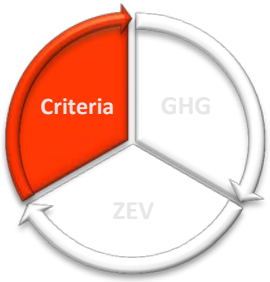
Advanced Clean Cars
PM Measurement Feasibility

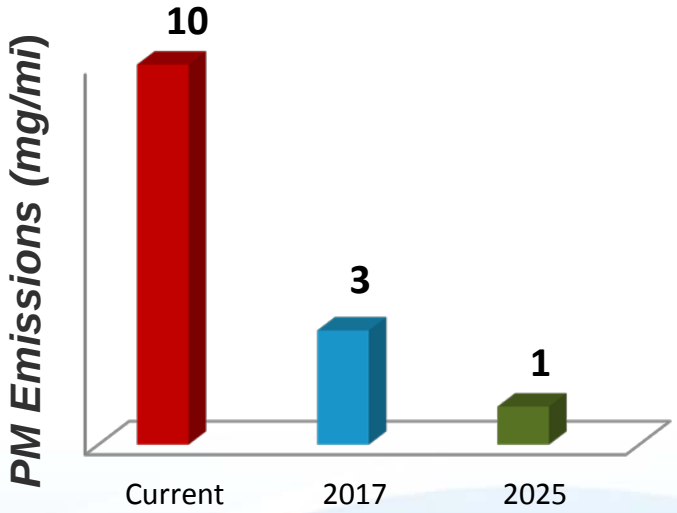
Informational Update
Diamond Bar, CA
October 22, 2015

California Environmental Protection Agency
Air Resources Board

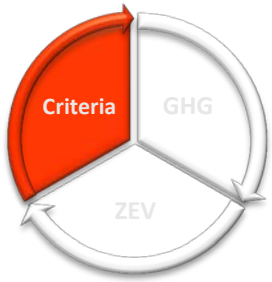


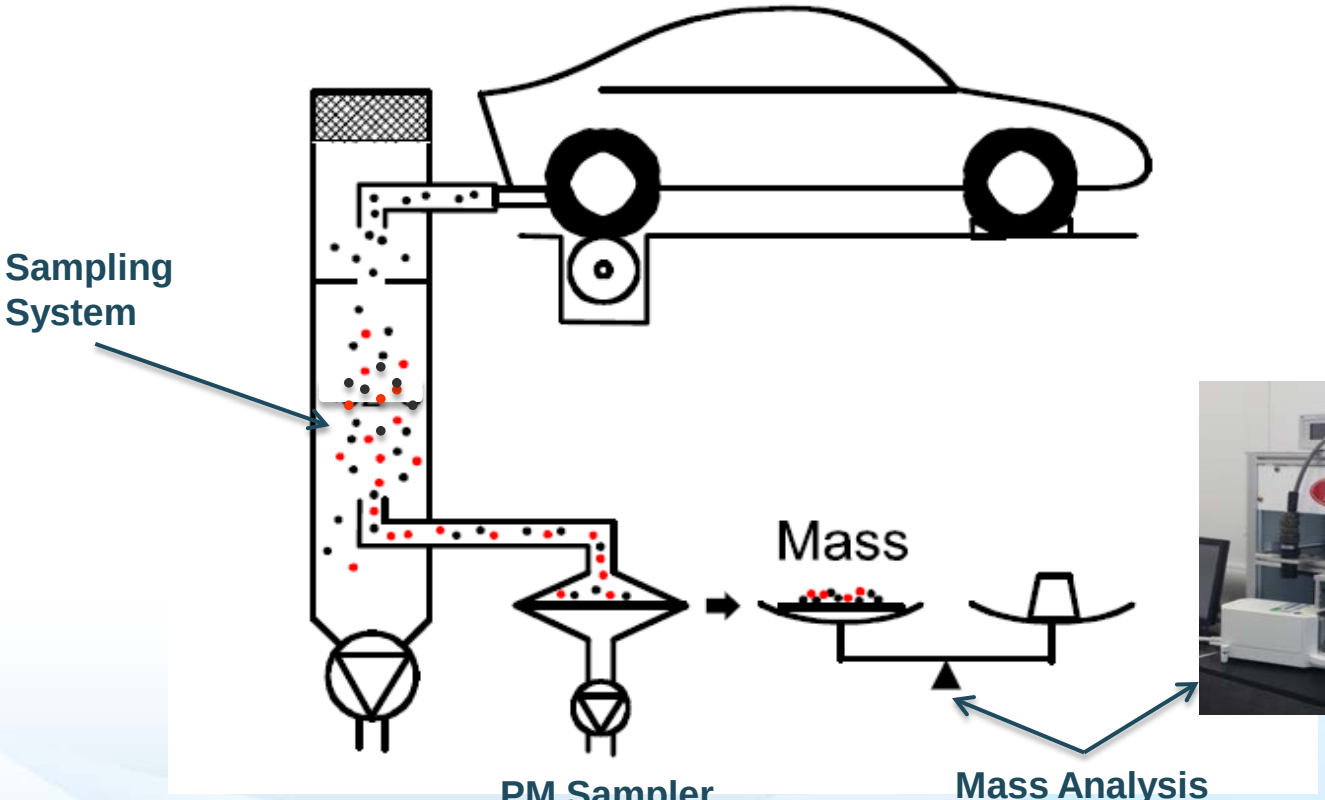
Background
LEV III PM Standards

- In 2012, the Board approved more stringent PM standards for light duty vehicles
- And directed staff to follow-up on two questions:
  - Can we measure emissions at 1 mg/mi levels?
  - Can we move the 1mg/mi standard to earlier than 2025 with new GHG technologies?

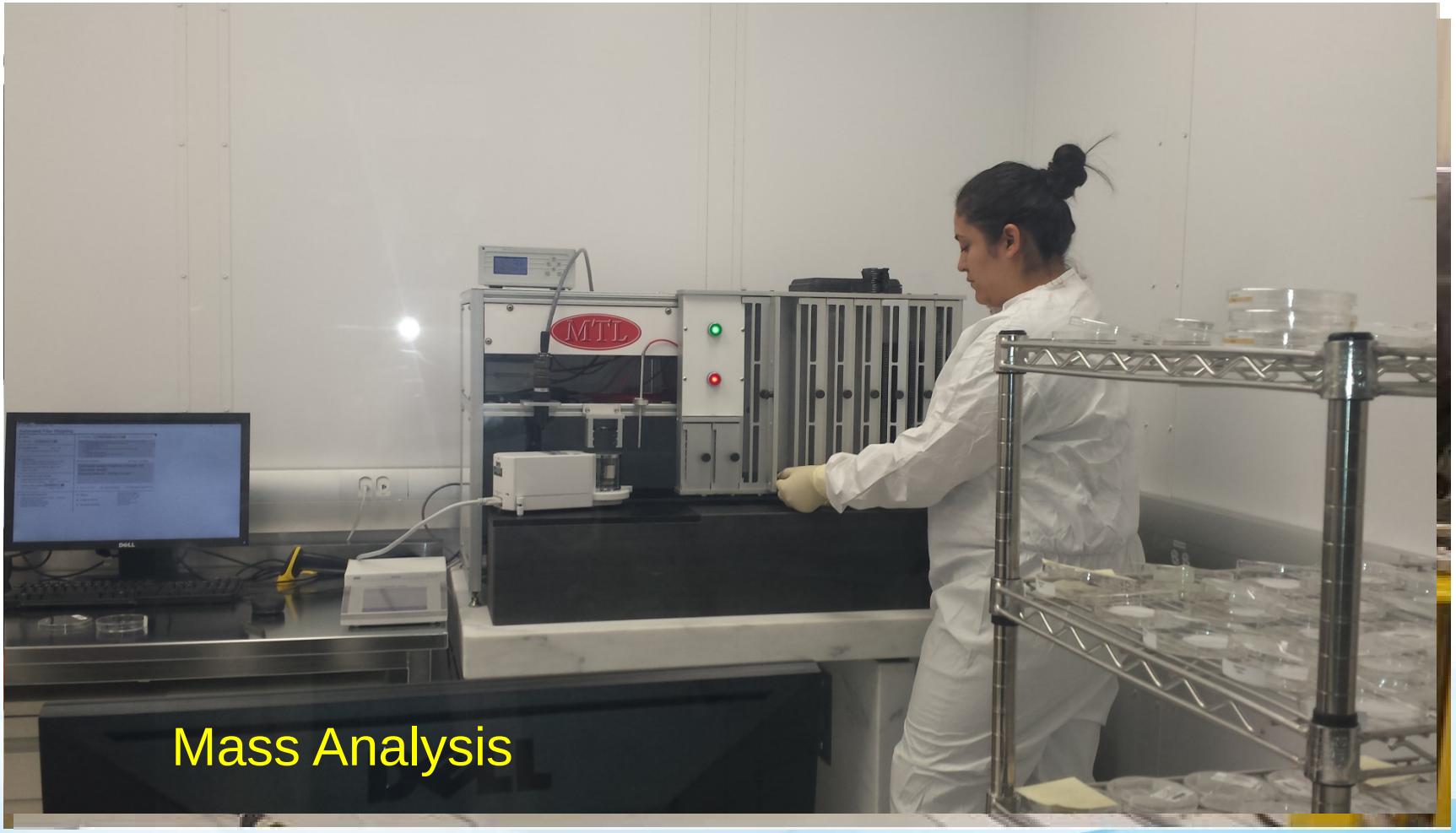


How Do We Determine Vehicle PM Mass Emissions?

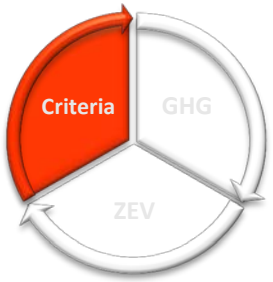




PM Emission Testing at ARB



Key Industry Concerns



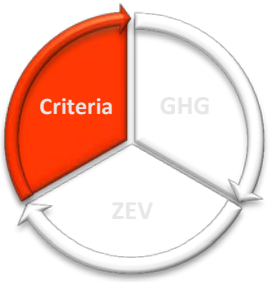
Is current mass-based method capable of quantifying PM mass at 1 mg/mile level?

What are the sources and magnitude of variability in laboratory measurements?

Can PM be measured reproducibly among different laboratories?

Are sampling options allowed by regulation equivalent?

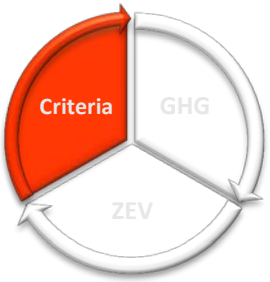
ARB Study Objectives



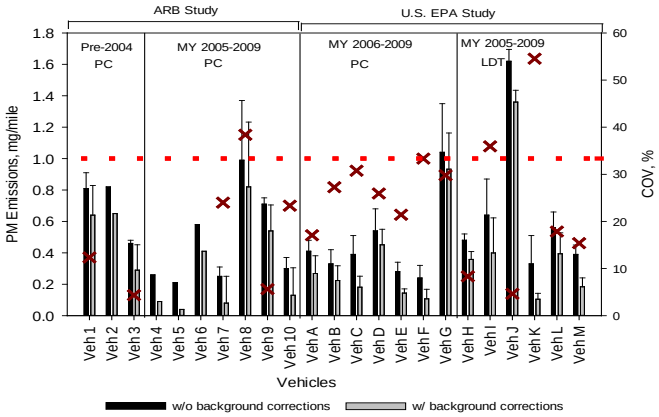
- **Address industry concerns**
- **Investigate use of alternatives to mass-based measurement:**
  - Particle number
  - Particle size
  - Black carbon

Summary of Testing

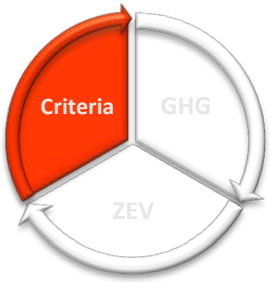
Assessing Measurement Feasibility



- **8** testing programs focused on individual measurement issues
- **67** unique vehicles tested
- Collected and analyzed PM from over **350** emission tests
- Over **2000** individual filters analyzed
- Utilized over **10** different measurement devices
- **5** peer-reviewed scientific publications from ARB's findings

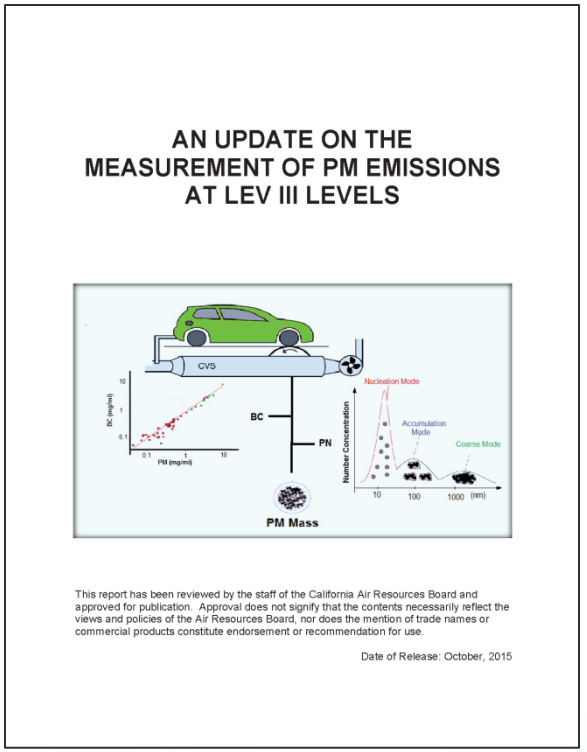


Technical Support Document



- Detailed report summarizing ARB staff's findings on PM measurement

- Posted: http://www.arb.ca.gov/msprog/levprog/leviii/leviii.htm

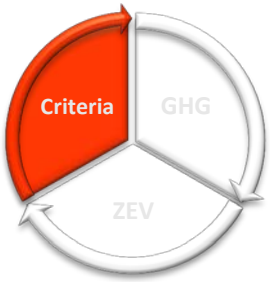


AN UPDATE ON THE MEASUREMENT OF PM EMISSIONS AT LEV III LEVELS

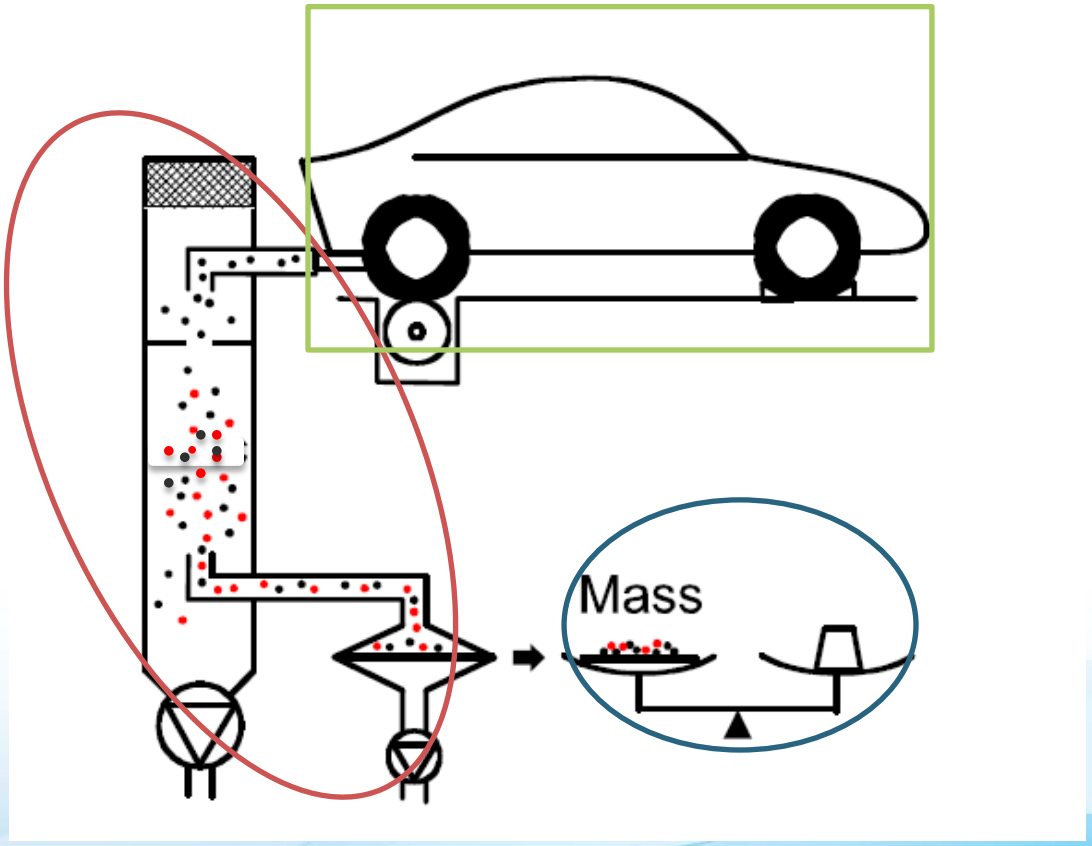
This report has been reviewed by the staff of the California Air Resources Board and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Air Resources Board, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

Date of Release: October, 2015

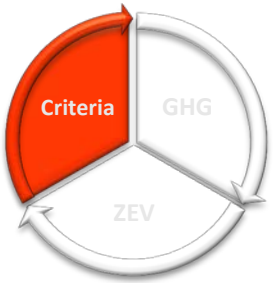
Sources of Total Variability

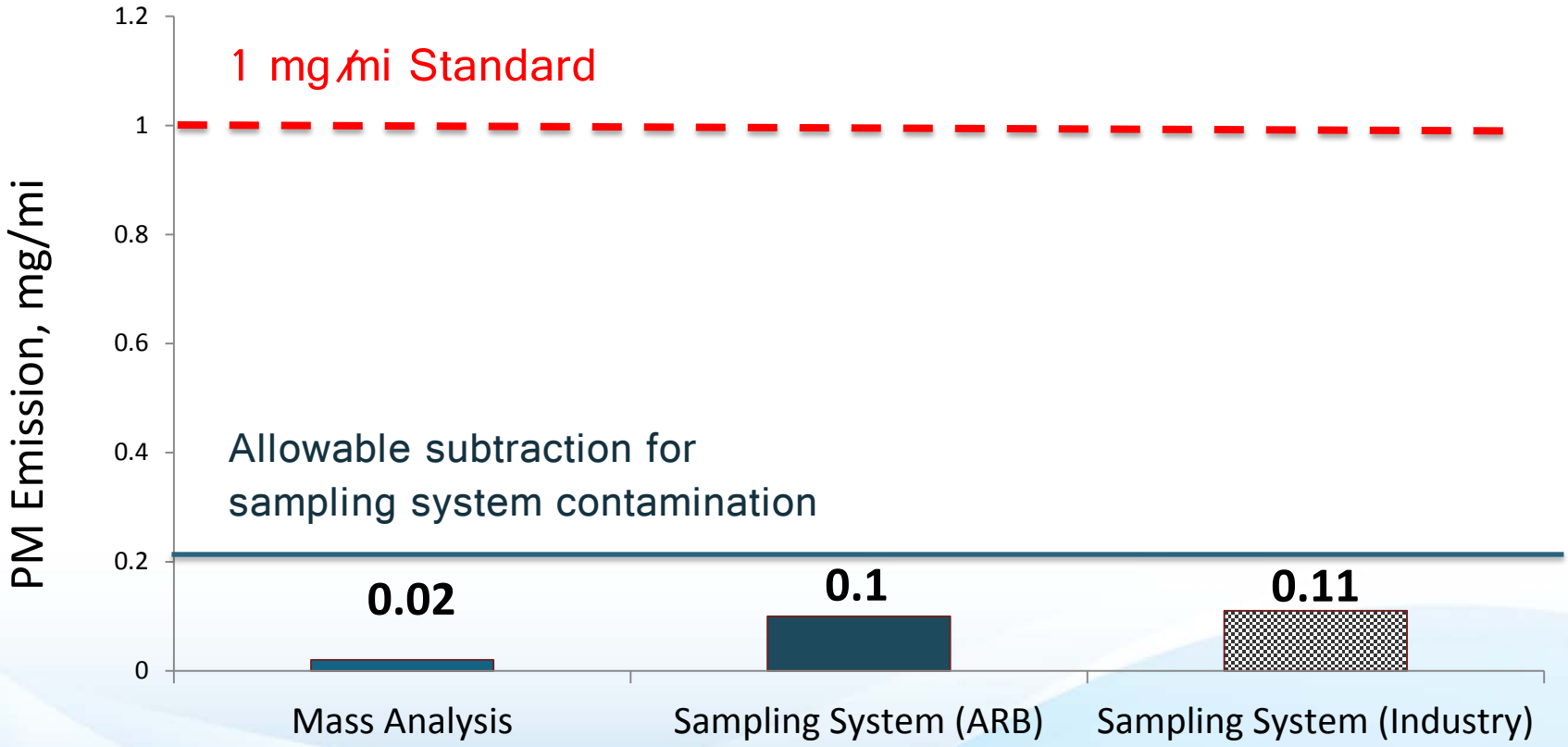


1. Mass Analysis
2. Sampling System
3. Emissions Source

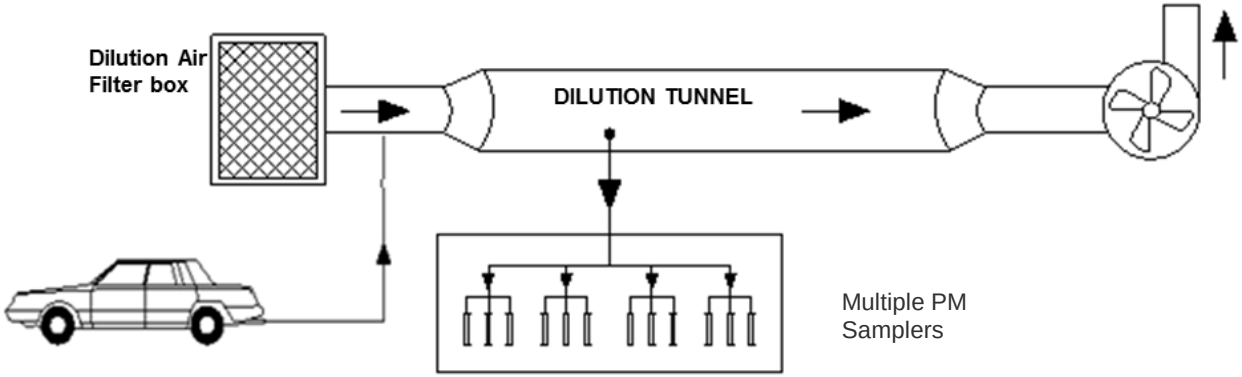


How Much Is the Result Influenced by Sampling and Mass Analysis?



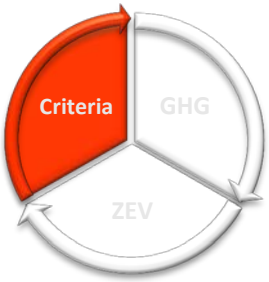


How Well do Repeated Measurements Show the Same Results?



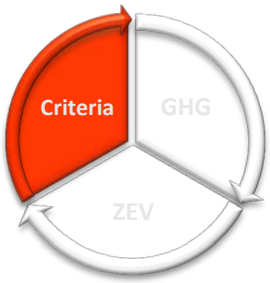
- Collected PM samples using up to five simultaneous samplers during a single test
- Compared results across many vehicles emitting at or below 1 mg/mi
- Precision found to be ±11% (~0.1 mg/mi)

Do We Get the Same Results for a Vehicle in Different Test Cells?



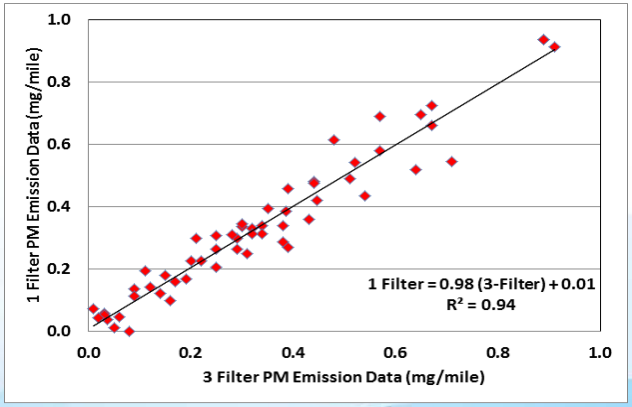
- Approximation of lab-to-lab variability
  - Different equipment, vehicle drivers, and equipment operators
  - Same low PM vehicle tested 9+ times per cell across three test cells at ARB
- No statistically significant difference in average emissions across the test cells
- Test-to-test variability is consistent across all test cells, which means this method is robust

New Sampling Option Evaluated

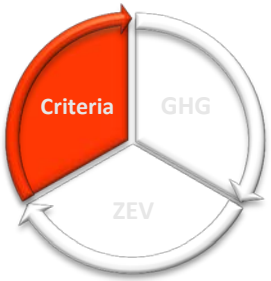


- Compared conventional 3-samples per emission test to a new 1-sample per emission test method

  - Confirmed results to be equivalent
  - Potential cost/resource savings from streamlined mass analysis

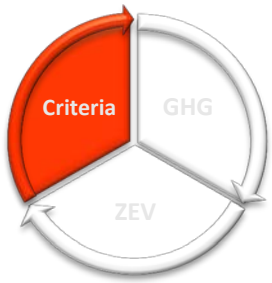


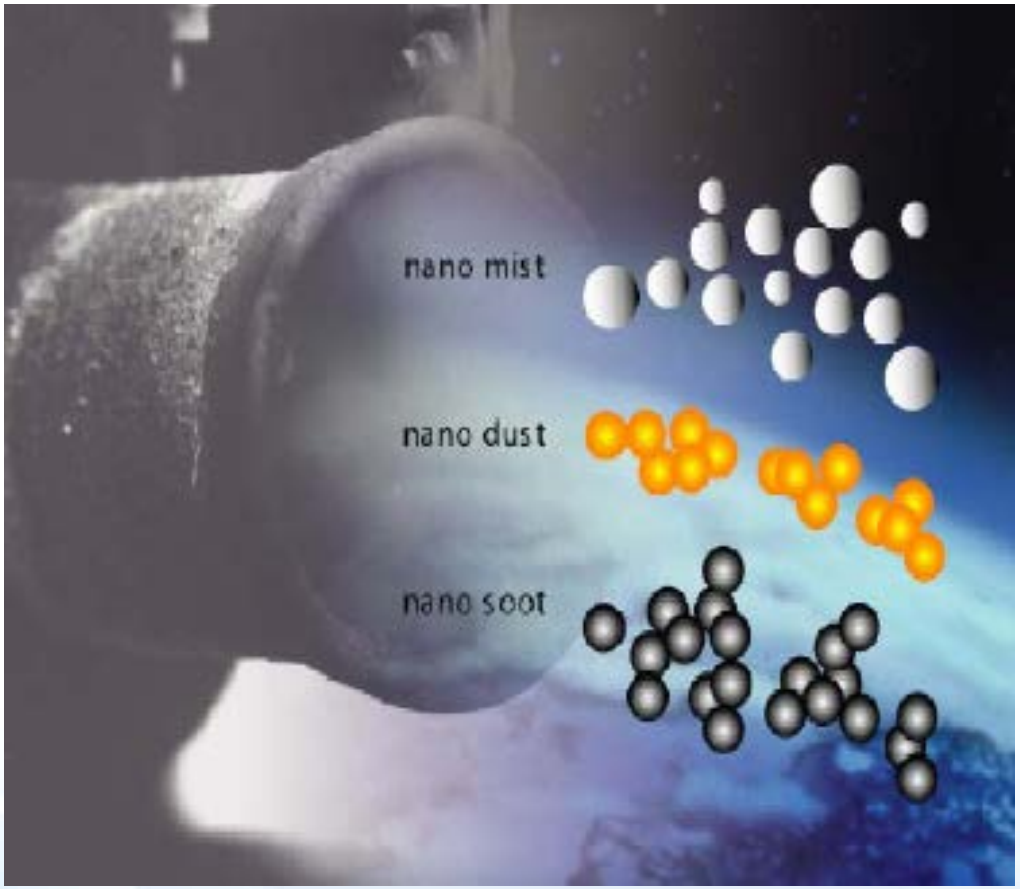
Staff Conclusion -- Regulatory PM Mass Method



- Current mass-based method is suitable and adequate
- Contamination in sampling process can easily be corrected by background subtraction already allowed by regulation
- Good precision (<0.1 mg/mi) confirms measurement capability is sufficient.
- Test-to-test variability is consistent among ARB's test cells. Measurement is not a concern.

What about other sampling methods?

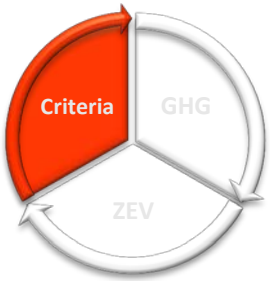




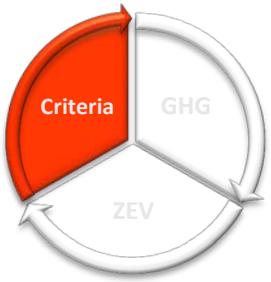
Courtesy of Dr. Markus Kasper/Matter Engineering, Switzerland

- Counting particles
- Sizing them
- Europe's particle number standard
- Measuring black carbon

"As One Goes So Do All Others"

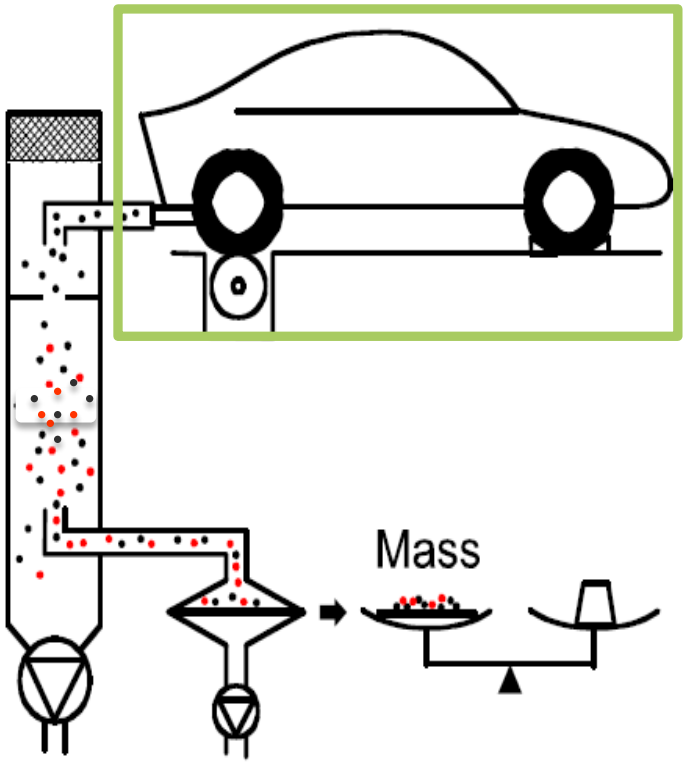


- Alternative methods generally in good correlation with PM mass
  - Reducing PM mass also reduces black carbon and number of particles
  - But exact relationships with PM mass vary significantly across vehicle types and test cycles
- Similar measurement repeatability
- Real-time data provides useful insight
  - Potential saving in test resources
- These metrics do not measure all parts of PM
- Instrumentation lacks robust calibration procedures

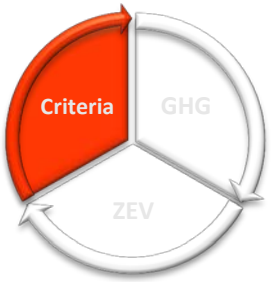


Next Steps -- Vehicle Feasibility

- Reassess vehicle feasibility to meet 1 mg/mi standard
  - Evaluate newer vehicle technologies for PM control
  - Evaluate vehicle variability
- Consider 1 mg/mi standard implementation timing
  - Earlier phase-in than 2025 model year possible?



Conclusion



- Mass-based method is adequate and will remain the approved test method for ARB's LEV III PM emission standards
- PM mass control technology will also likely reduce number of particles and black carbon emissions
- ARB will continue research on improvements in sampling and measurement approaches for their potential to improve data quality and reduce testing costs