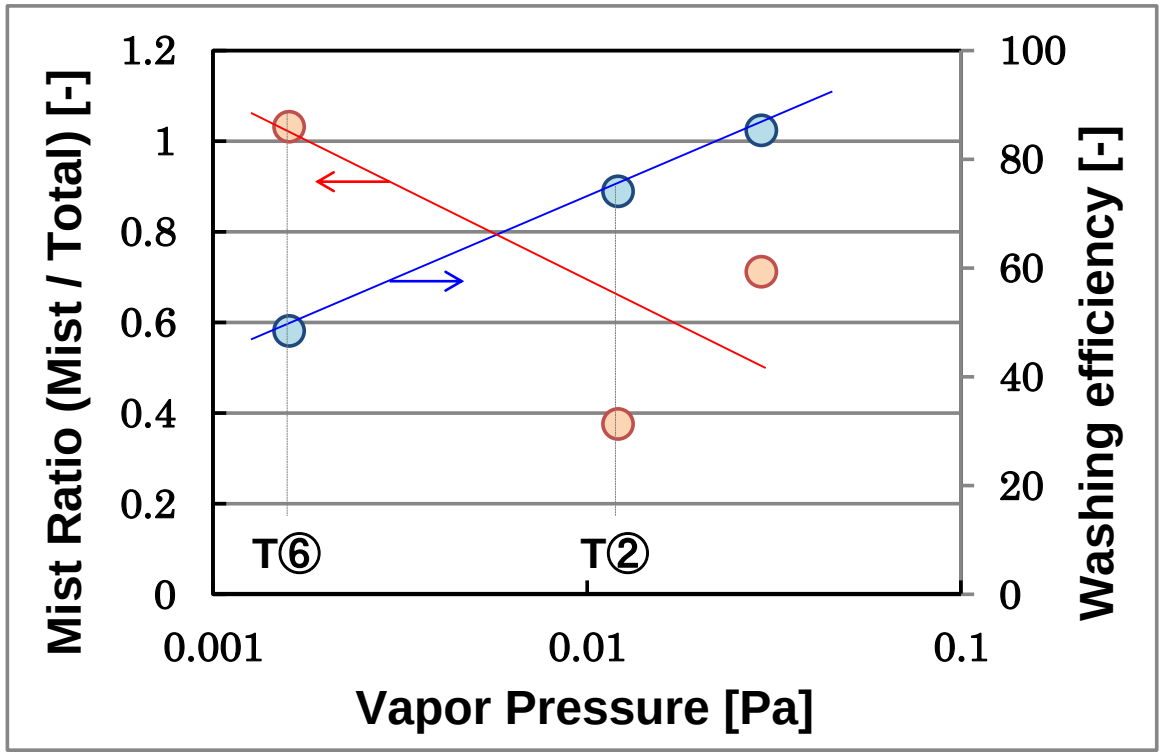
Conducted emissions test with artificial flue gas, to evaluate the effect of CO_2 and other impurities contained in actual flue gas

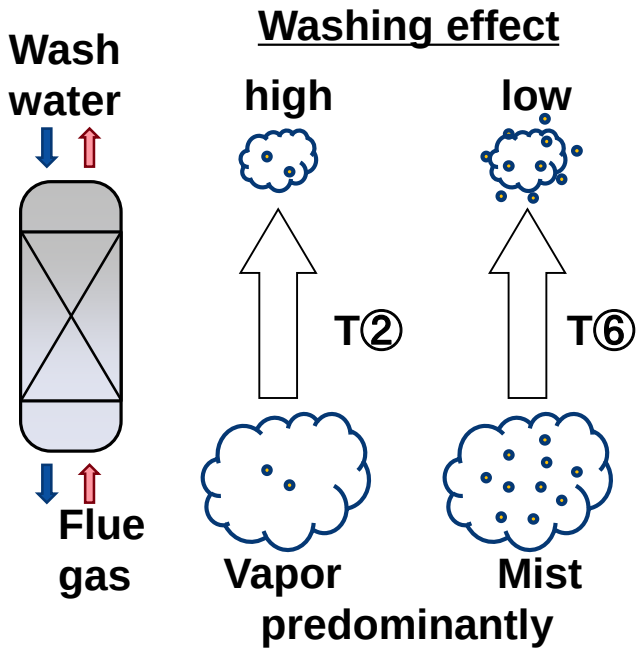


	Flue gas	Air	Air + CO_2
Impurities (e.g. aerosol)	Large	Small	Small
CO_2	12vol.%	None	12vol.%



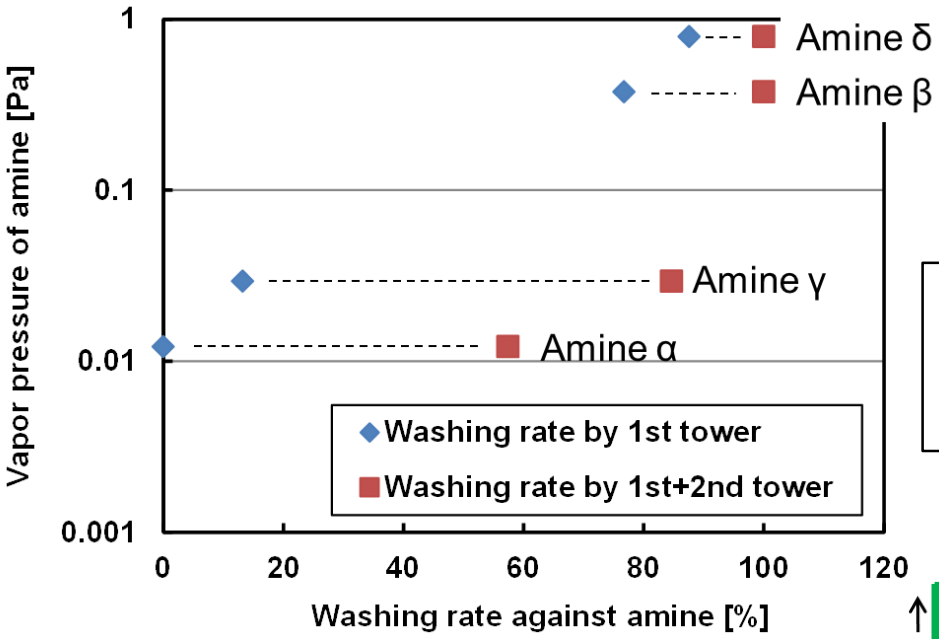
CO_2 contained in actual flue gas is less likely to contribute amine emissions. We also confirmed that the ratio of mist based emission decreased in artificial flue gas test compared to actual flue gas test.
(On the other hand, vapor based emission is not decreased)



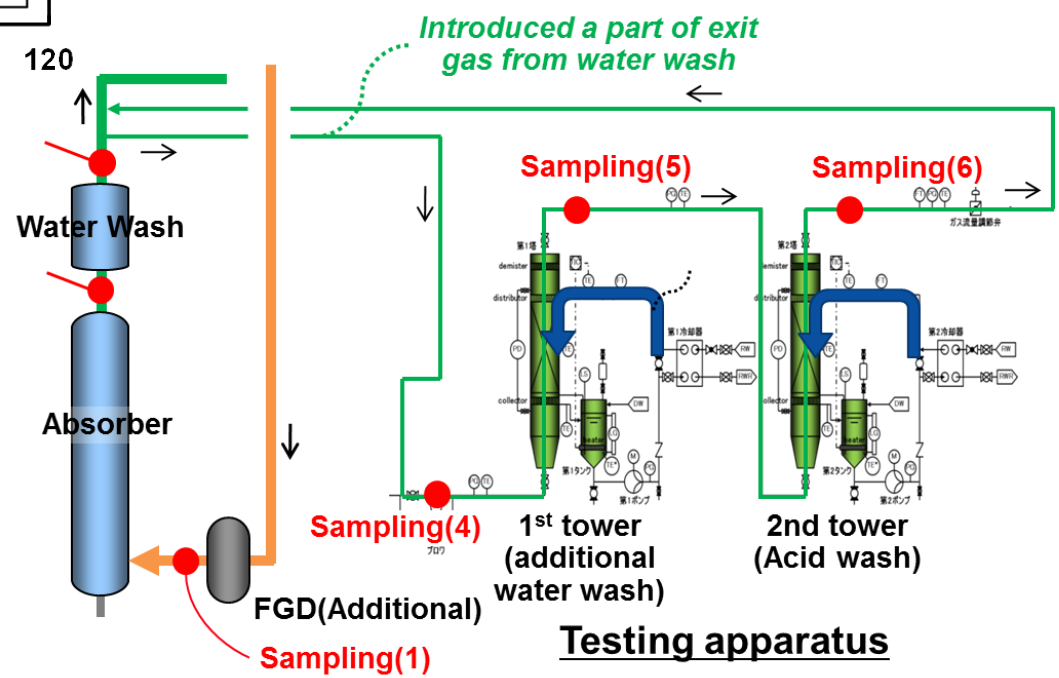


*Vapor pressure ;measuring vapor pressure of amine from 1wt% aqueous solution at 40℃, respectively

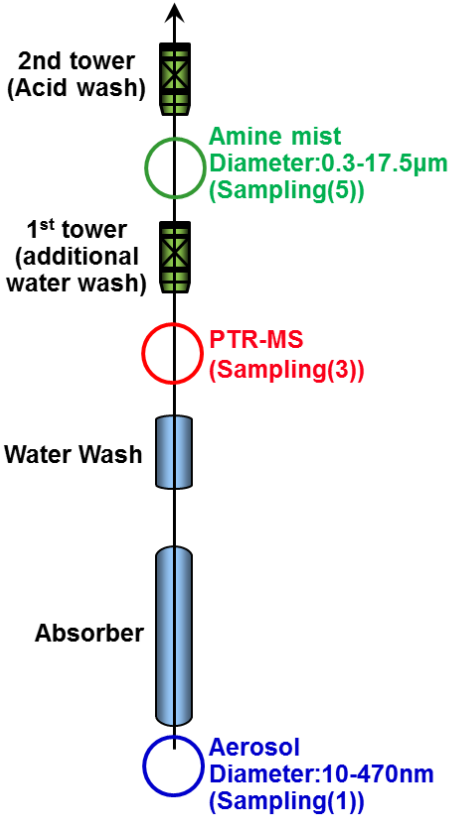
The higher vapor pressure is, the higher washing efficiency becomes by washing column, on the other hand, the less mist ratio of total emissions is.

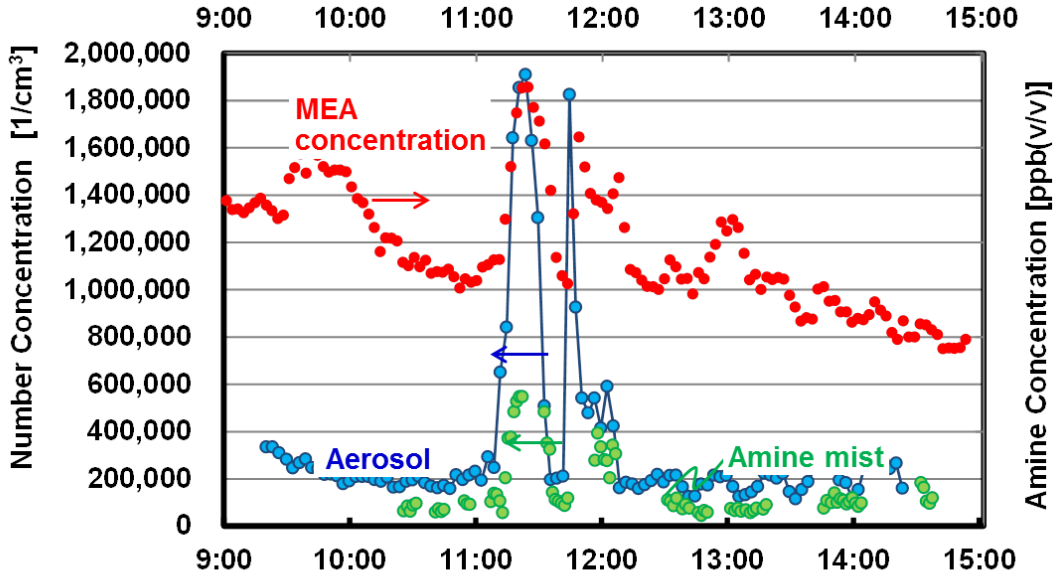


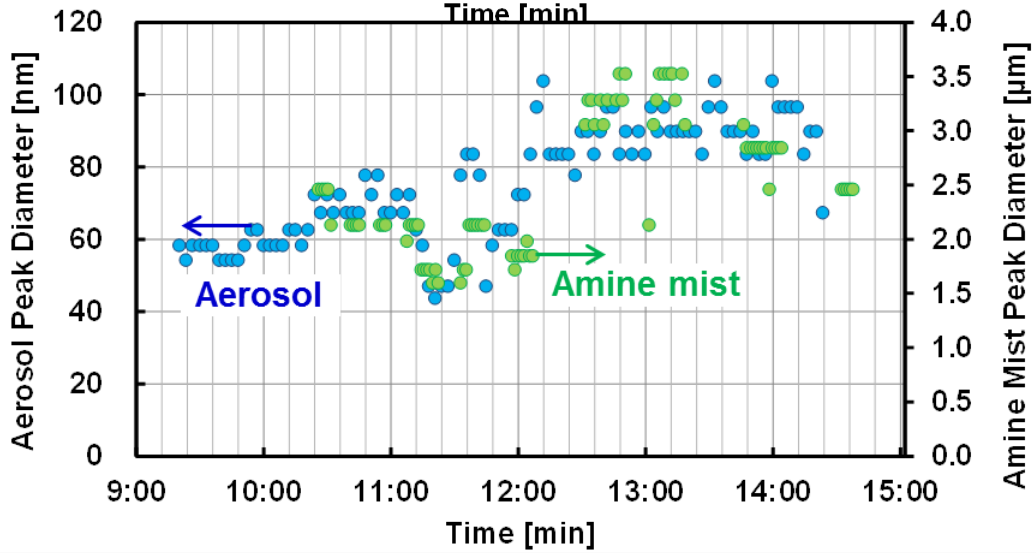
The higher vapor pressure is, the higher washing efficiency become by washing



Testing apparatus

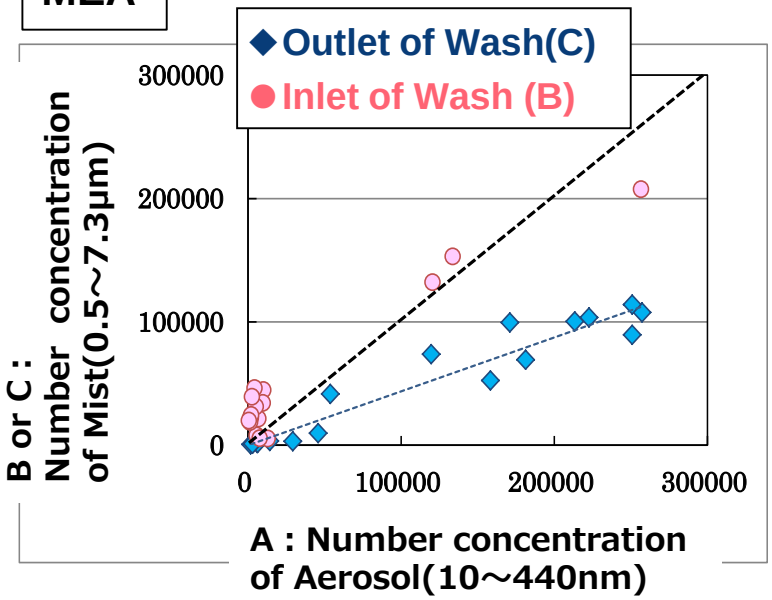




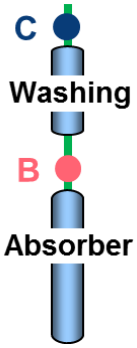


the fluctuation tendencies of the peak diameter were very similar between them (aerosol and amine mist)

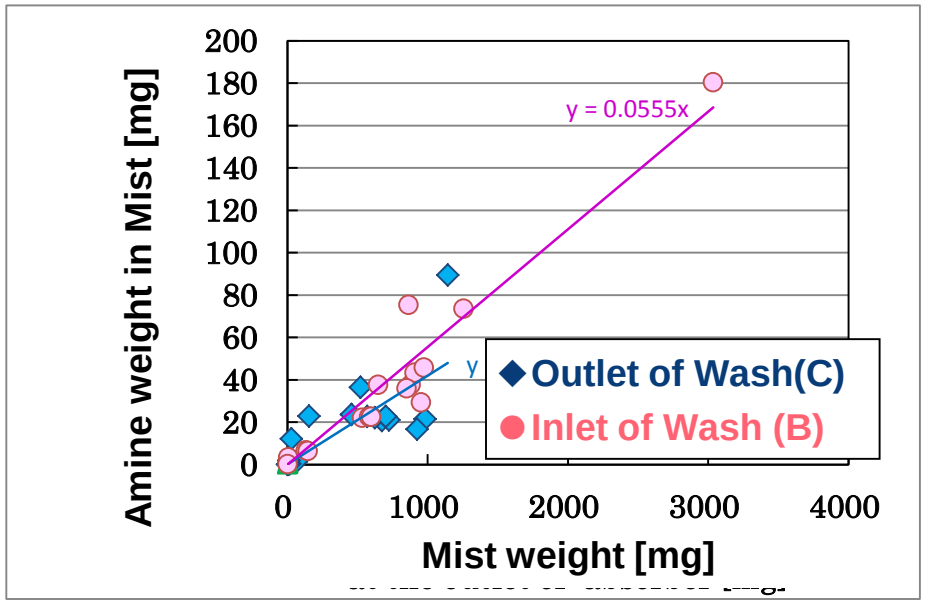
MEA



Amine mist was removed to half by water wash



MEA



Slope on a graph Means amine concentration in mist.
Amine concentration in mist were not changed through washing