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Fine PM Emission Factors for Gas Turbine Engines

Glenn C. England
Principal Consultant
ENVIRON International Corporation
Irvine, California 92629

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Overview

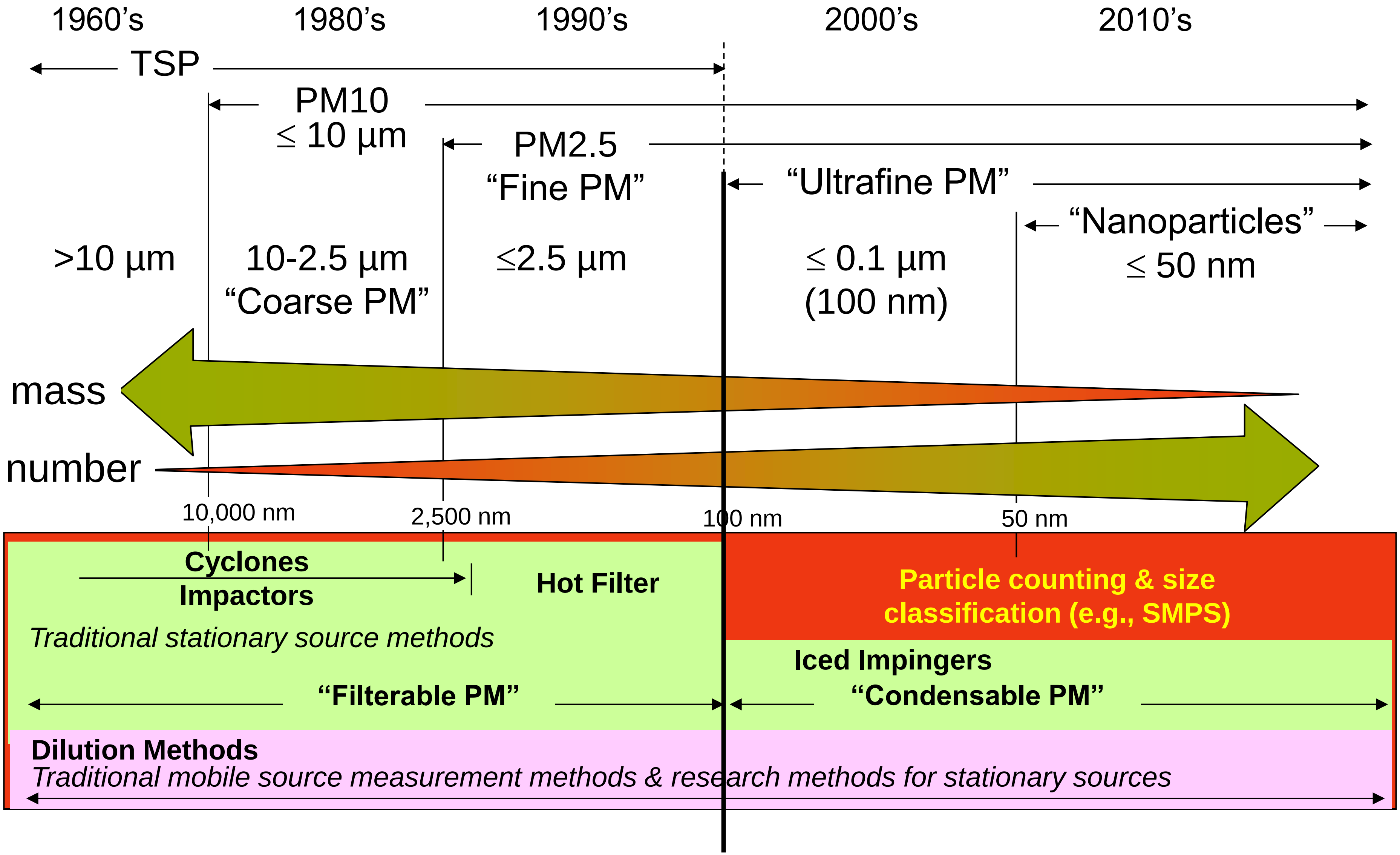
- Particulate matter (PM) & regulations
- PM Emissions from gas-fired engines
- Emission factors
- Measurement influences & impacts

We need better measurements of PM emissions from gas-fired sources

Why Are Fine PM Emissions from Gas Turbines Relevant?

- Increasing natural gas use for power generation
- Typical 500 MW NGCC plant “emits” ~30-50 tpy
  - All submicron aerosols
- New Source Review
  - 10 tons/year PM2.5 Prevention of Significant Deterioration threshold
    - triggers modeling, technology, offset requirements = time, $
  - Includes filterable and condensable PM
- Impediment to licensing new power plants in California due to lack of PM10/2.5 offsets
- Evolving interest in human health effects of “ultrafine” PM and nanoparticle emissions

Particulate Matter



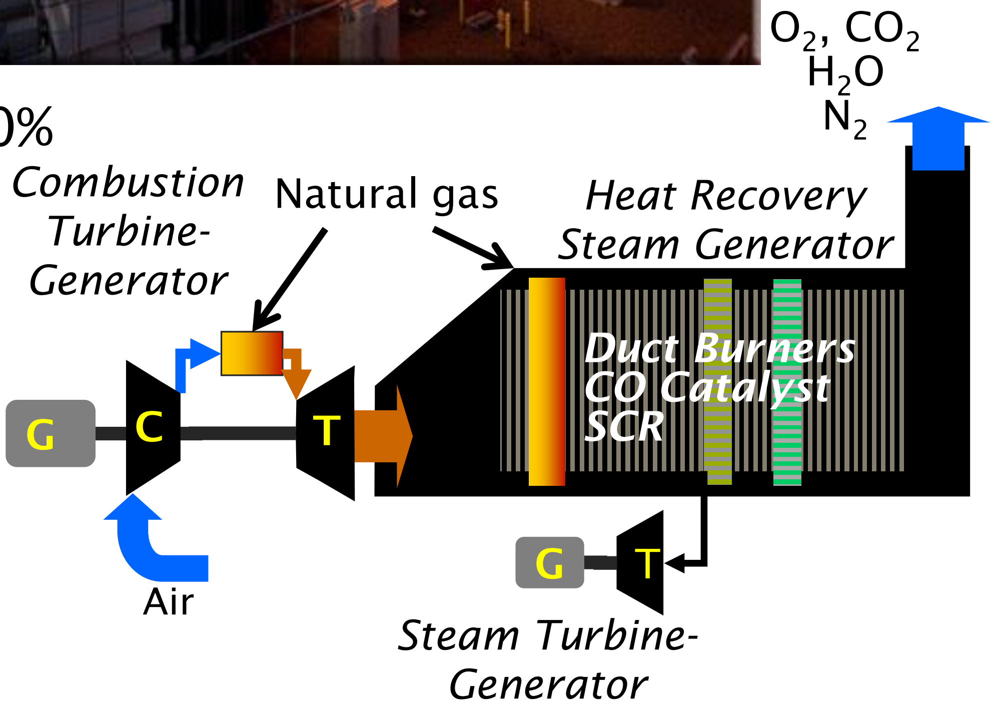
PM10 and PM2.5

- Definitions - 40 CFR 51, §51.50:
  - *Filterable PM2.5/PM10 : Particles that are directly emitted by a source as a solid or liquid at stack or release conditions and captured on the filter of a stack test train.*
  - *Condensable PM: Material that is vapor phase at stack conditions, but which condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack.*
- Particulate matter is defined by the test methods used to measure it!

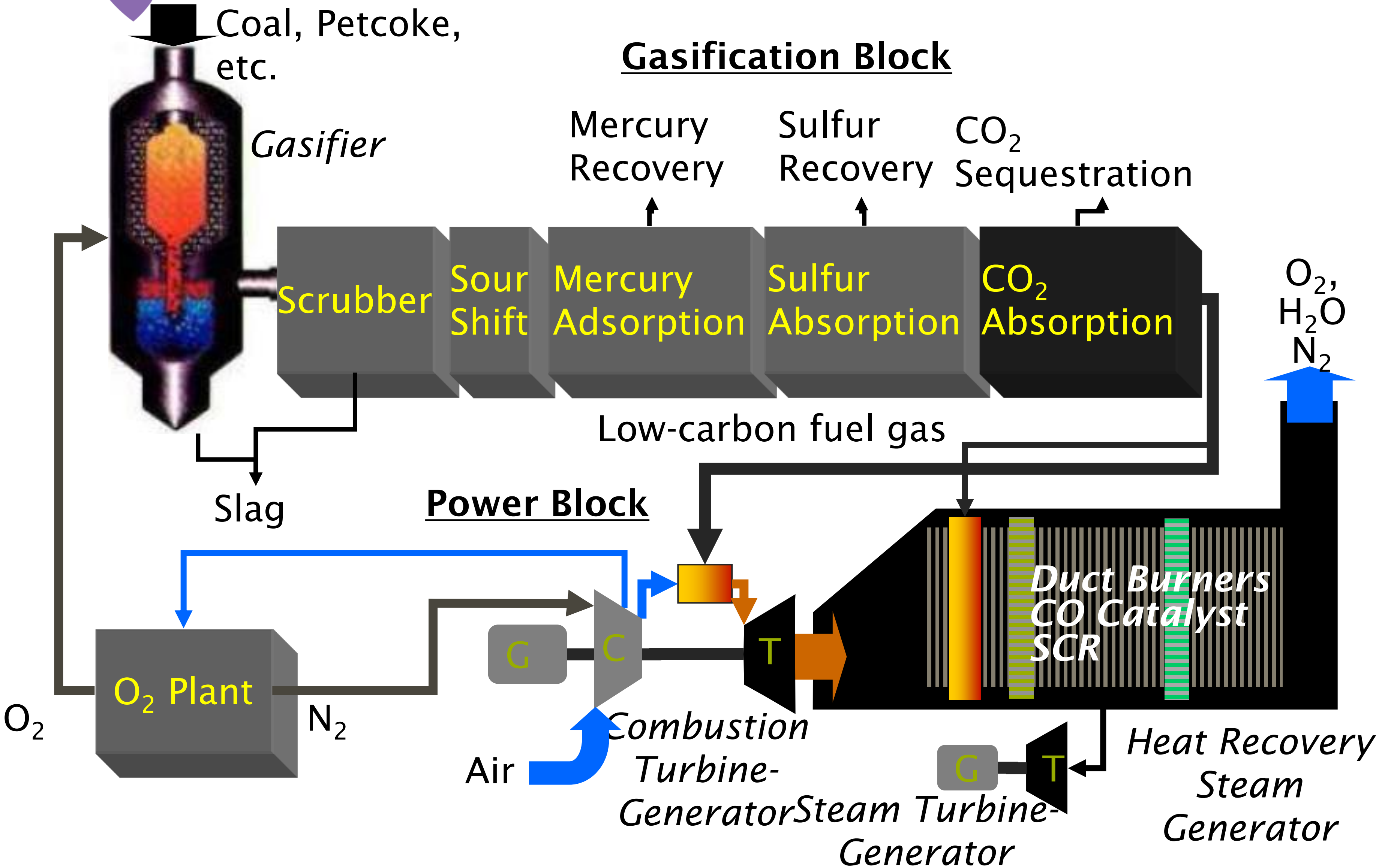
Natural Gas-Fired Combined Cycle

- Gas turbines & steam turbines
  - Brayton+Rankine
  - “2 on 1” or “3 on 1” blocks
  - ~500-800 MW/block
  - Duct burners
  - Thermal efficiencies ~55->60%

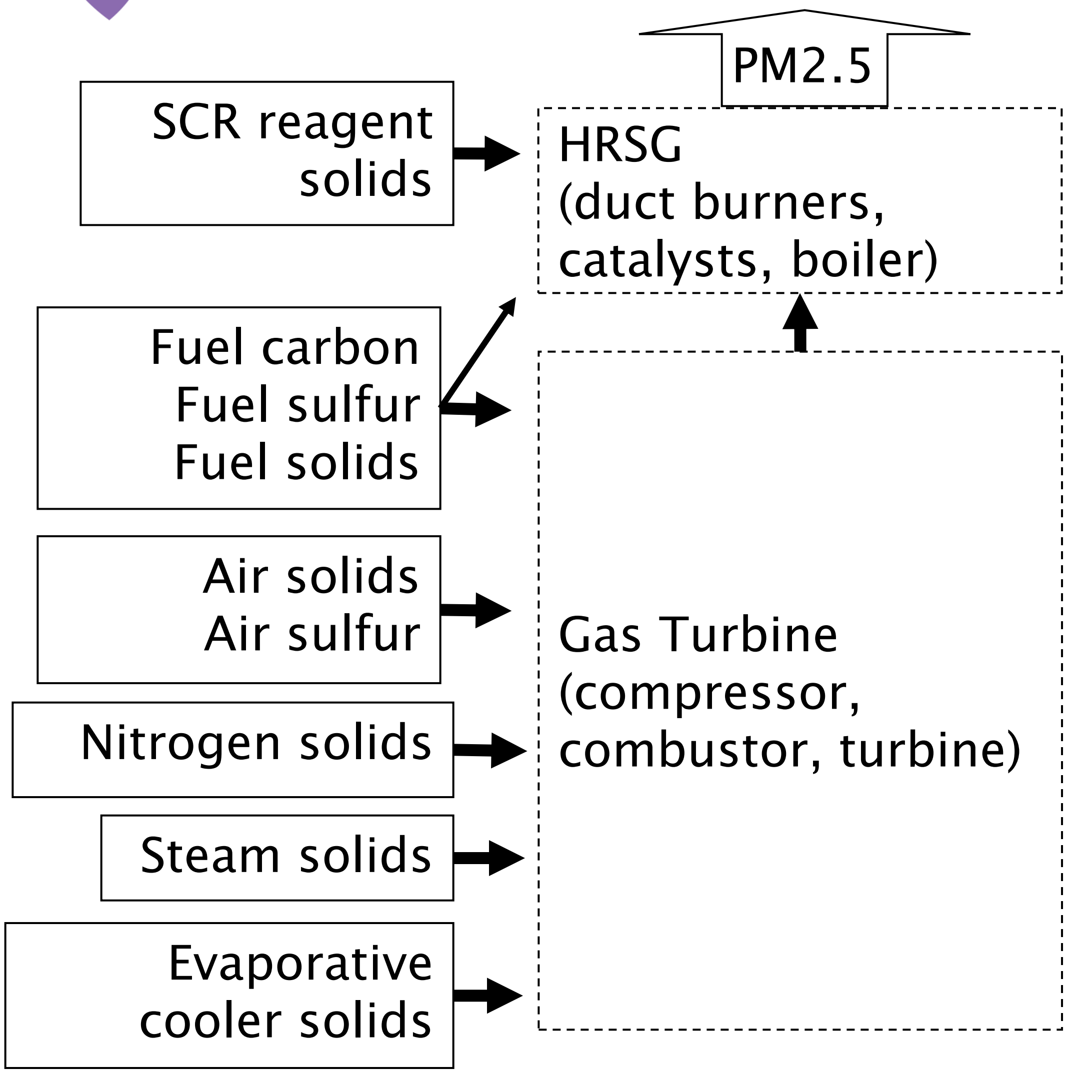
- Emissions controls
  - Lean pre-mix combustors
  - SCR
    - 2-5 ppm NO_X limits
  - CO oxidation catalysts



IGCC with CO_2 Separation

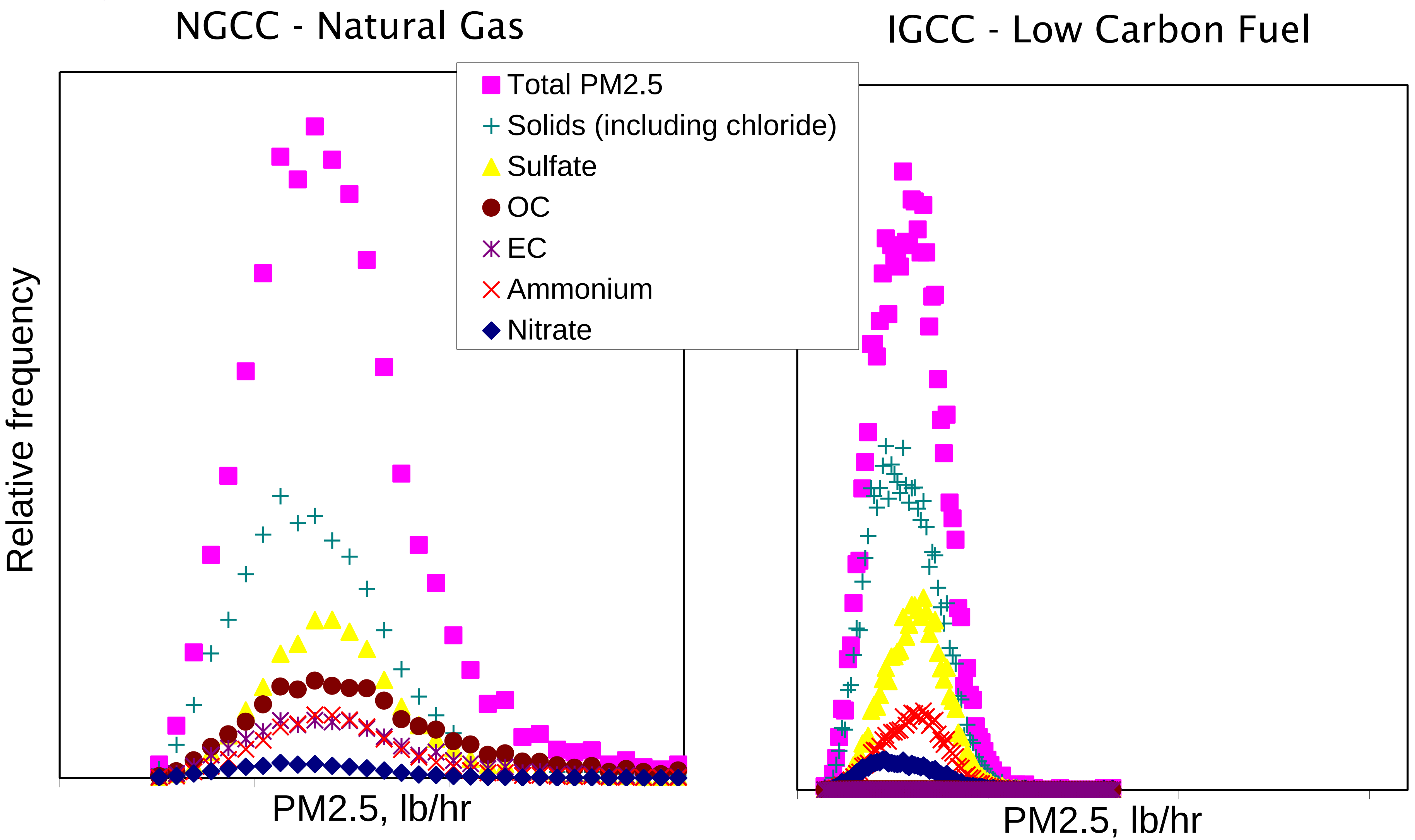


PM2.5 Sources



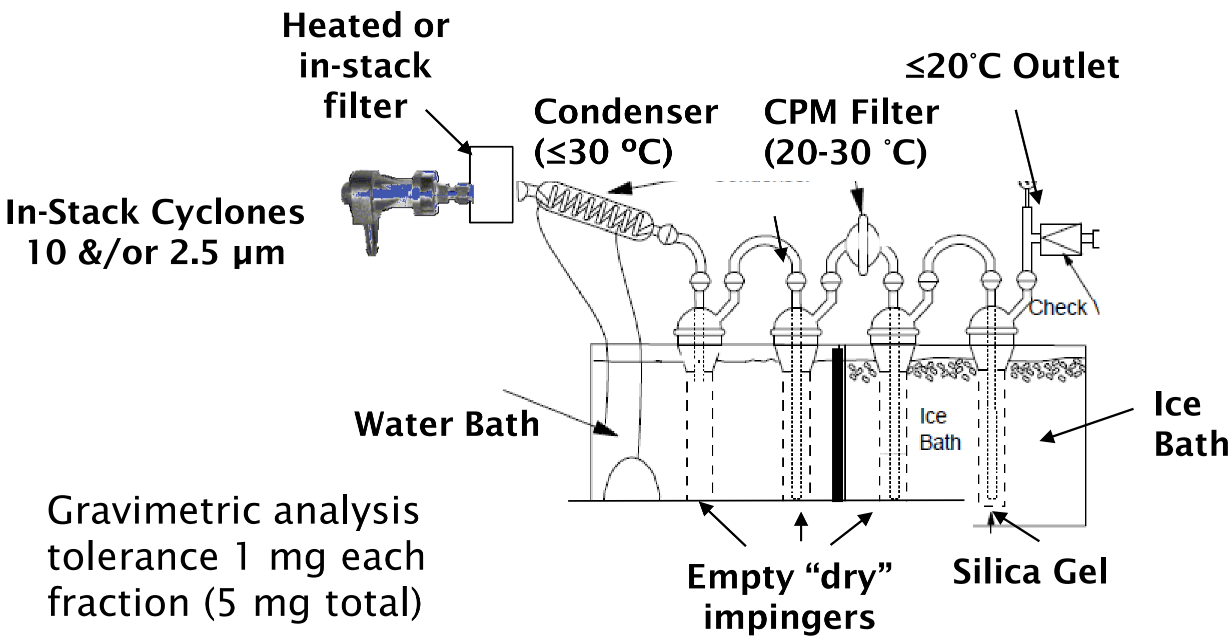
- Incomplete fuel combustion (carbon conversion to soot, organics)
- Combustion and post-combustion conversion of sulfur (& chlorine) to acid aerosols & salts
- Vaporization and condensation of volatile elements
- Transmission of non-volatile elements
- Corrosion/erosion of system components
- Aerosol nucleation, condensation, accumulation and breakup

Effect of CO_2 (and S) Separation



PM Measurements - traditional

- Hot filter/impingers
  - Collect filterable & condensable separately (?)
  - Dry & weigh filters, evaporate & dry probe/cyclone rinses
  - Organic extraction, evaporate & weigh impinger residues



Gravimetric analysis tolerance 1 mg each fraction (5 mg total)

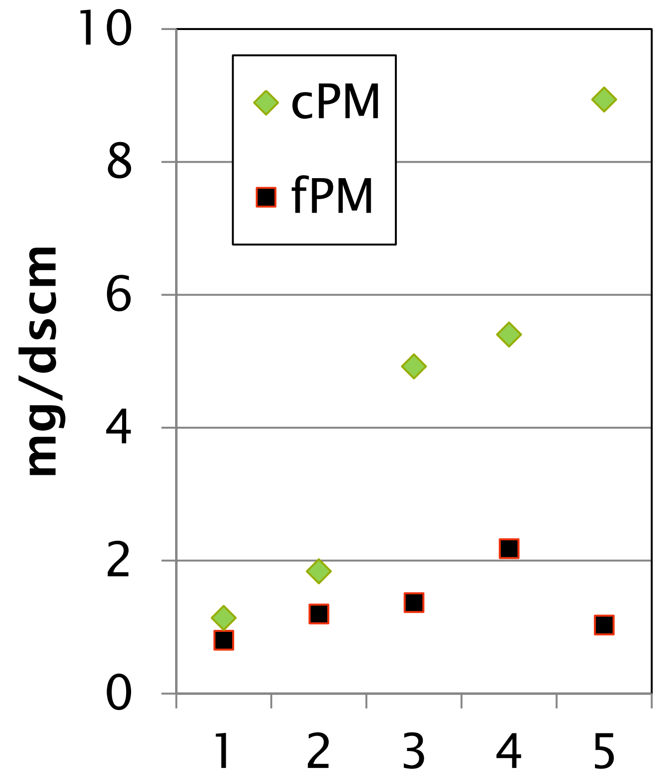
EPA Methods 201A/202 (2010)

EPA Method 5
State & local variations

High bias due to measurement artifacts can be significant (dissolved gases e.g. O_2, SO_2, NH_3, VOC, HCl → solid residues)

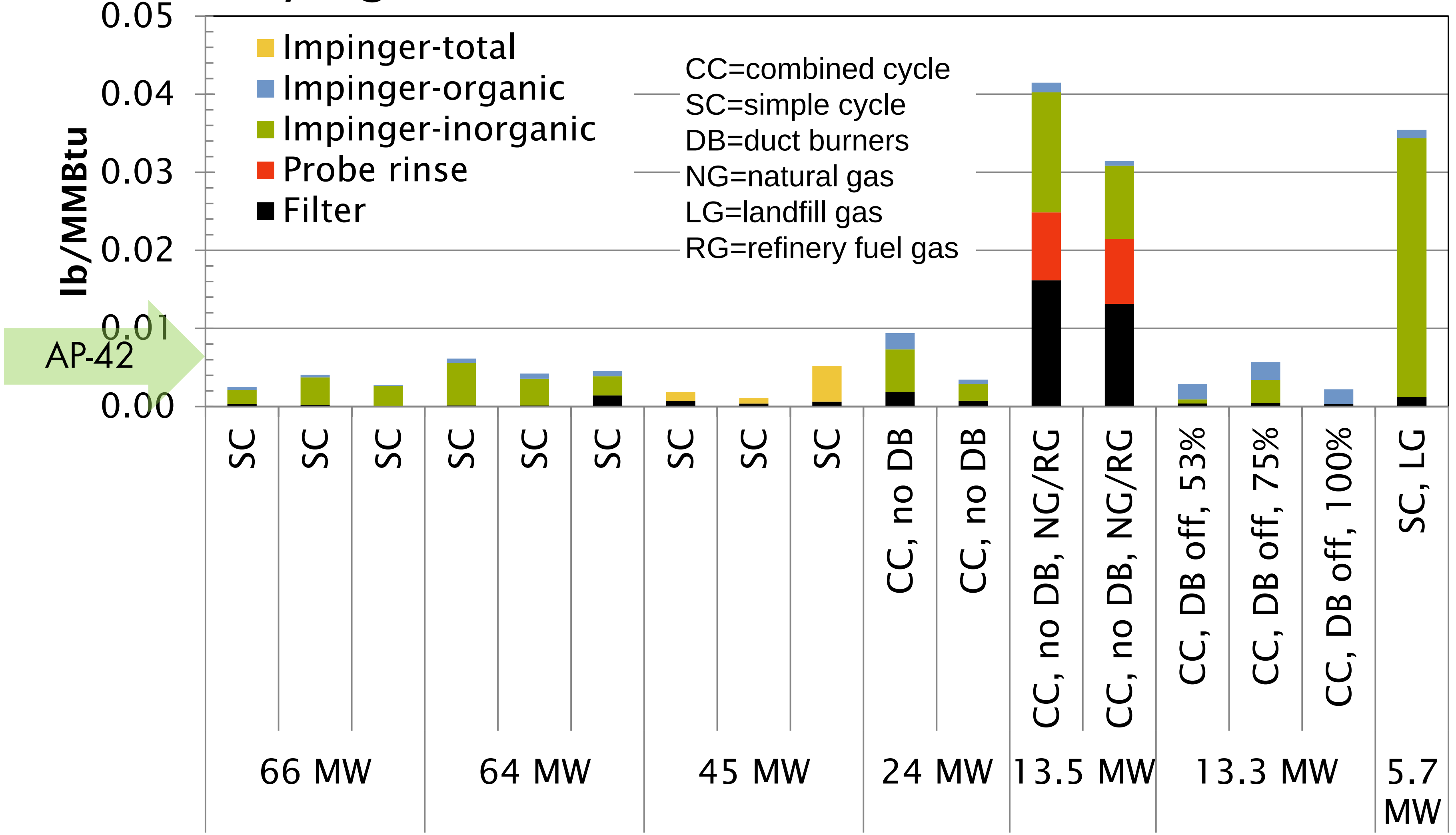
AP-42 PM Emission Factors - GTs

- Ch. 3.1, gas turbines, natural gas (April 2000)
  - EPA Methods 5 and WDNR 5
  - 5 tests, 4 units 1994-1996
- Total PM 0.0065 lb/MMBtu
  - cPM is 71% of total
  - Uncertainty >100%



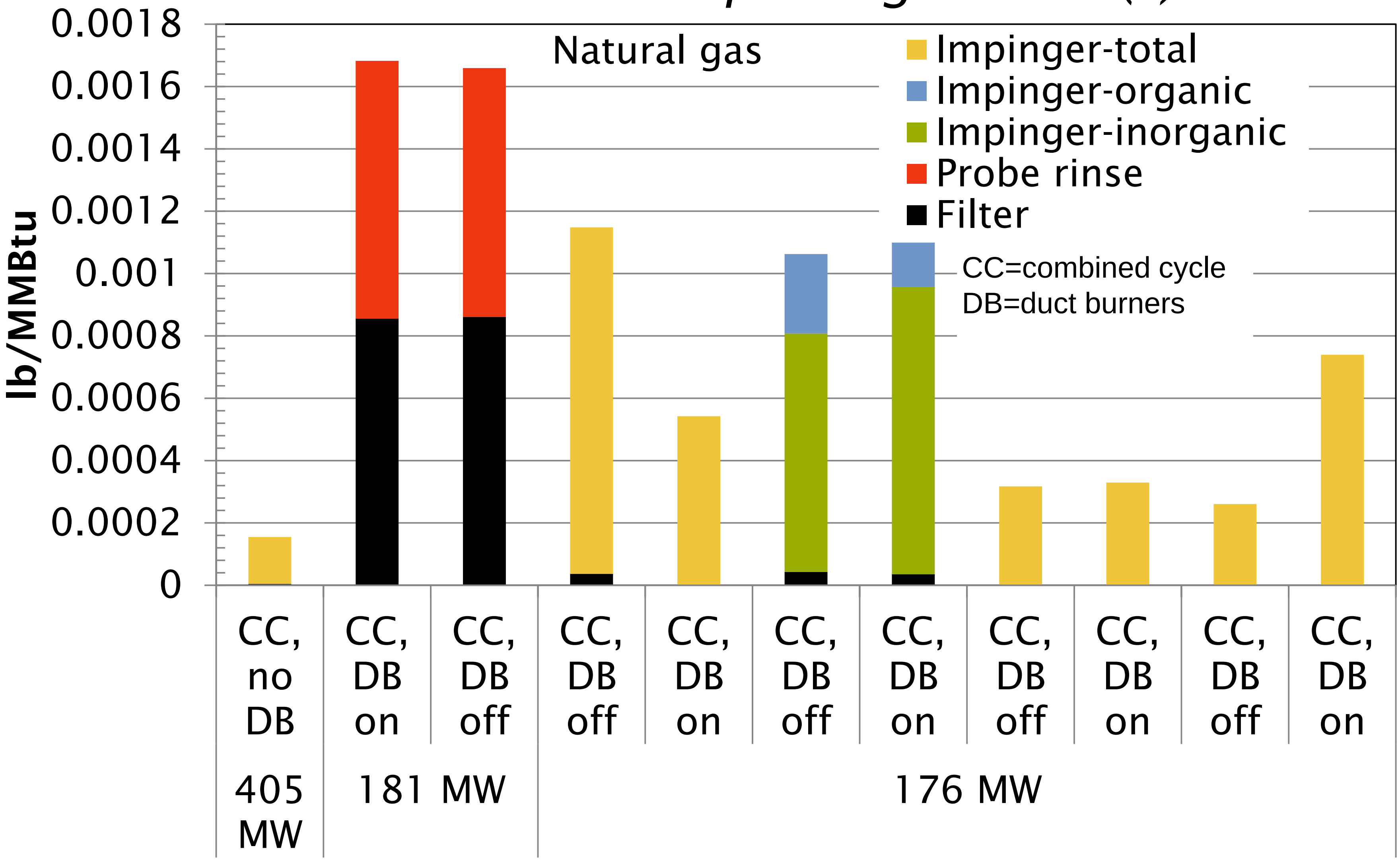
Measured Gas Turbine PM Emissions

Impinger catch dominates measured emissions



Measured Gas Turbine PM Emissions

Lower emission rate for larger units (?)



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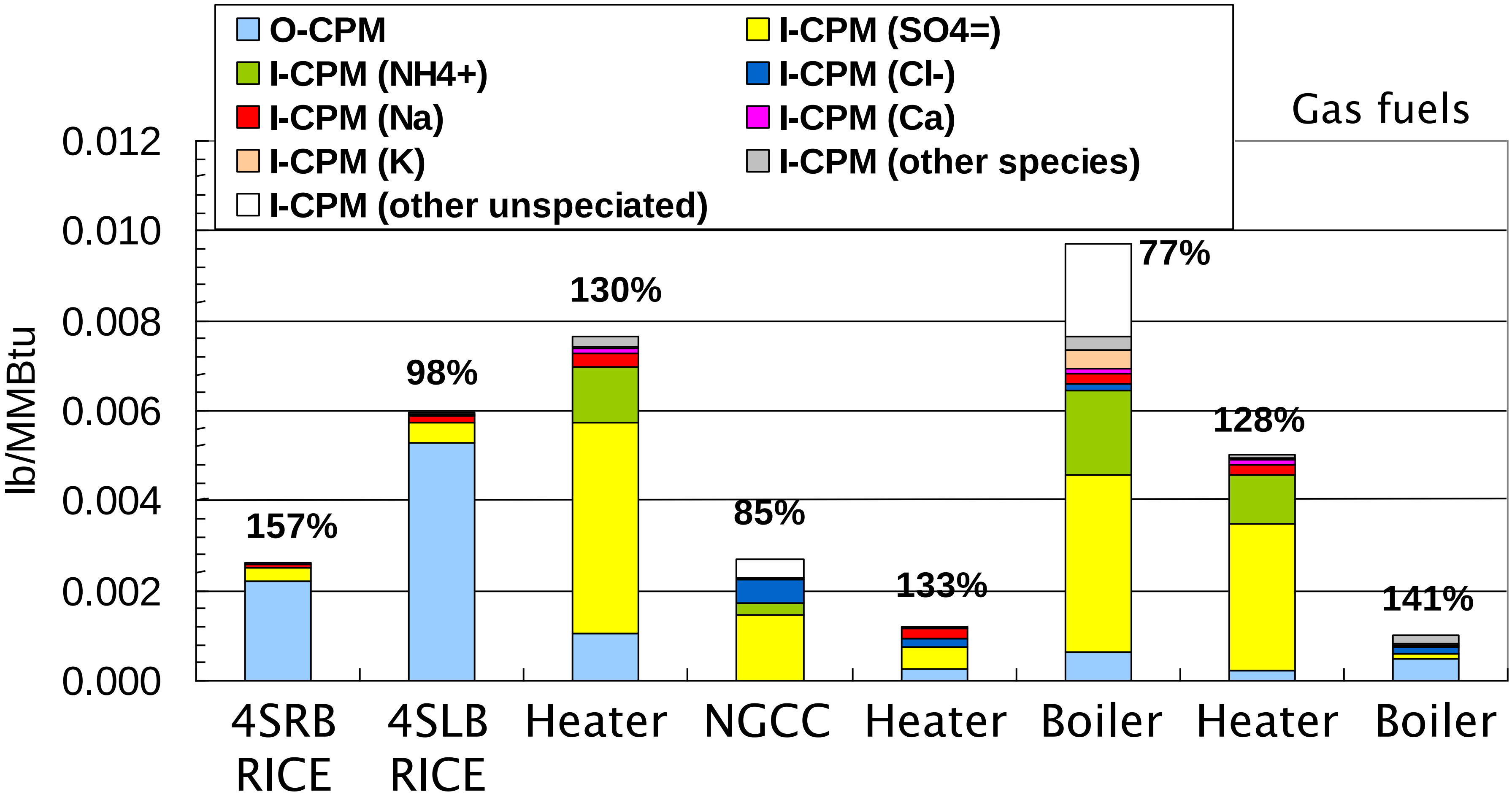
Condensable PM Speciation Method 202 (1991)



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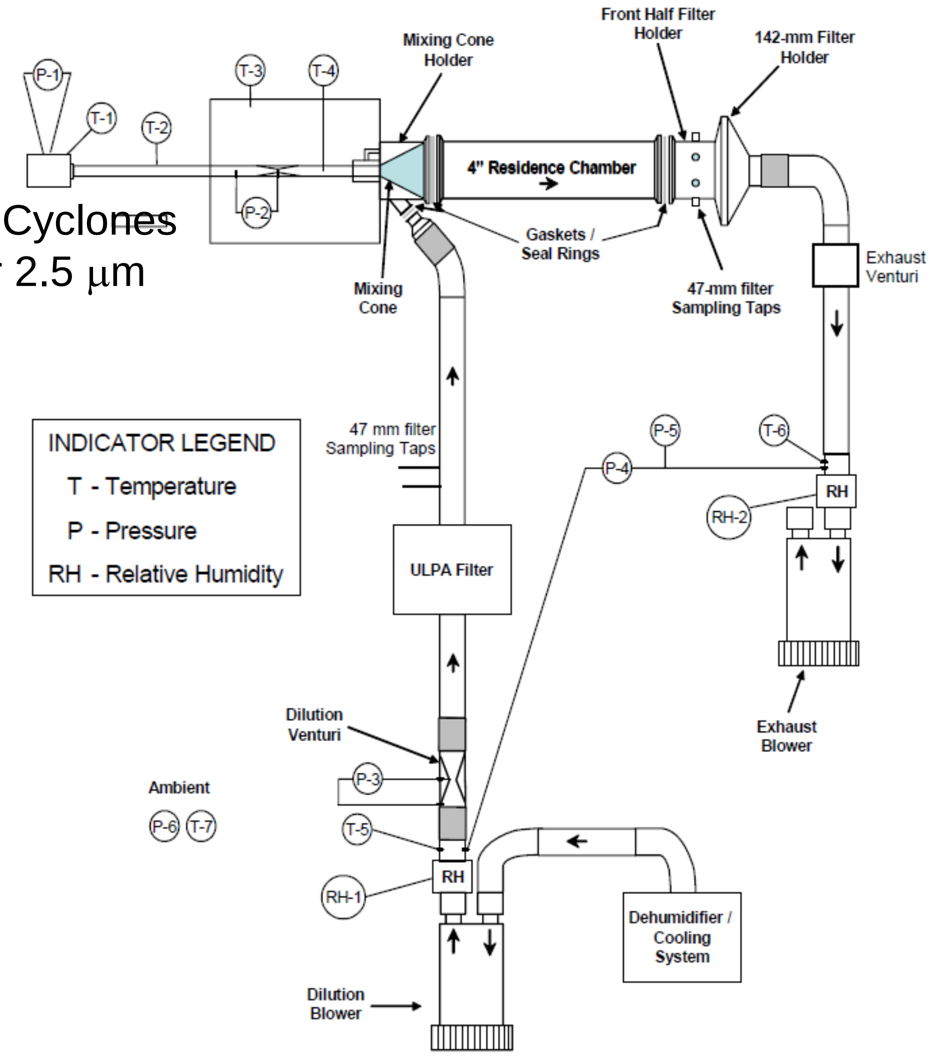
Dilution Methods

In-Stack Cyclones
10 &/or 2.5 μm

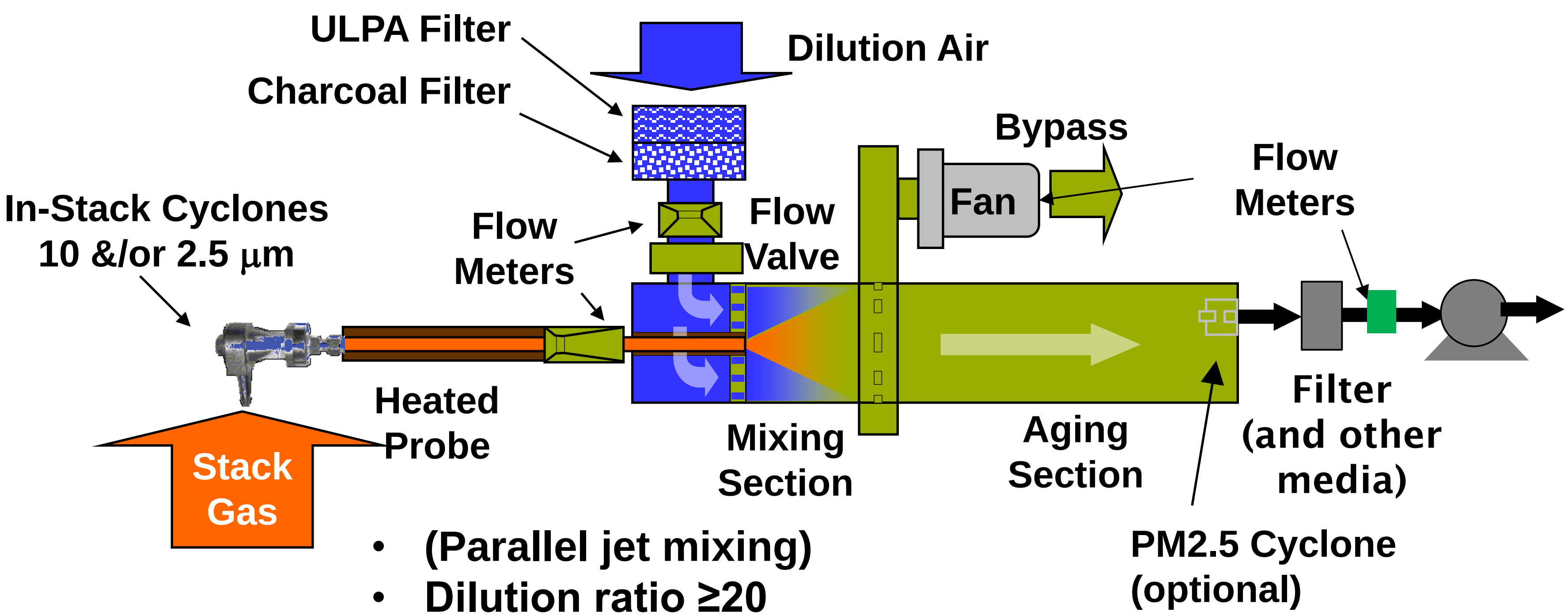


EPA CTM 039 (2004)

- **Stirred jet mixing cone**
- **Dilution ratio 10-40**
- **Dilution air <50% RH, 80°F**
- **Mixing residence time 0.2 sec**
- **Diluted sample <85°F**
- **Water & acetone recovery rinses required**
- **Method 5 gravimetric analysis**
  - **0.1 mg balance**
  - **Evaporate & dry rinses**
  - **Dry & weigh filter**

Dilution Methods

ISO 25597 (2013)

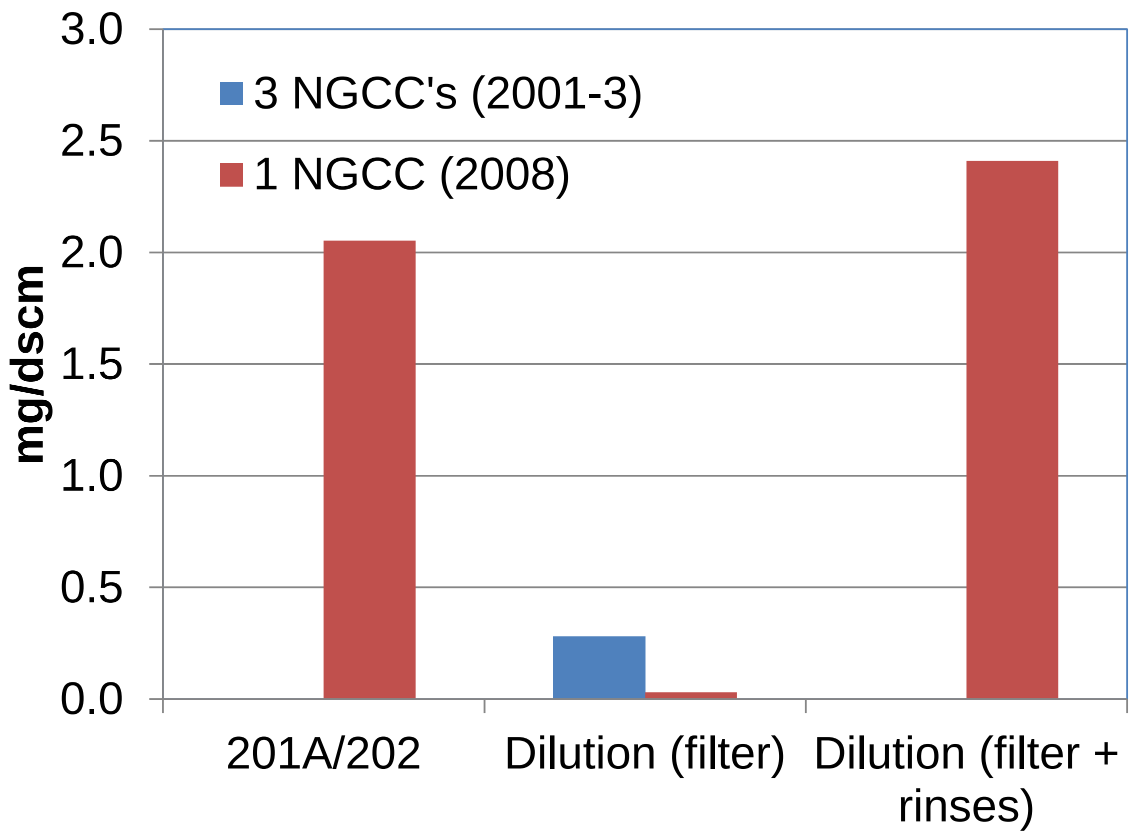


- (Parallel jet mixing)
- Dilution ratio ≥20
- Aging residence time 10 sec
- Diluted sample RH <70%
- PM2.5 cyclone after aging
- Ambient air gravimetric analysis
  - 0.001 mg balance, equilibrate @ 20-25°C, 45-55% RH
- Recovery rinses (test or run)

Dilution Methods vs. 201A/202-1990

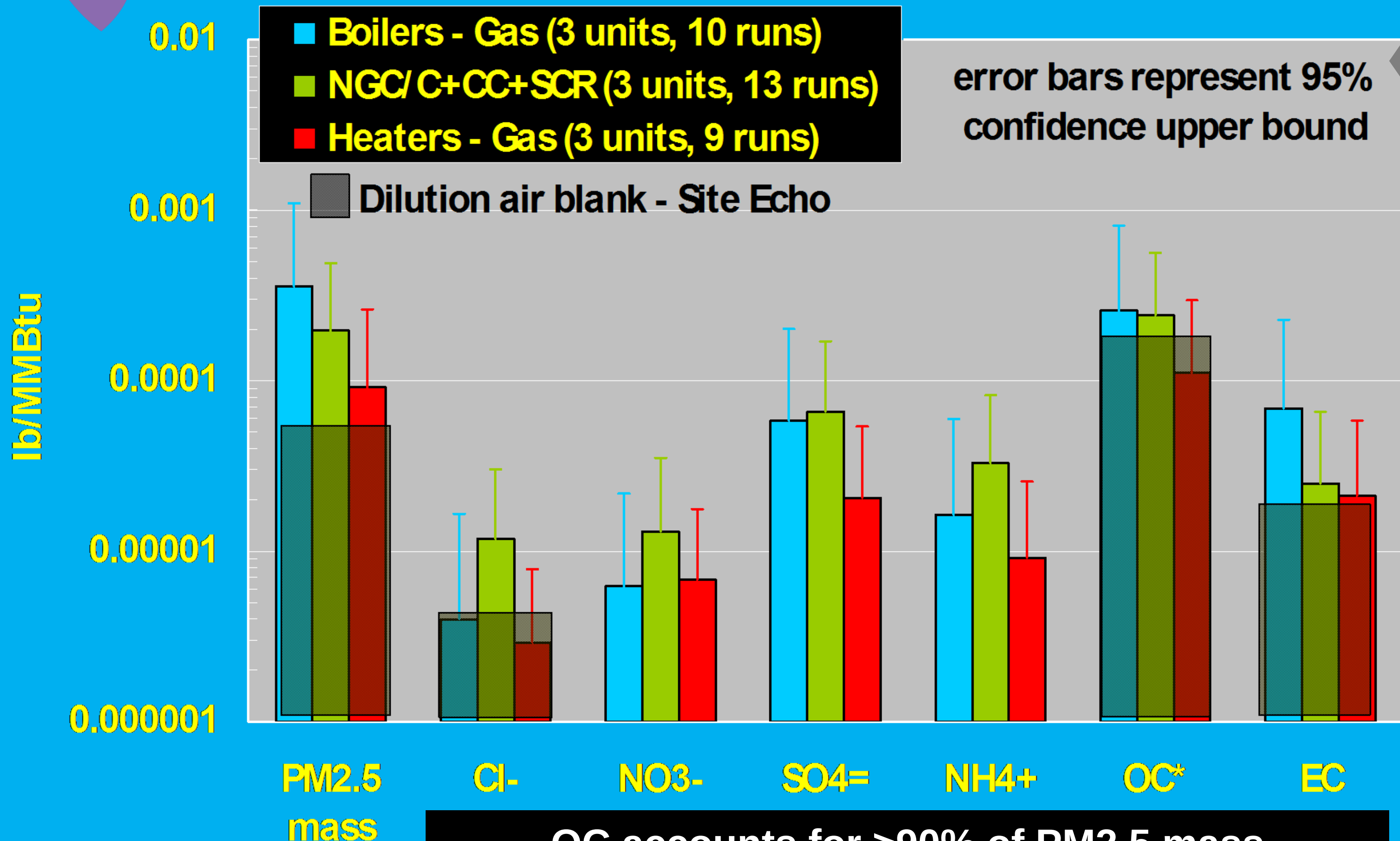
- Dilution filter results consistently much lower than M201A/202-1990 results in side-by-side tests at 7 different gas-fired sources

- Two different dilution methods
  - Modified EPA CTM 39 (2008)
  - "ISO 25597" (2001-2003)
- M202 (1991) iced impingers
  - sulfate artifact adds significant positive bias
- Blanks and samples typically indistinguishable
  - Concentrations at measurement "noise" level



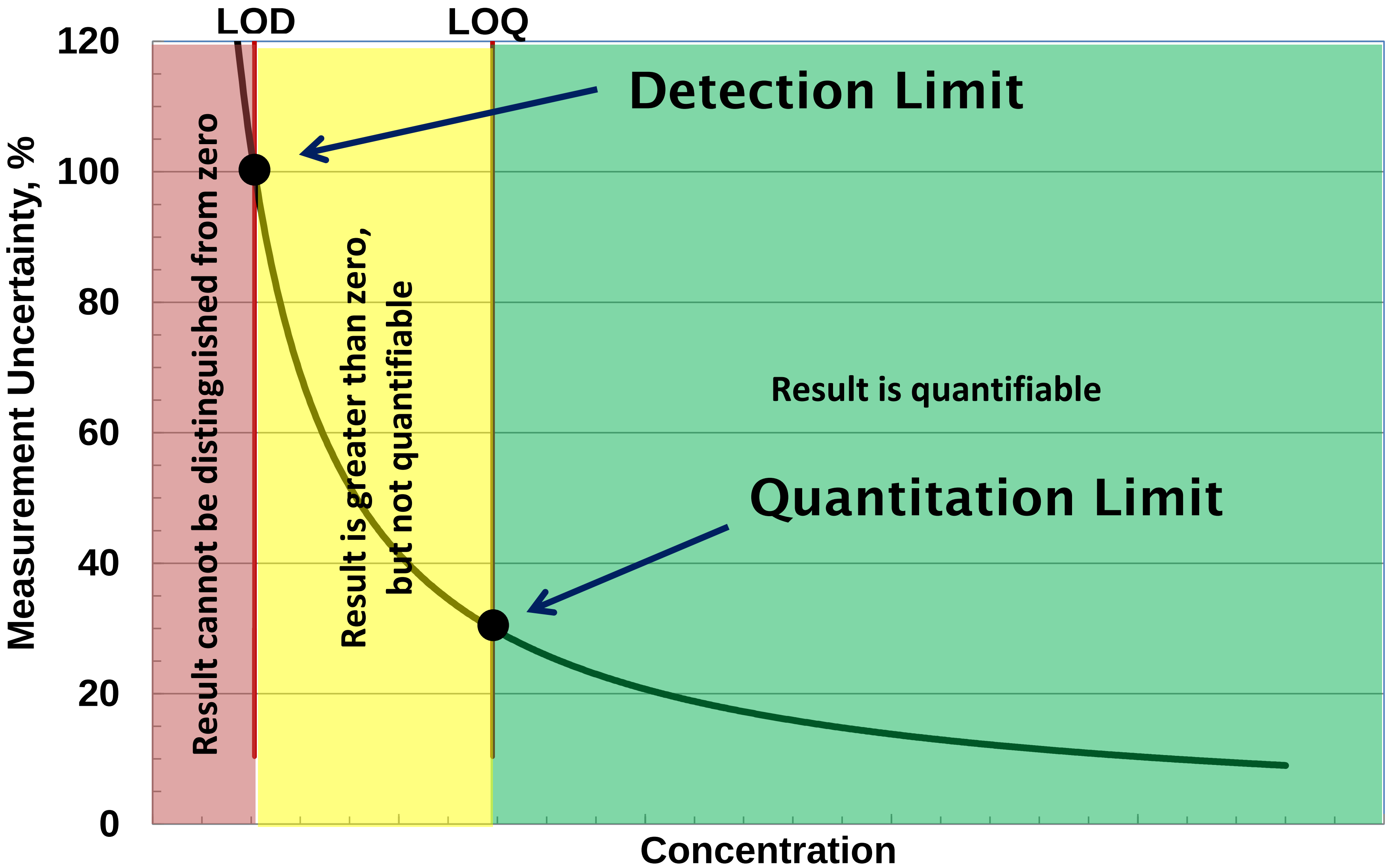
PM2.5 Emission Factors – Dilution Method

AP-42



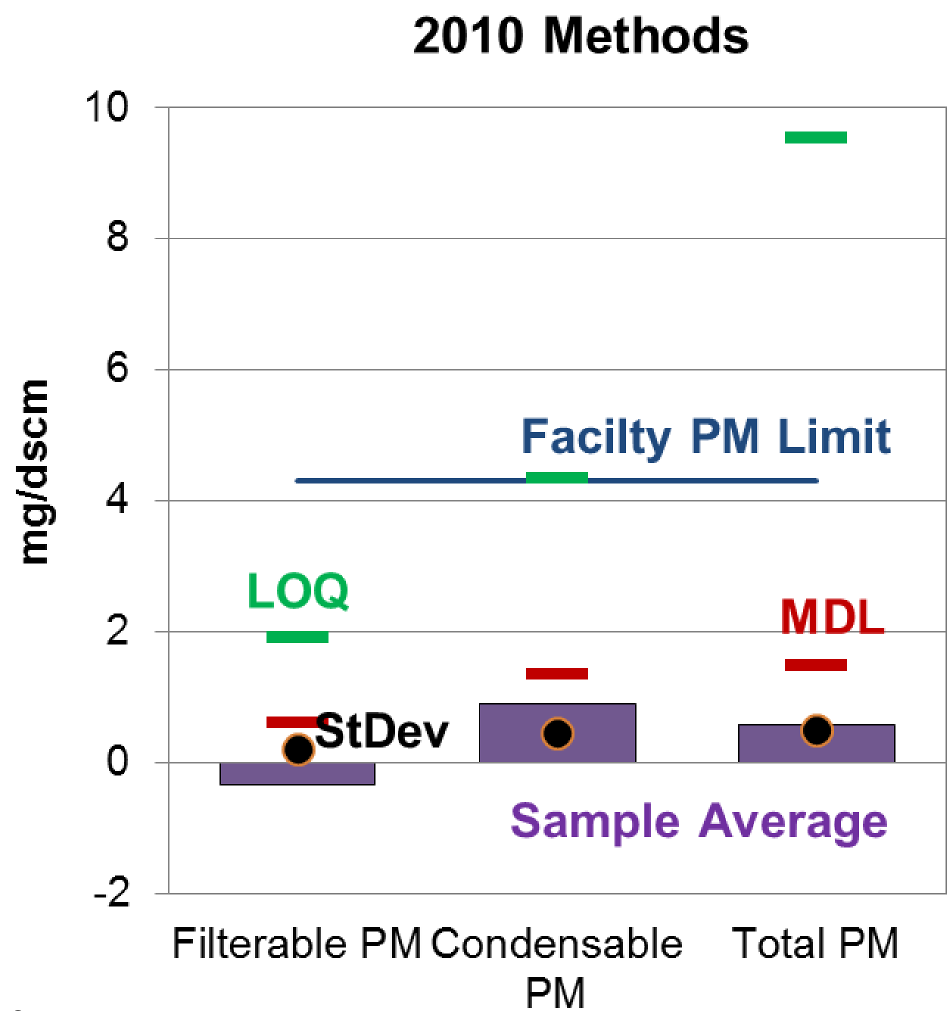
OC accounts for >90% of PM2.5 mass (but measurement background indicates artifact)

Detection & Quantification

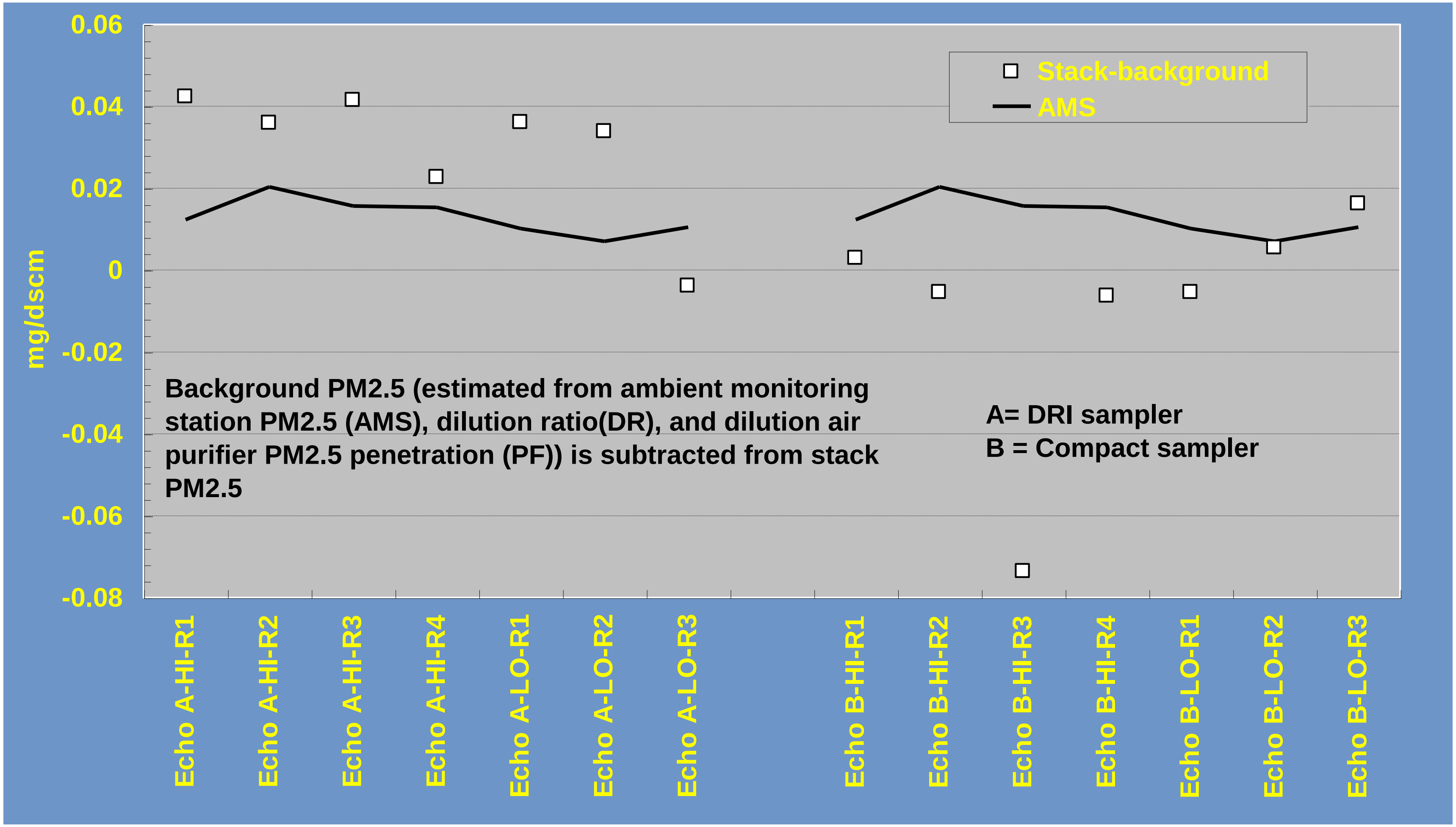


Detection Limits

- 500 MW NGCC Block
- Fuel sulfur < 1ppm
  - low driving force for SO_2 artifact
- EPA Methods 201A/202
- Paired trains, 4 runs
  - 8 samples, 2 train blanks
  - Blanks & samples similar
- Measured emissions are below detection & quantitation limits
  - Facility permit limit between LOD and LOQ



NGCC Stack PM2.5: Dilution Results



Stack and ambient air PM2.5 concentrations are similar

Summary

- Current AP-42 factors for gas-fired sources
  - Few sources
  - High uncertainty
  - Old, problematic methods
- EPA Methods 201A & 202 (& similar methods) remain problematic for gas-fired sources
  - Lack sufficient sensitivity
  - Blank levels are significant – not due to reagent contamination!
  - New Method 202 reduces but doesn't eliminate artifacts
- Dilution methods offer advantages for gas-fired sources
  - Greater accuracy due to absence of SO_2 and VOC artifacts & greater analytical sensitivity
  - Resulting PM2.5 emission factors are ~1/10 or lower of those based on hot filter/cooled impinger methods e.g. AP-42

Summary (cont'd)

- Dilution method evaluation & refinement
  - Refine & validate test conditions & procedures
  - Reduce background levels in dilution air & probe recovery solvents
  - Reduce organic carbon artifacts
  - Reduce relative variability of results
- More tests
  - Document method performance in field
  - Develop robust emission factors

We need better measurements of PM emissions from gas-fired sources

Questions?

Glenn England

gengland@environcorp.com

949-798-3643