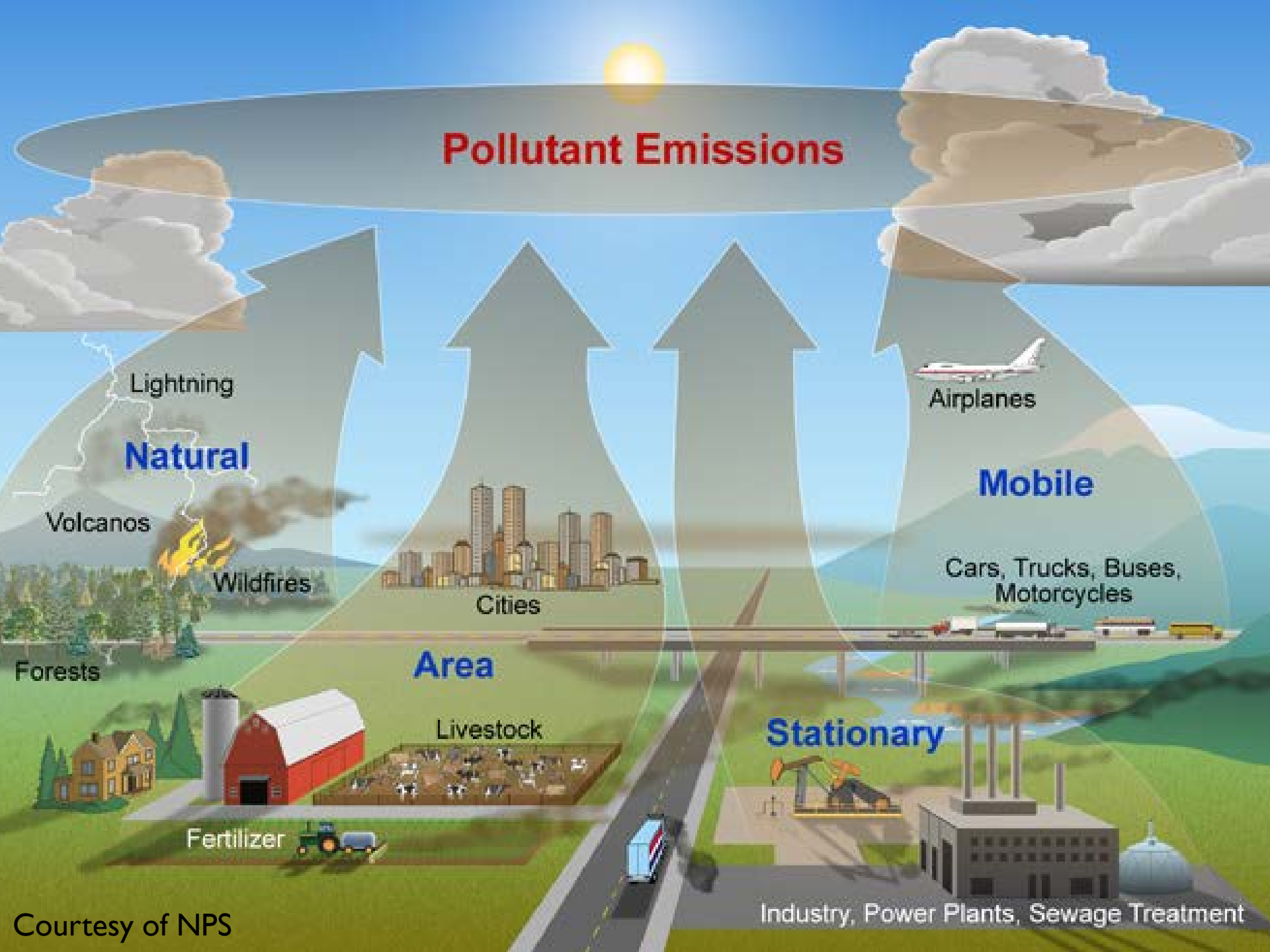
Real-life Filter Loading Test Rig: Salt-Soot-Oil mixture, RH Effect, and Temperature

Chenxing Pei, Qisheng Ou, and David Y.H. Pui
Particle Technology Laboratory, University of Minnesota

CFR

UNIVERSITY OF MINNESOTA

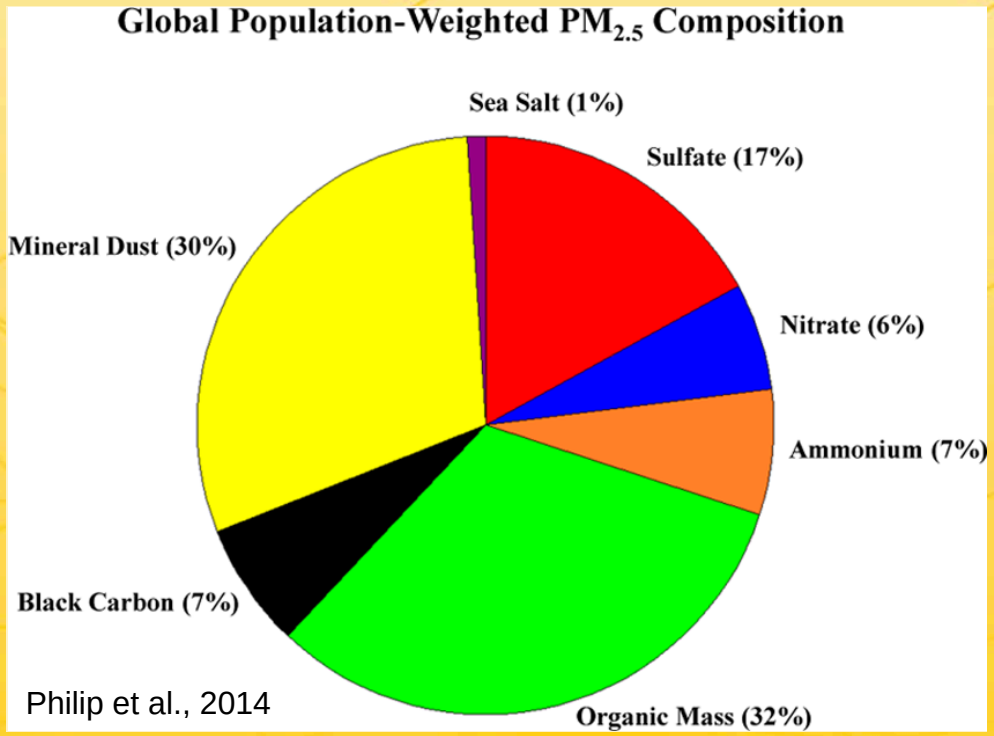


Courtesy of NPS

EPA Criteria Air Pollutants

PMs Affects the Filter Performance

- Dust
- Salt
  - NaCl
  - $(NH_4)_2SO_4$
  - NH_4NO_3
- Organic matter
  - VOCs
- Soot



Philip et al., 2014

Extreme Temperature and RH on Earth

Temperature

- Lowest reliably measured temperature on earth:
  - −89.2 °C; −128.6 °F; 184.0 K
  - Vostok Station, Antarctica
  - July 21, 1983
- Highest confirmed temperature on earth:
  - 54 °C; 129 °F; 327.2 K
  - Mitribah, Kuwait
  - July 21, 2016

Relative Humidity

- Lowest relative humidity:
  - 0.36% (46.5 °C with -33.2 °C dewpoint)
  - Safi-Abad Dezful, Iran
  - June 20, 2017
- Highest relative humidty:
  - 100% !
  - Rain, fog

Comparison between Life & Lab

Life

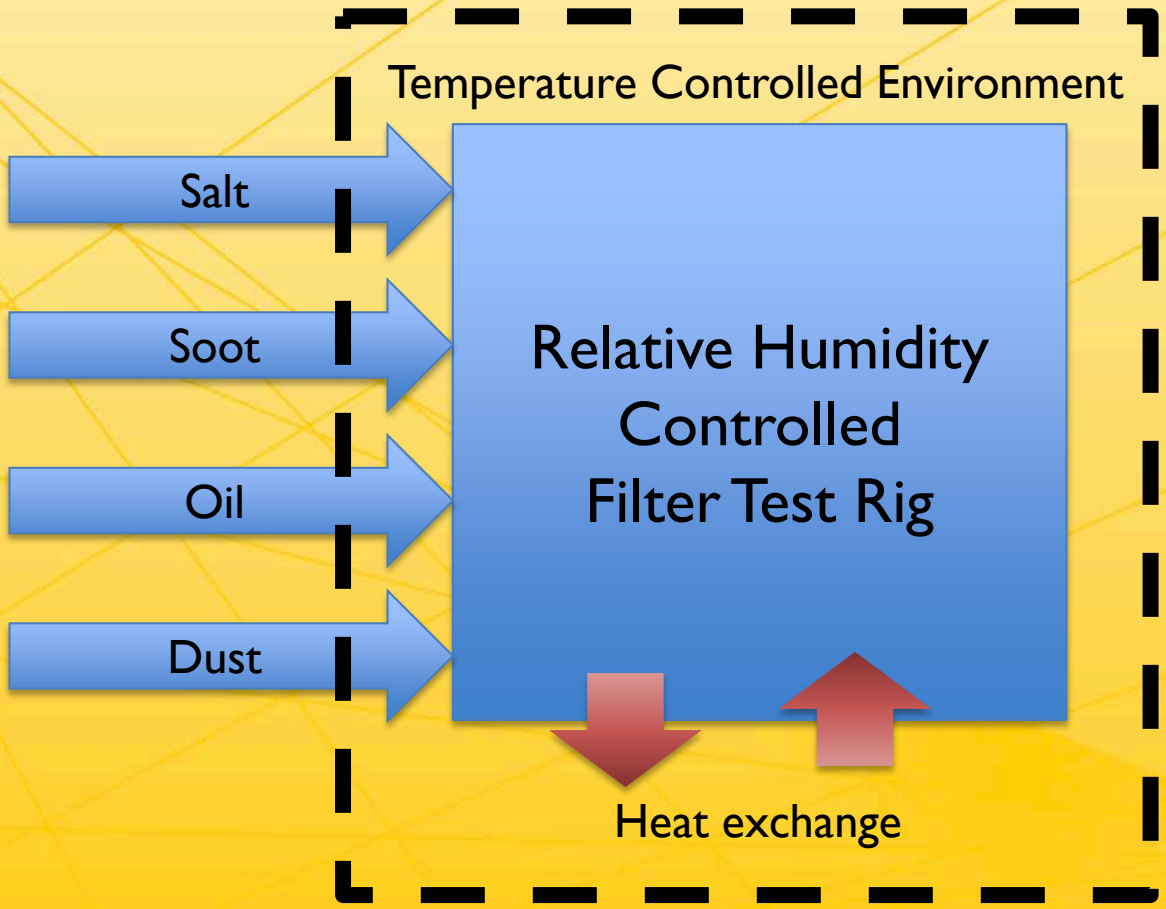
- Particle:
  - Multiple pollutants existence
- Temperature:
  - −89.2 °C to 54 °C
- Relative Humidity
  - 0.36% to 100%

Lab

- Particle
  - Single test aerosol
- Temperature:
  - Room temperature
  - Unknown
- Relative Humidity
  - Uncontrolled
  - Unknown

How well the lab filter test could represent the real life filter performance?

Real-life Filter Test Rig is needed

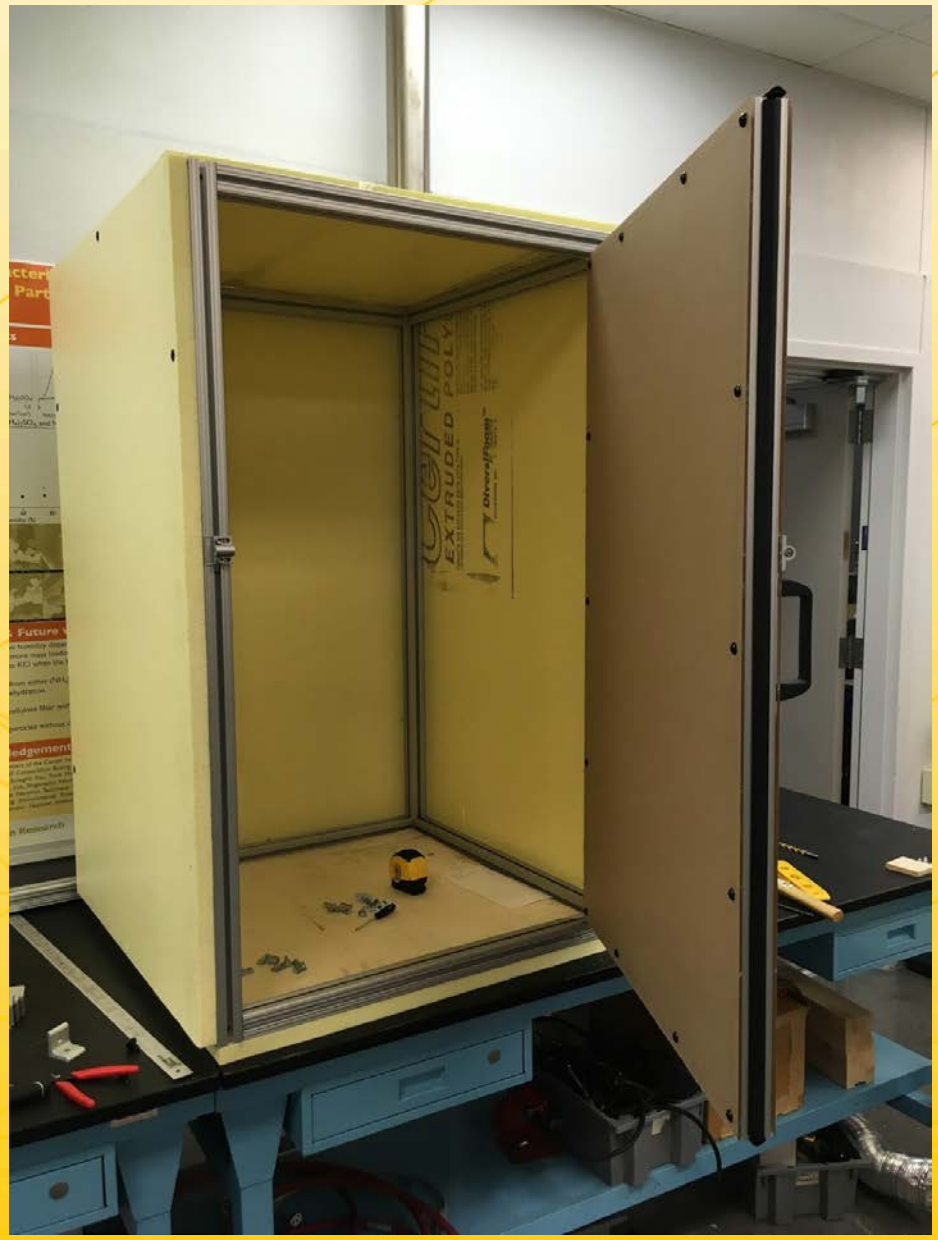


Design Specification

- Temperature range:
  - -20°C to 50°C
- Relative humidity range:
  - 0% to 100% in the temperature range
- Module design for particle generation
- Multi-sample testing capability
- Automated test system

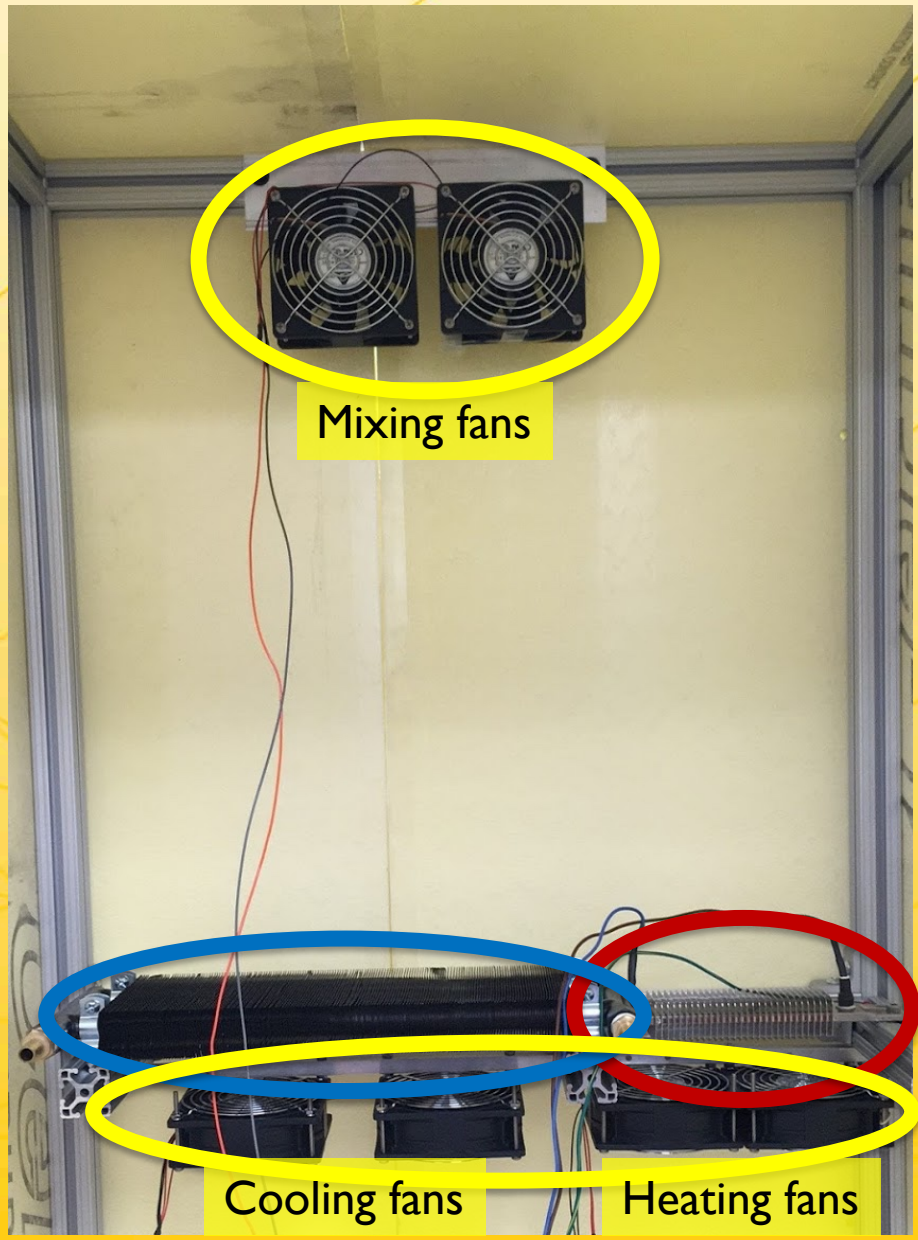
Insulation Enclosure

- A 2.5ft×2.5ft×4ft (L×W×H) structure was built with 80/20 aluminum frame.
- 1 inch thick polystyrene sheet covers 5 faces of the frame except the front face, which one is covered by home-made double panel acrylic sheet.



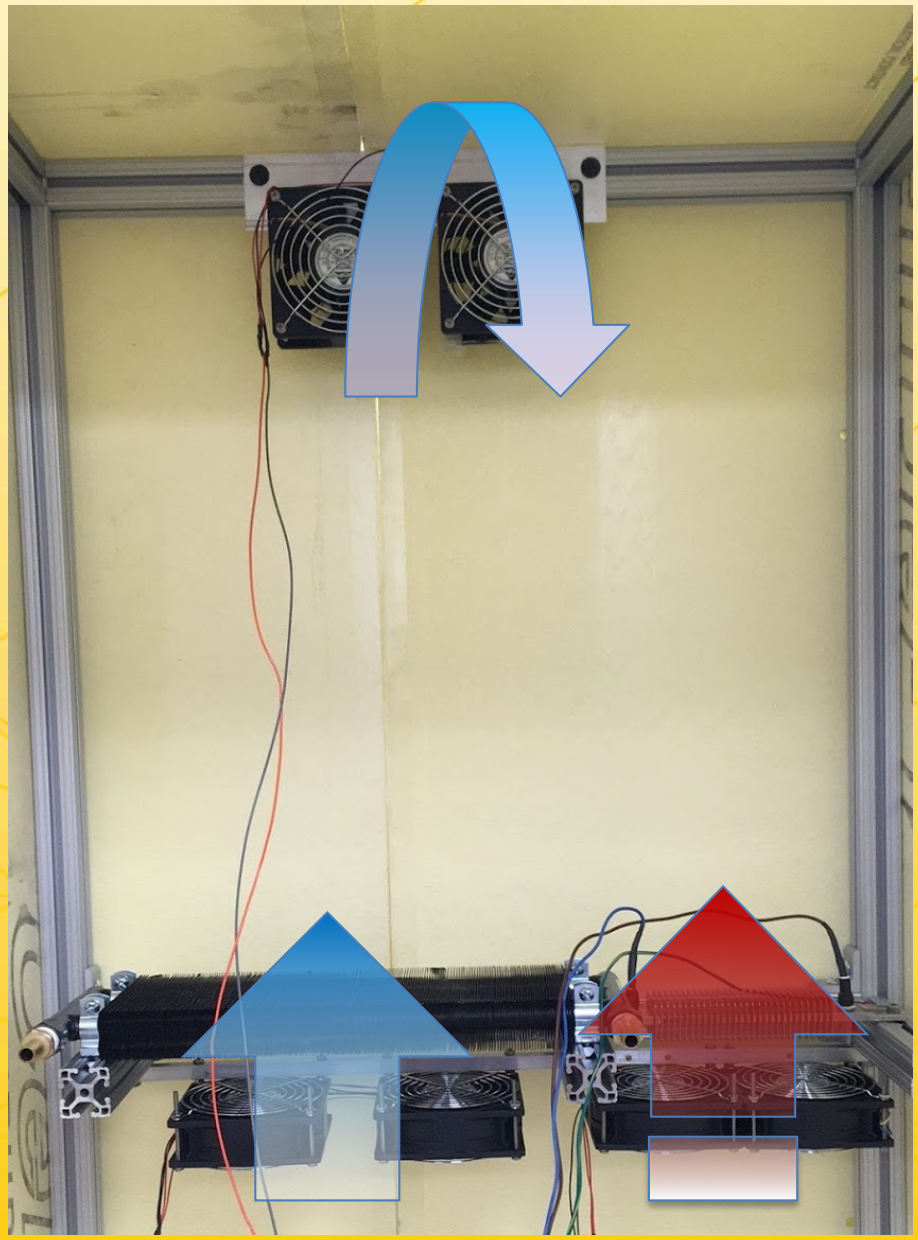
Heating and Cooling I

- Two 350W electric heaters with fins are installed to heat the enclosure
- A radiator type heat exchanger coupled with a chiller is utilized to cool the enclosure
- 3 pairs of fans are used to circulating air in the enclosure



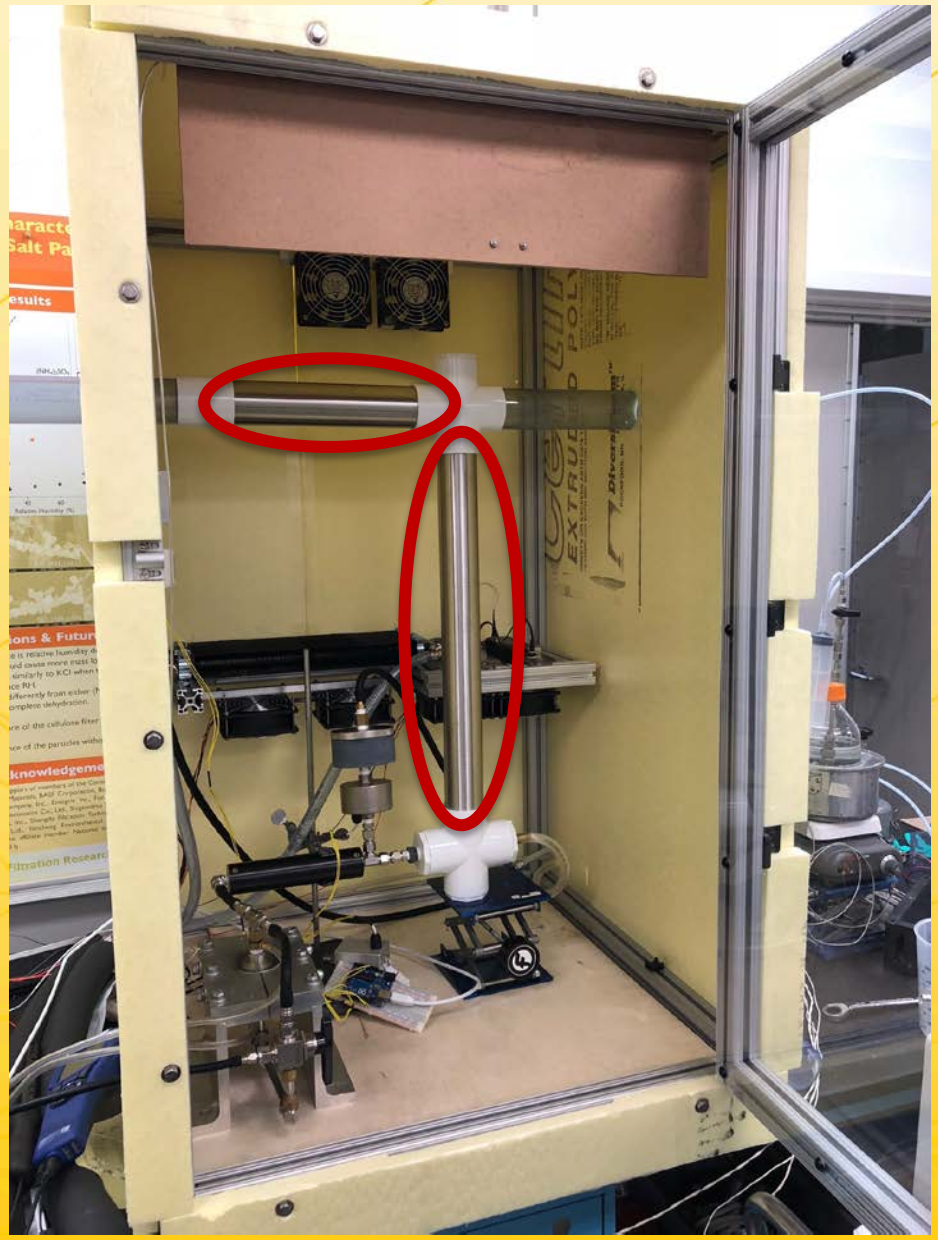
Heating and Cooling II

- 3 Pairs of fans runs constantly, and each of the fan supply ~210 CFM air flow.
- Chiller is set 5°C below the test temperature.
- The heaters are PID controlled by a temperature controller which is setting to the test temperature.

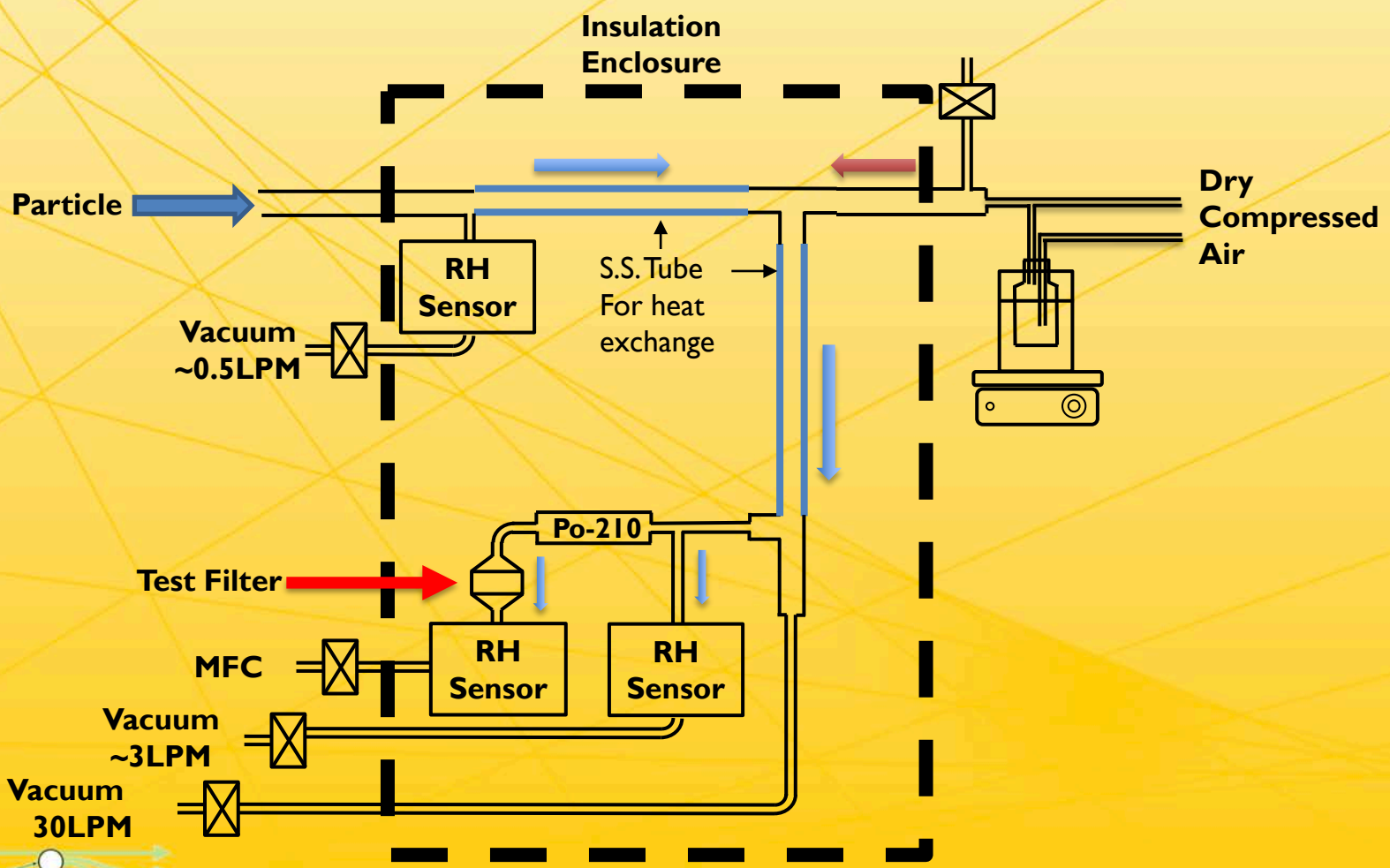


Install filter test rig in insulation enclosure

- Replace the PVC tube by stainless steel tube to enhance the heat transfer between the aerosol system and insulation enclosure.
- Temperature sensitive devices, such as pressure transducer, flow meter, are not installed inside the insulation enclosure.



Test System

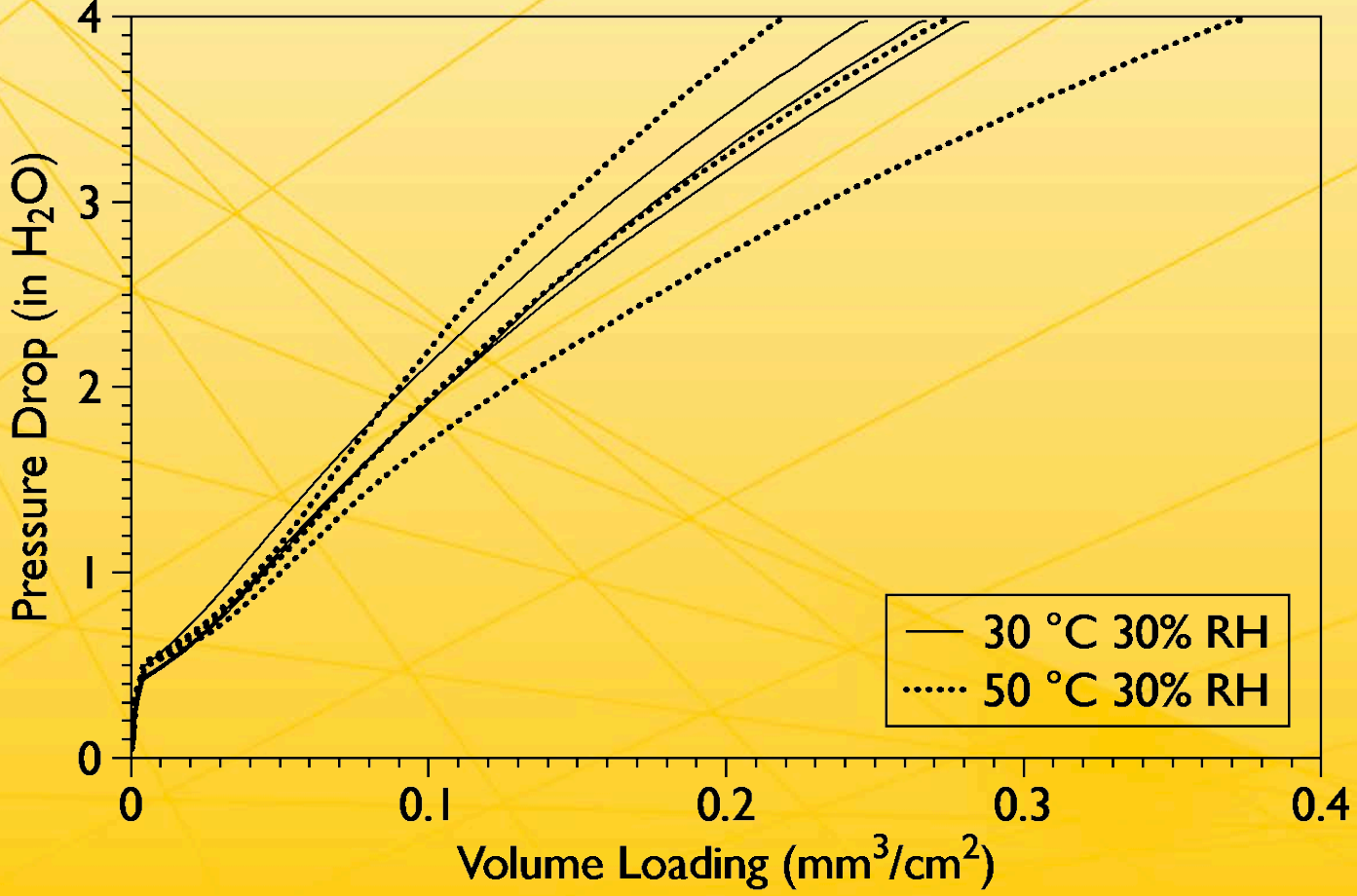


Test System

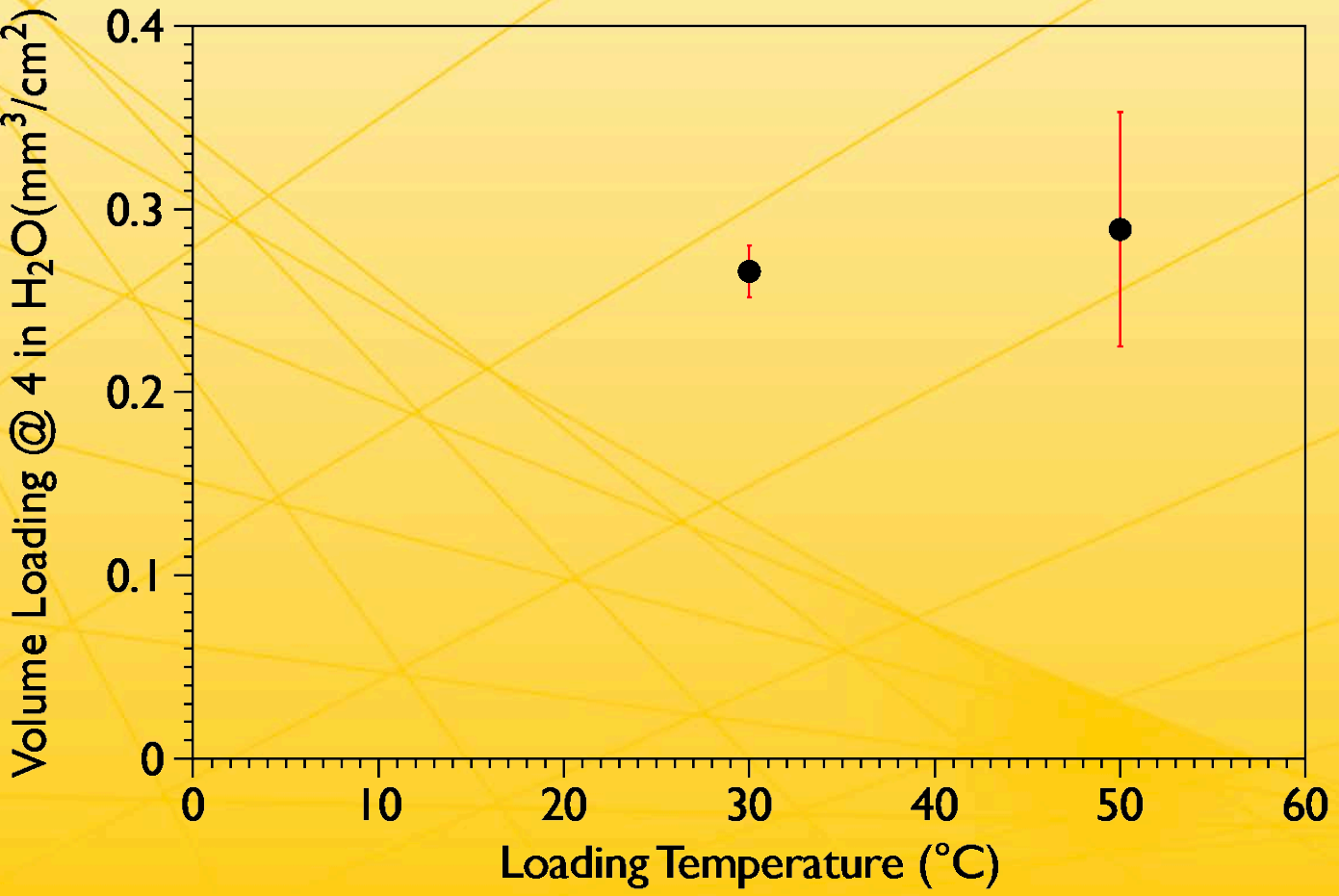
Current Status

- Temperature range:
  - 0°C to 50°C
- Relative humidity range:
  - 0% to 100% in partial temperature range
  - At 0°C, only high RH(~>60%) could reach
  - At 50°C, only low RH(~<45%) could reach
- Module design for particle generation
- Single sample testing
- Semi-automated test system

Test Runs' Loading Curves



Test Runs' Volume loading



Future Work

- Achieve stable low relative humidity loading at low temperature, and stable high relative humidity loading at high temperature.
- Add the second filter holder to perform the parallel filter testing.
- Rewiring current electric components.