

# Investigation of the simplified measurement technique of the secondary aerosols formed from gaseous emissions of vehicle exhaust (2)

**TOYOTA Motor Corporation**

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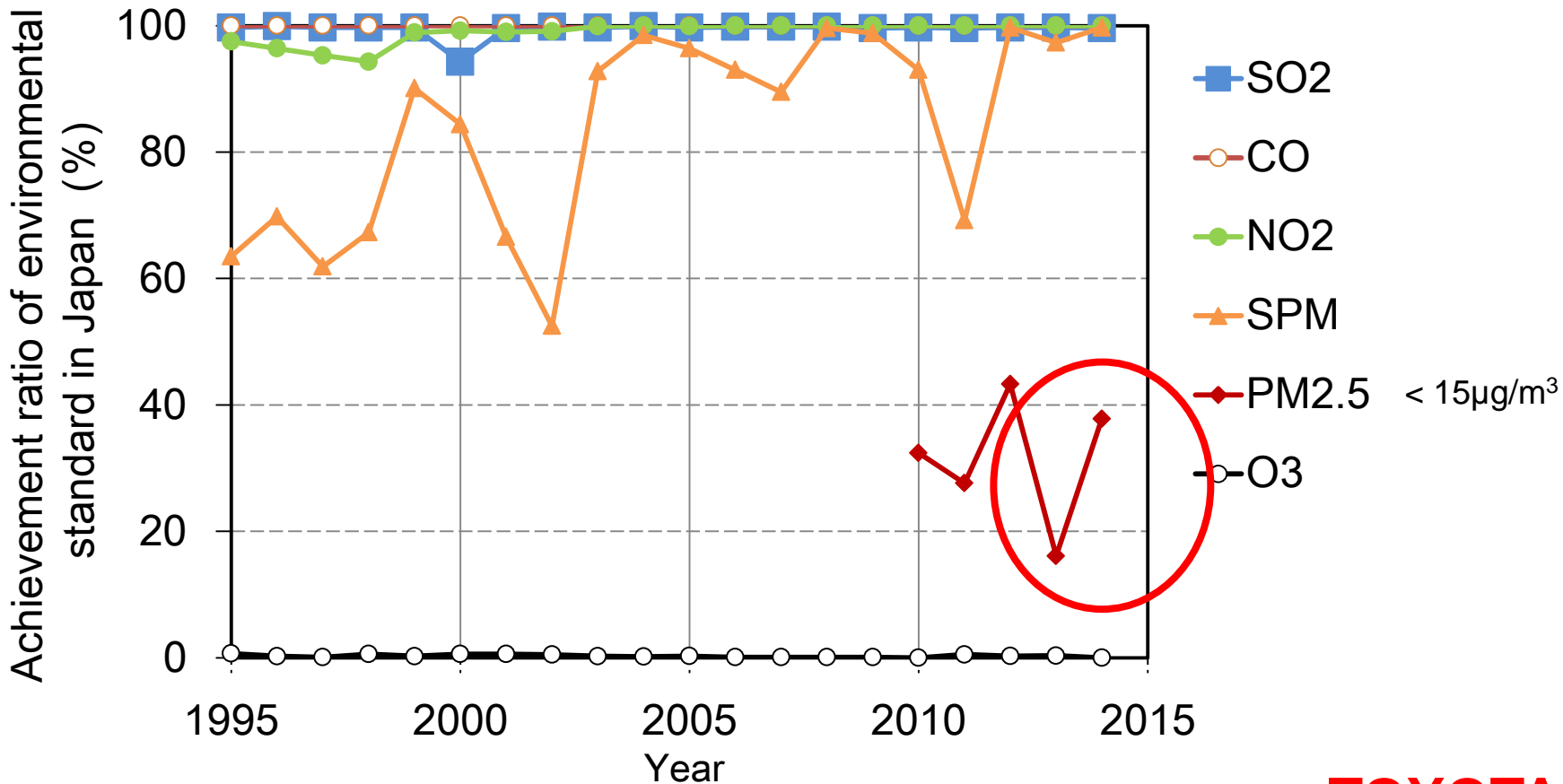
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- 2. Reactivity of the secondary aerosol generation to hydrocarbon**
- 3. Evaluation of transiently secondary aerosol from exhaust gas**
- 4. Conclusion**

# Background

► The achievement ratio of PM<sub>2.5</sub> environmental standard is low in Japan.

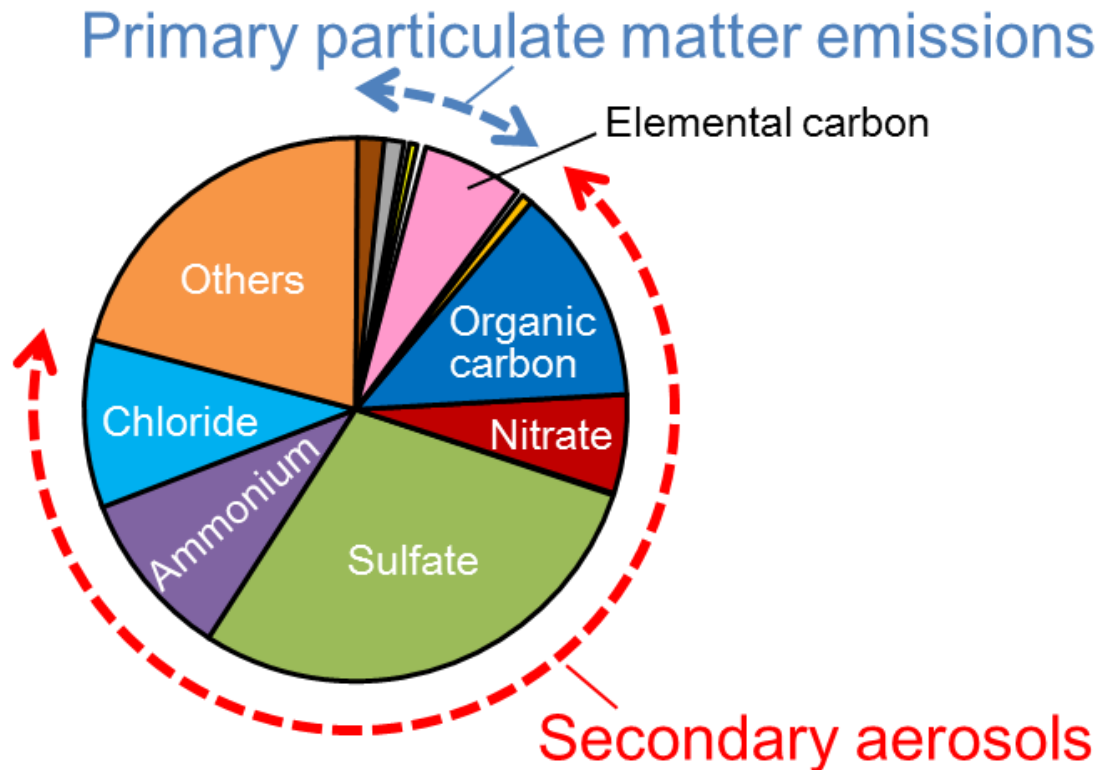
Achievement of environmental standard in Japan



# Background 2

- ▶ The ratio of secondary aerosols in PM<sub>2.5</sub> is high in Japan.
- ▶ The contribution of emission source including automobiles to the secondary aerosols is unidentified.

## An example of PM<sub>2.5</sub> composition in recent Japan



# Motivation

## Needs(1)

Understanding the actual atmospheric situation of the secondary aerosols derived from automobile exhaust.

- Generation of the secondary aerosols
- Contribution ratio to the  $PM_{2.5}$



## Needs(2)

The measurement technique of the secondary aerosols.

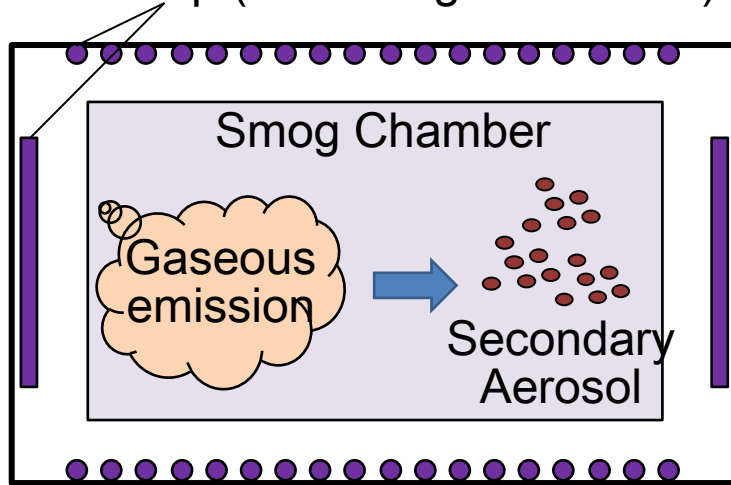
[ **Small, Simple, Swift** ]

- Application to engine bench and chassis dynamometer
- Survey of various vehicle systems

# Standard Tools

## Smog Chamber

UV Lamp (Wavelength: >300nm)

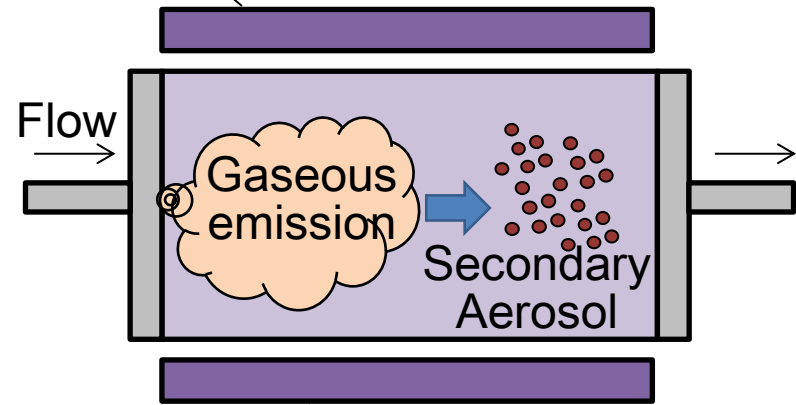


Volume: more than 1m<sup>3</sup>

## Flow Reactor

Potential Aerosol Mass chamber / Micro Smog Chamber *etc.*

UV Lamp (Wavelength : <300nm)



Volume: about 0.02m<sup>3</sup>

Advantage

- Can simulate the reaction in atmosphere

- **Portability** (Small, Simple)
- **Short reaction time**

Weak Point

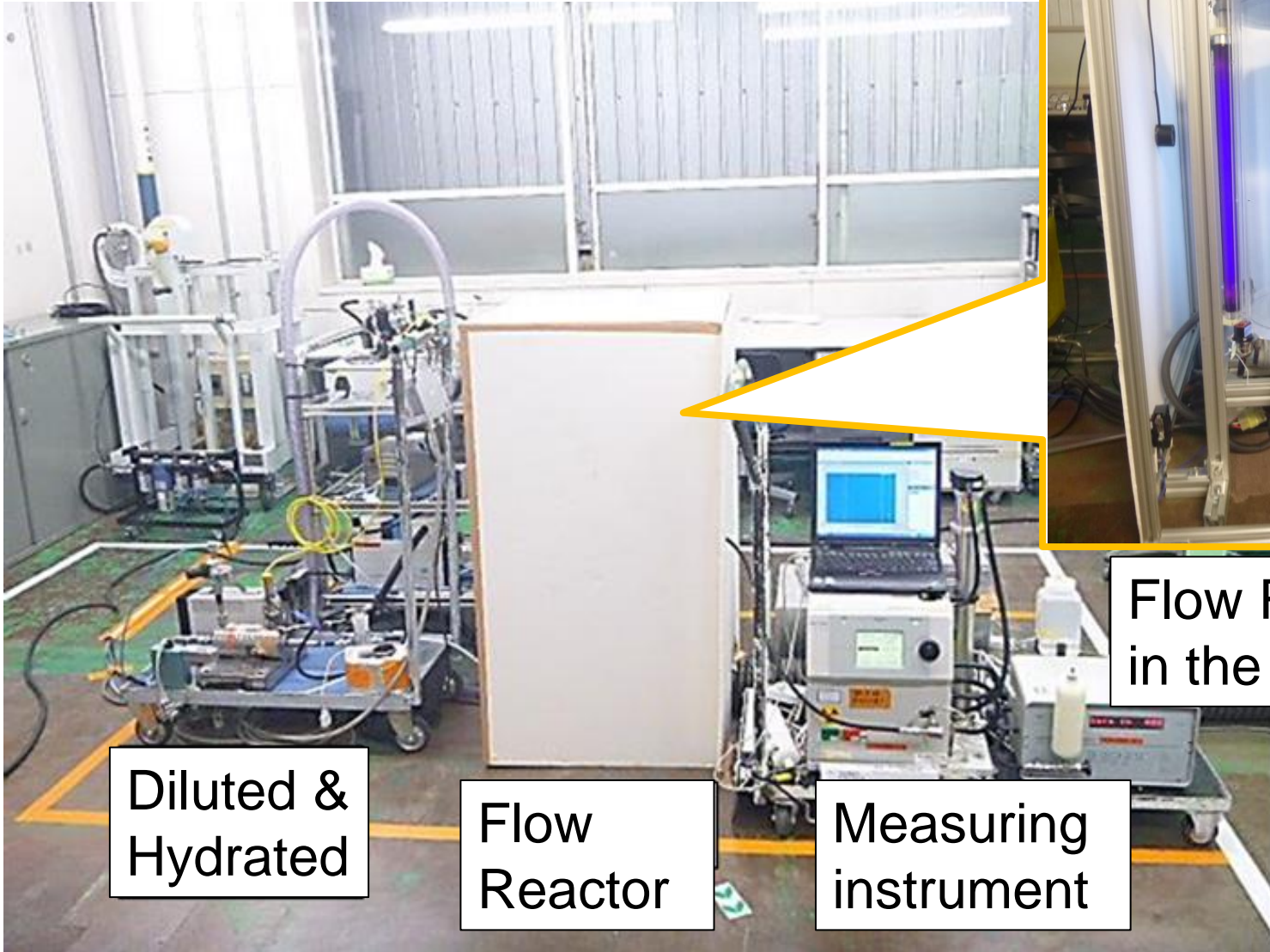
- Complicated handling
- Long reaction time (>1hr)

- High wall loss
- Different from the atmospheric reaction



# Our Flow Reactor System

500mm x 225mm i.d.



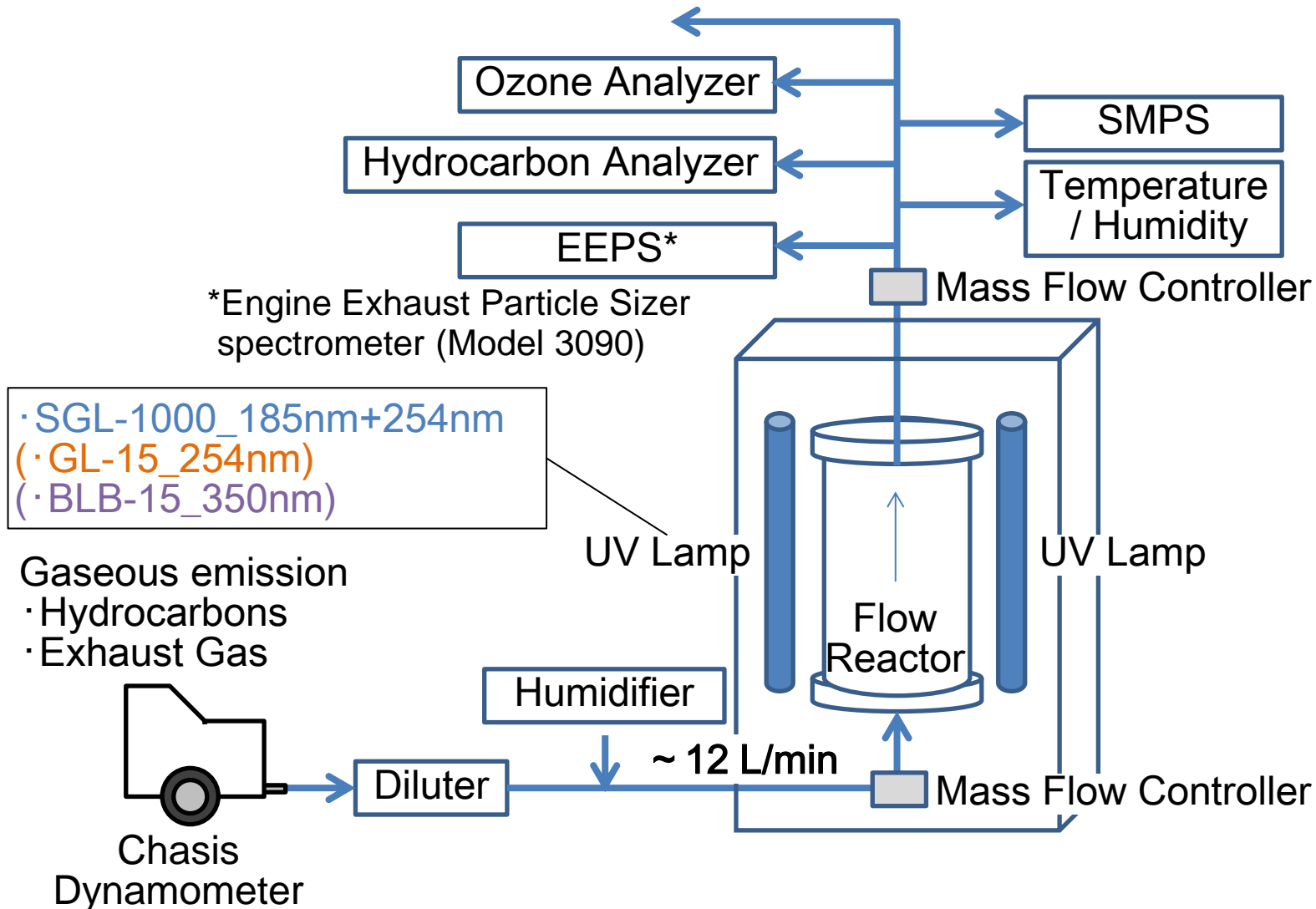
Flow Reactor in the cover

Diluted & Hydrated

Flow Reactor

Measuring instrument

# Our Flow Reactor System





# Objective

(Ref.)PosterNo.57@2017 ETH conference

## Investigation of the simplified measurement technique of the secondary aerosols formed from gaseous emissions of vehicle exhaust

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TOYOTA Environmental Action

- Steadily introduce low-emission vehicles that contribute to improving the urban environment in each country and region.
- Contribute to atmospheric environment improvement through collaboration with research organizations in each country.

### Motivation Needs(1)

Understanding the actual atmospheric situation of the secondary aerosols derived from automobile exhaust.

- Generation of the secondary aerosols
- Contribution ratio to the  $PM_{2.5}$

### Needs(2)

Evaluation method of the secondary aerosols.

[Small, Simple, Swift]

- Application to engine bench and chassis dynamometer
- Survey of various vehicle systems

### Objective

To investigate the evaluation methods of the secondary aerosols formed from gaseous emissions with flow reactor.

### Background

The achievement ratio of  $PM_{2.5}$  environmental standard is low in Japan.

The ratio of secondary aerosols in  $PM_{2.5}$  is high in Japan.

The contribution of automobiles to the secondary aerosols is unidentified.

### Standard Tools

	Smog Chamber	Flow Reactor
Outline	UV Lamp (Wavelength: ~300nm) Smog Chamber	UV Lamp (Wavelength: ~300nm) Preheated Aerosol Chamber Mass Flow Controller
Advantage	Can simulate the reaction in atmosphere	Can simulate the reaction in atmosphere
Weak Point	Complicated handling Long reaction time (1~1h)	High wall loss Different from the atmospheric reaction

### Methods

#### Toyota Tools

#### Chamber

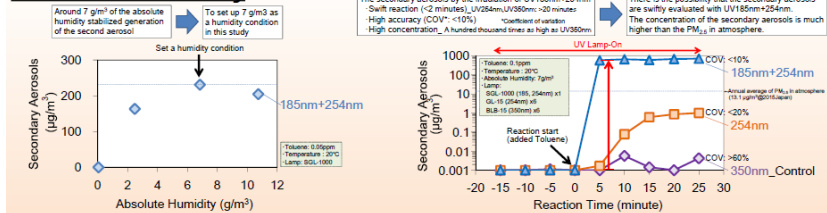
#### Lamps

Ultraviolet(UV) of short wavelength are used for the acceleration of the photochemical reaction.

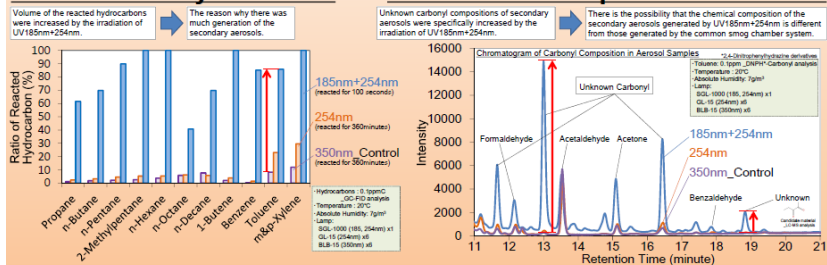
- UV185nm  $O_3$ ,  $O_2$  Generation of Ozone
- UV254nm  $C_2O$ ,  $OH$  Generation of Hydroxyl radical
- UV350nm As control test of photochemical reaction

## Results

### 1. Effect of Humidity



### 2-2. Precursor Hydrocarbons



**Conclusion**

- Secondary aerosols can be evaluated swiftly with UV185nm+254nm.
- The chemical composition of the secondary aerosols may be different from those in atmosphere.

We will investigate the method that the gaseous emission is not irradiated by the short wavelength UV in future.



[Last year]  
We reported the effect of UV wavelength and humidity of the flow reactor.

[This study]  
We examined the application to evaluate transient generation of secondary aerosols from the exhaust gas.

1. Background

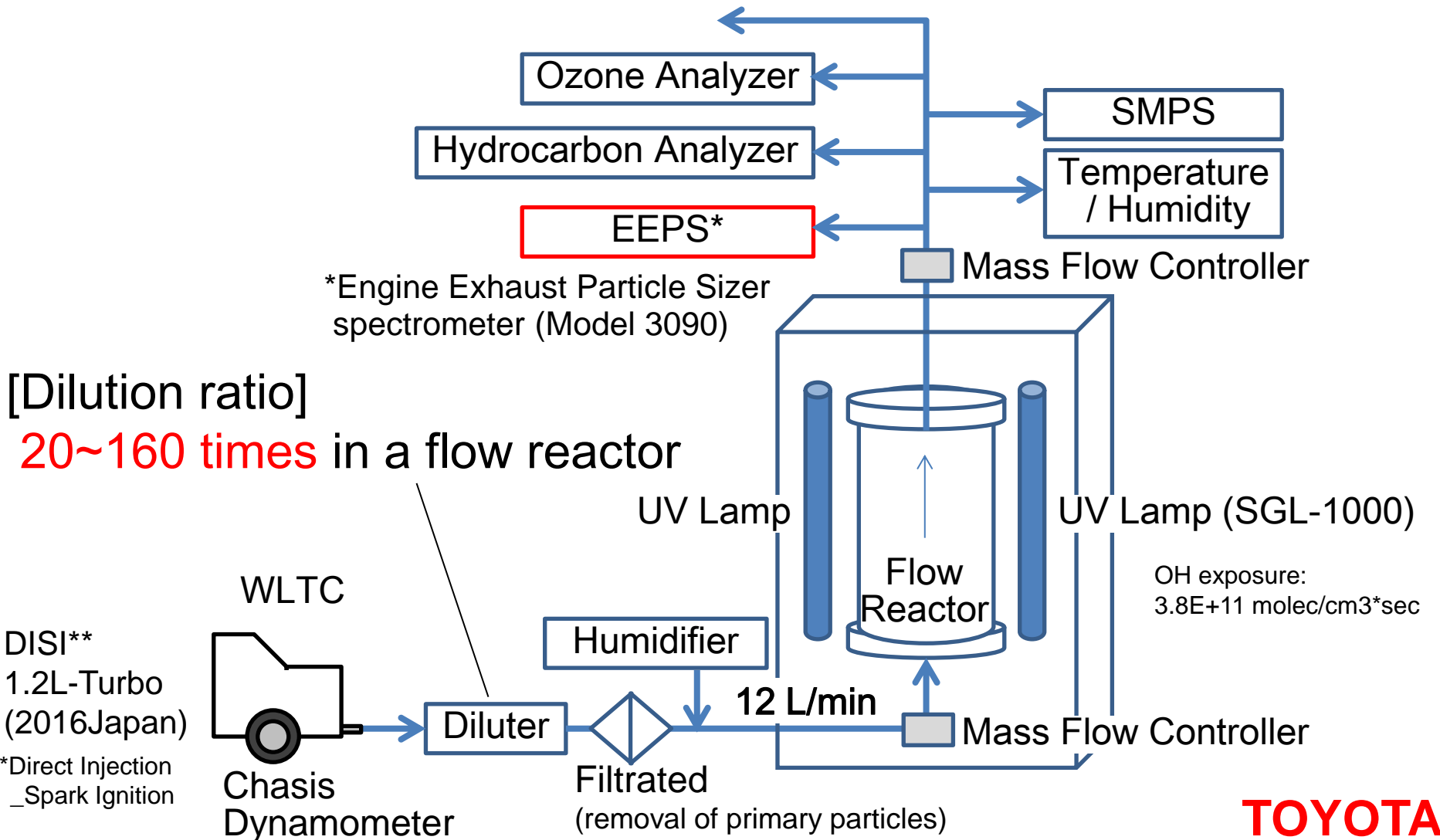
**2. Reactivity of the secondary aerosol generation to hydrocarbon**

3. Evaluation of transiently secondary aerosol from exhaust gas

4. Conclusion

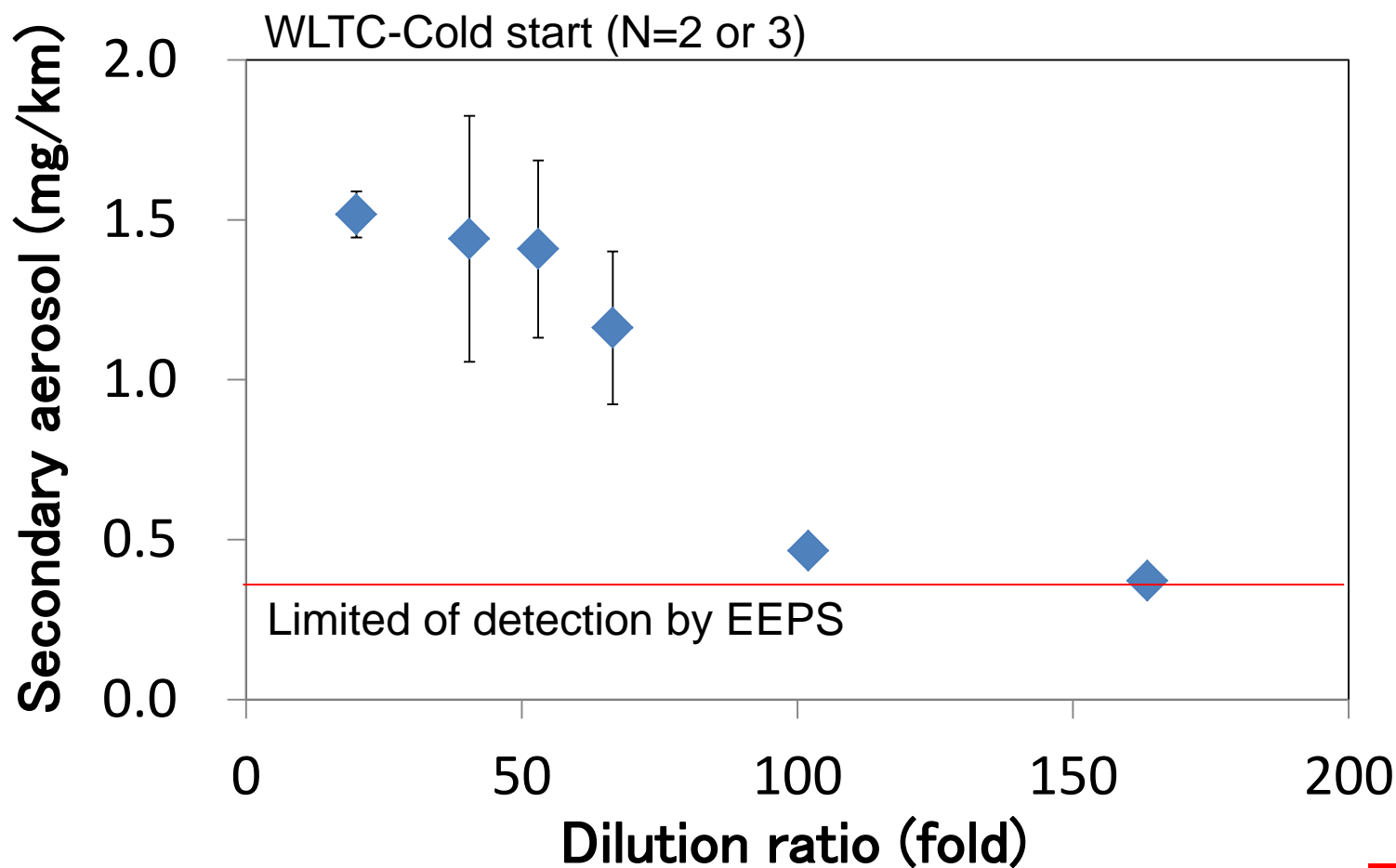
# Method

We evaluate the reactivity of secondary aerosol generation to hydrocarbon by being changed the dilution ratio of exhaust gas.



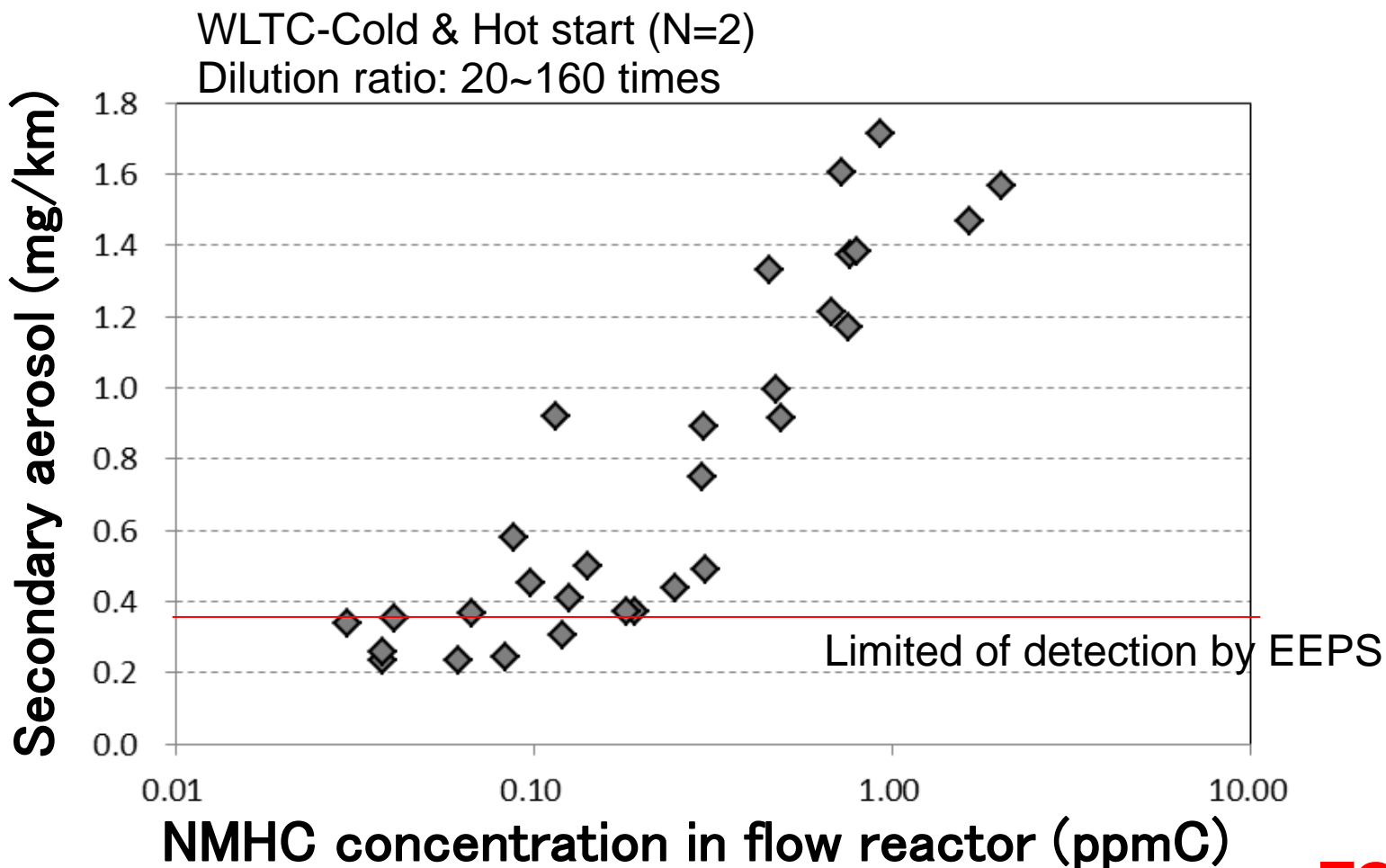
# Effect of Dilution Ratio of Exhaust <sup>12</sup>/<sub>122</sub>

The generation per kilometer of the secondary aerosols varies according to the dilution ratio of the exhaust gas.



# Contribution of Hydrocarbon

Our flow reactor system can detect the secondary aerosols generated from NMHC\* of more than about 0.1 ppmC.

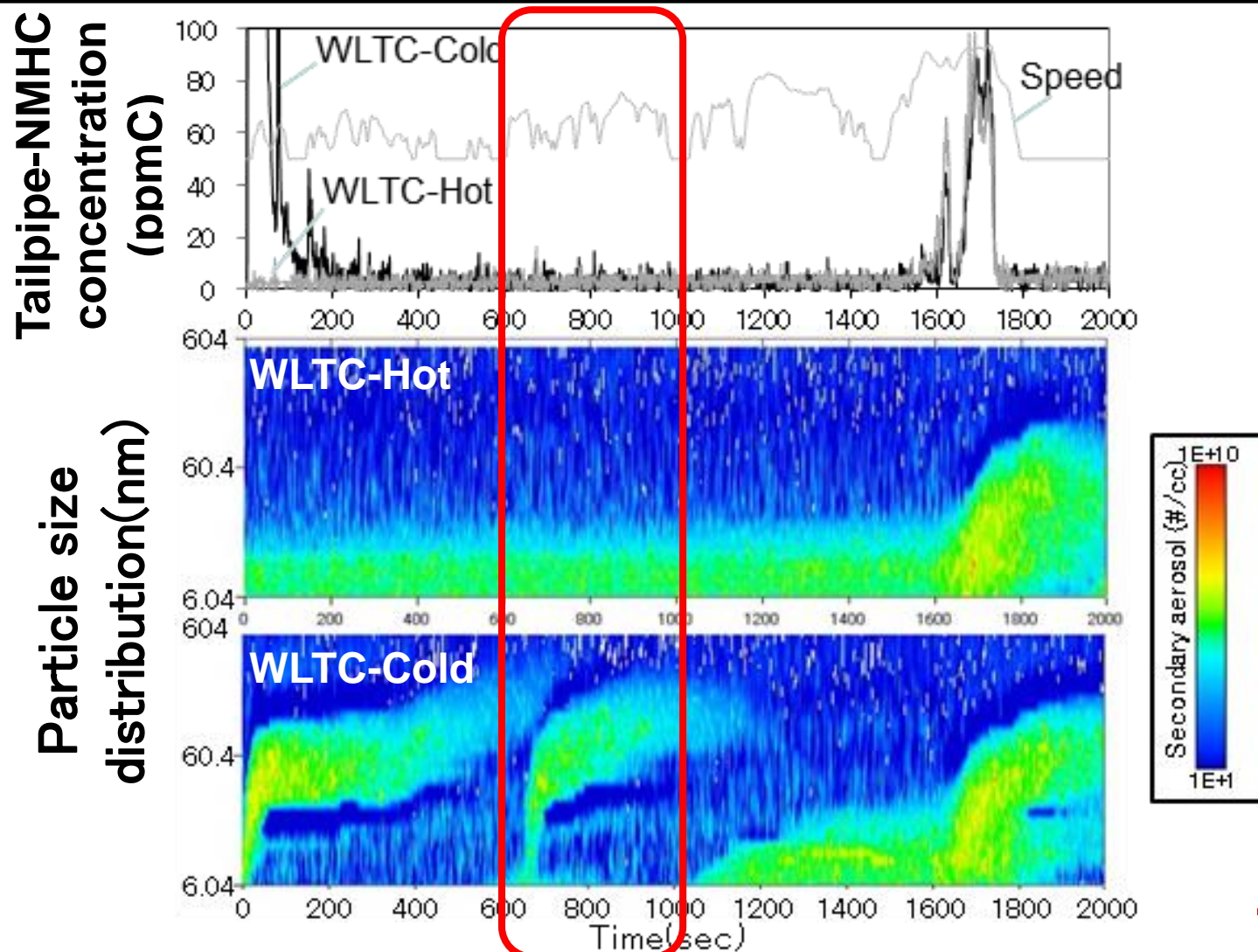


\*Non-Methane HydroCarbons

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# WLTC Cold vs. Hot Start

Even if NMHC are the same level, the generation of secondary aerosol are different between WLTC-Cold and Hot start.

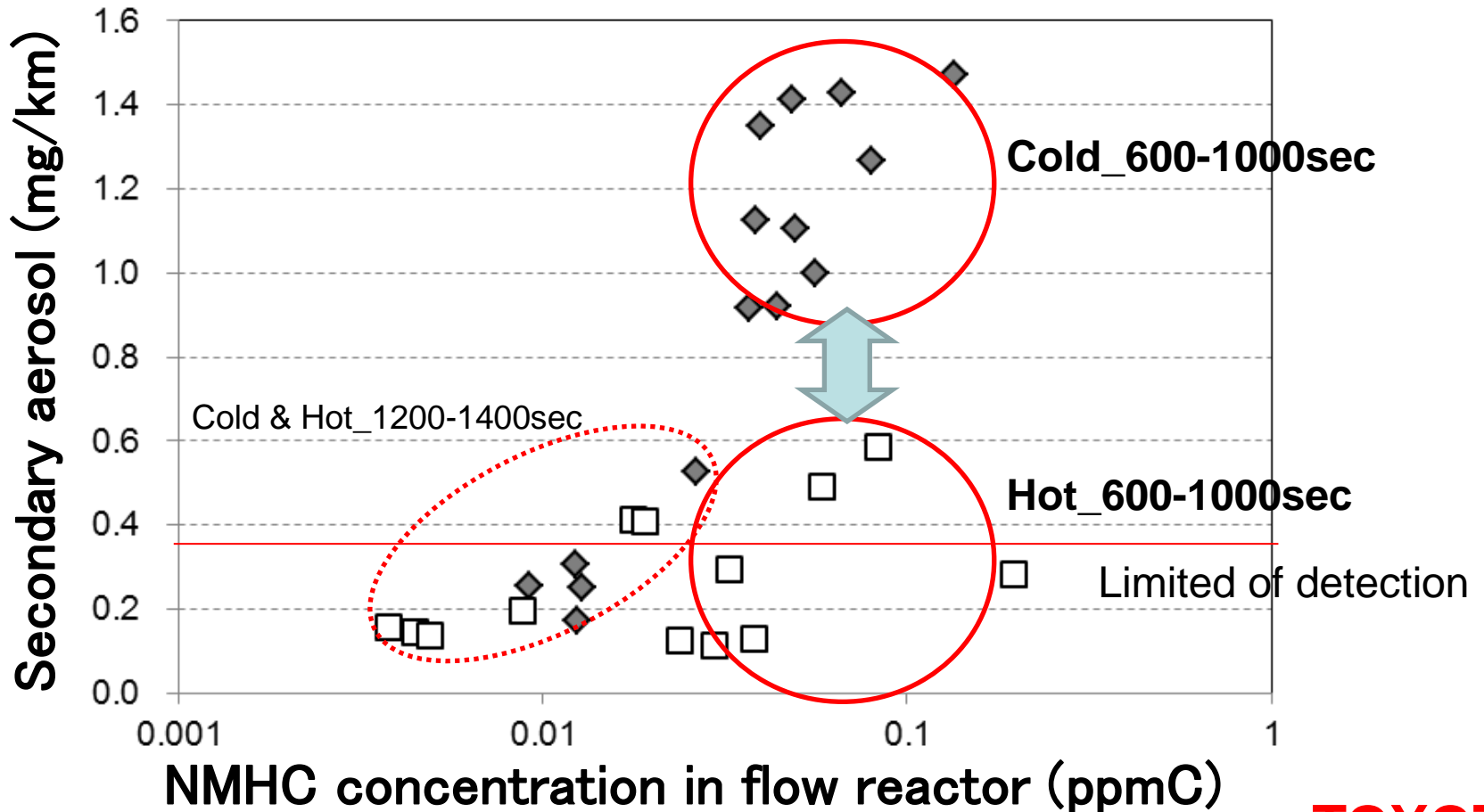




# Contribution of Hydrocarbon

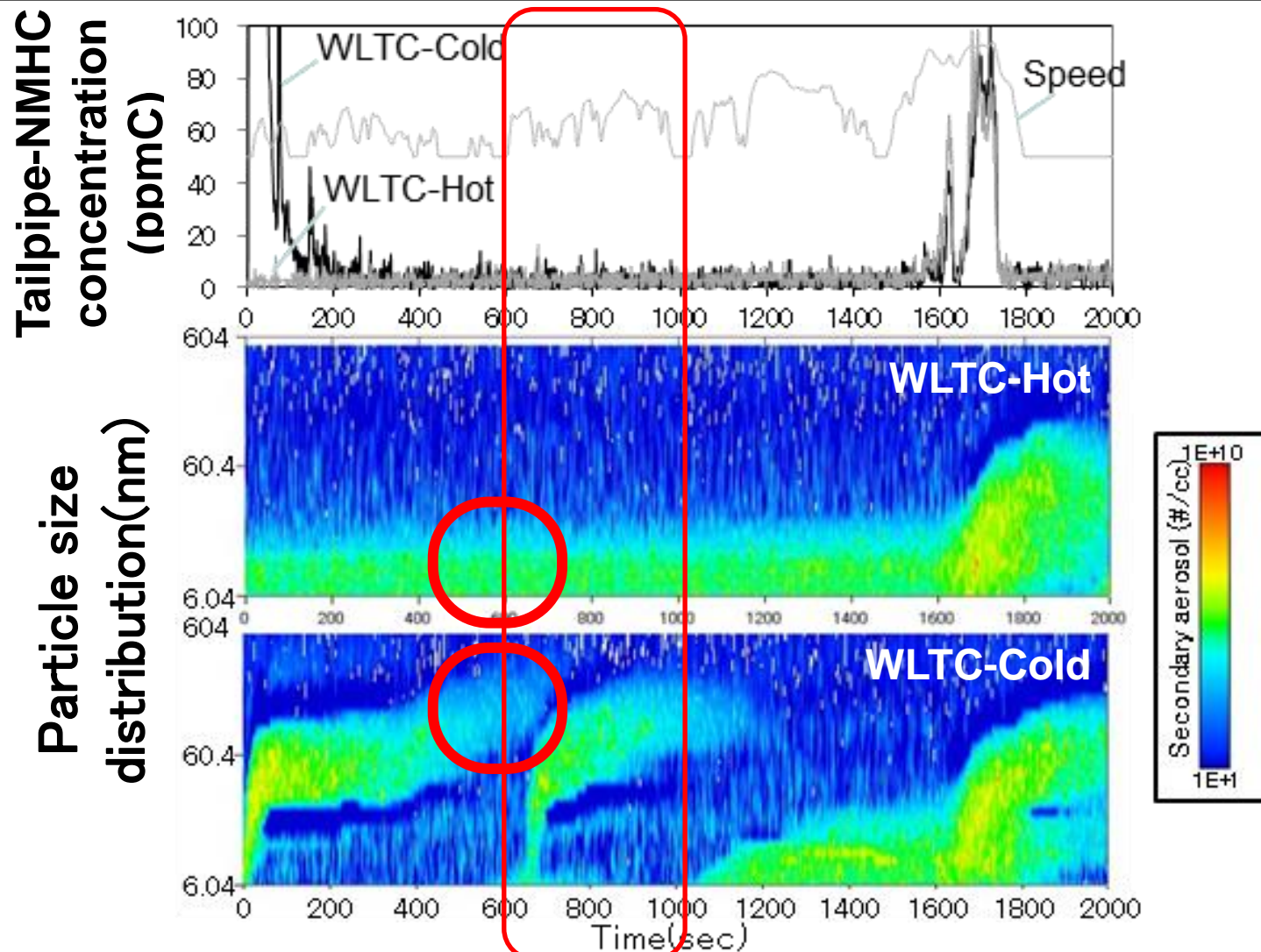
Even if NMHC are the same level, the generation of secondary aerosol are different between WLTC-Cold and Hot start.

Day variation data



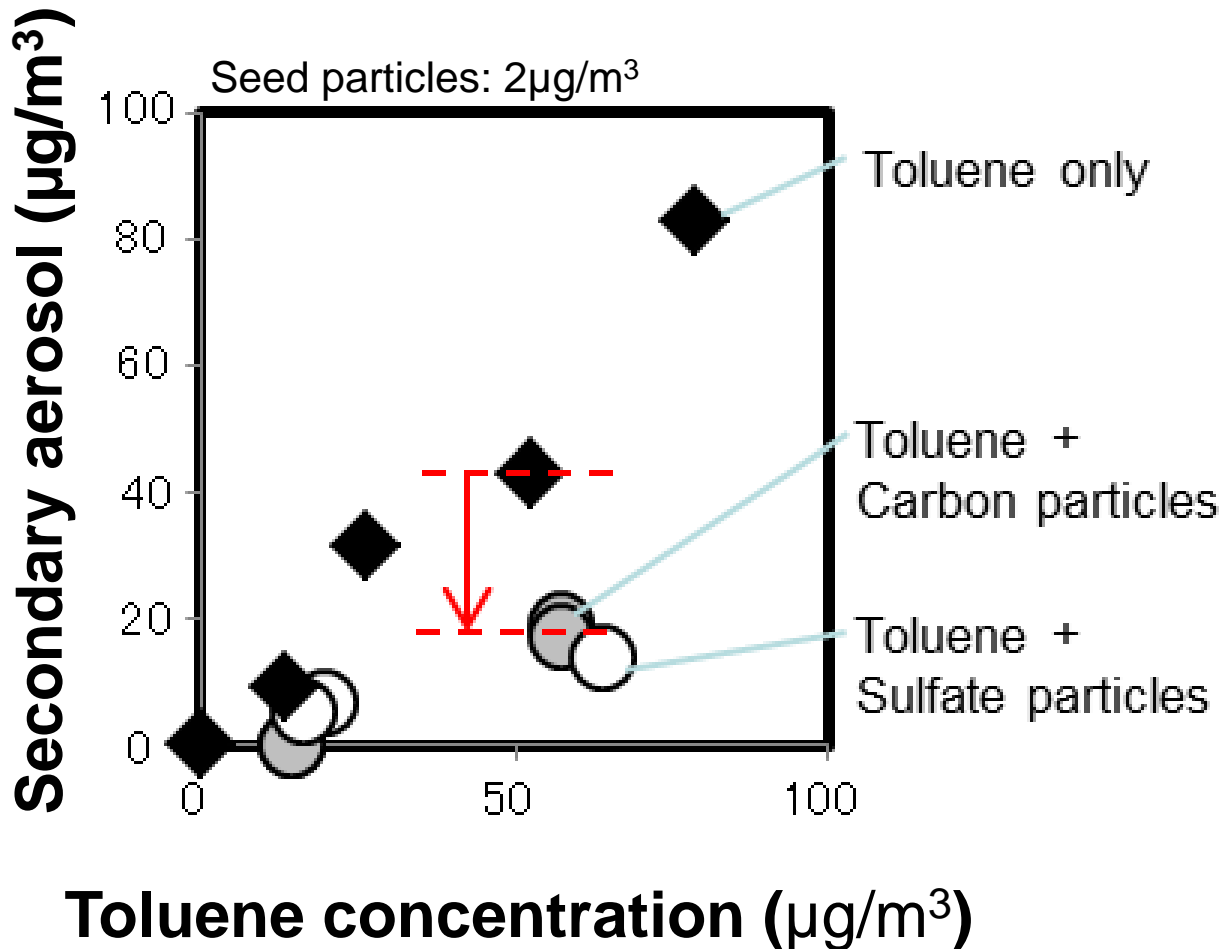
# Hypothesis

We supposed that the seed particles in a flow reactor affect the generation of secondary aerosols.



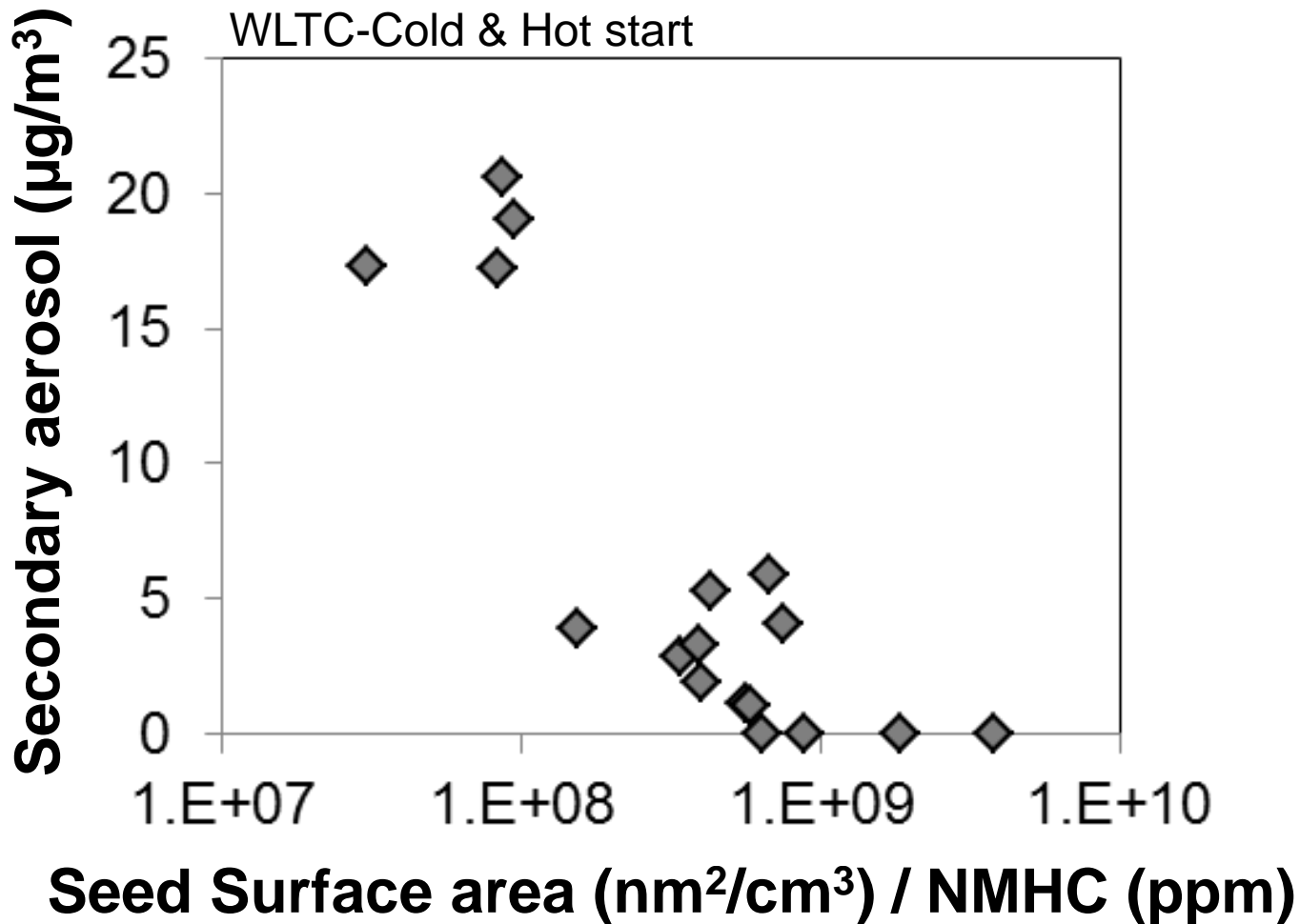
# Effect of Seed Particles

Each seed particle decreases the secondary aerosol generated from toluene.



# Effect of Seed Surface Area

The secondary aerosol generate in a flow reactor when seed surface area per NMHC is less than  $1.0E+9$ .



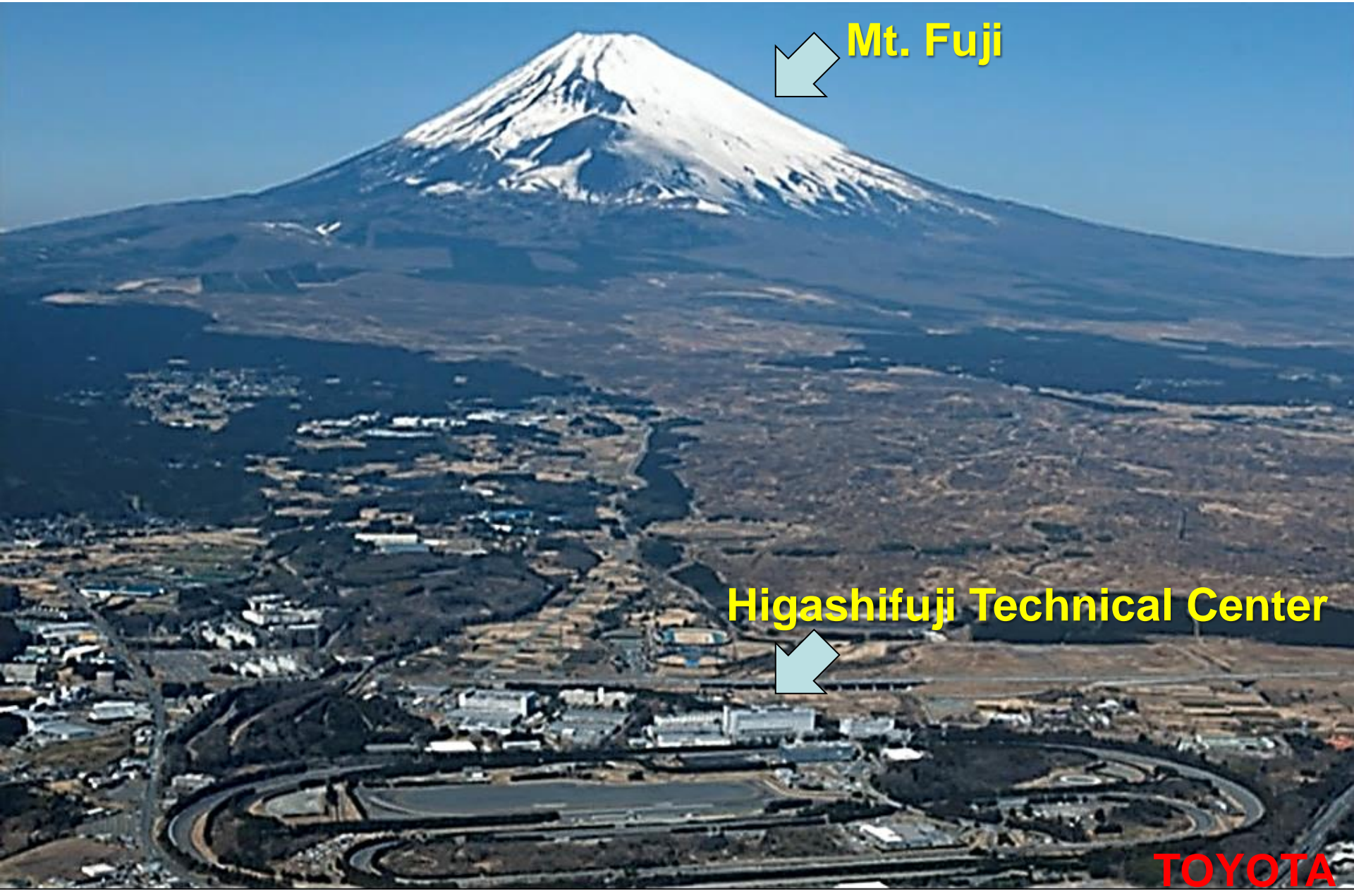
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# Conclusion

- Even if NMHC are the same level after engine warmed up, the generation of secondary aerosols by a flow reactor are different between WLTC-Cold and Hot start.
- The generation of secondary aerosols are decreased by seed particles in a flow reactor.
- It is necessary to remove the seed particles from a flow reactor to evaluate the transient generation of secondary aerosols.
  - ⇒ But it is very difficult, because the countermeasure mentioned above includes many problems.



# Thank you for your attention



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TOYOTA