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Particulate Matter Measurement Progress in the US and California

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ABSTRACT

As part of the regulatory efforts to continue to reduce ambient levels of particulate matter (PM) and nitrogen oxides (NO_X), new and considerably more stringent emission standards for on-road heavy-duty (HD) engines are set to take effect starting in 2007. These new limits will require the use of advanced engine design strategies, new fuels and lubricants, and aftertreatment control all integrated in a new technology package. The levels of regulated pollutants from these new engine technologies will be reduced substantially relative to current emission levels. So much so that extensive research and development is underway to improve the traditional sampling approaches used for engine/vehicle certification. The 2007-compliant technologies will likely yield PM emissions whose composition will be appreciably devoid of carbonaceous material. Thus, a new comprehensive assessment of the health implications of diesel emissions may be warranted. For PM emissions, the legislative filter-based method in current practice does have detection capabilities to adequately measure at levels expected for 2007 engines. Technical amendments to regulatory measurement procedures are currently being developed. In this presentation, the authors will offer an update on various relevant PM measurement and health assessment efforts in progress or planned in the United States and that involve global cooperation. Examples will be cited from on-going research initiatives and technology-forcing programs in California. The goal of this talk is to present current information and to enrich the global debate about PM emissions.

Wednesday, June 30, 2004 • The Sacramento Bee

EPA cites air-particle risk in L.A., San Joaquin Valley

By Elizabeth Shogren and Miguel Bustillo
LOS ANGELES TIMES

WASHINGTON – The U.S. Environmental Protection Agency declared Tuesday that 13 California counties, encompassing Los Angeles, San Diego and the San Joaquin Valley, are shrouded with unhealthy level[illegible] and mus[illegible]

Those that fail will risk the loss of federal funds.

For three decades, the federal government has been designating communities that violate health-based standards for smog and soot – larger particles. But this is the first time it has designated areas that violate the [illegible]ealth-based standards [illegible]

Although health concerns provided the primary impetus for reducing fine-particle pollution, successful cleanups would also remove much of the haze over cities and rural areas alike. "The value of this will be seen as well as felt," Leavitt said.

The San Joaquin Valley [illegible] Los Angeles

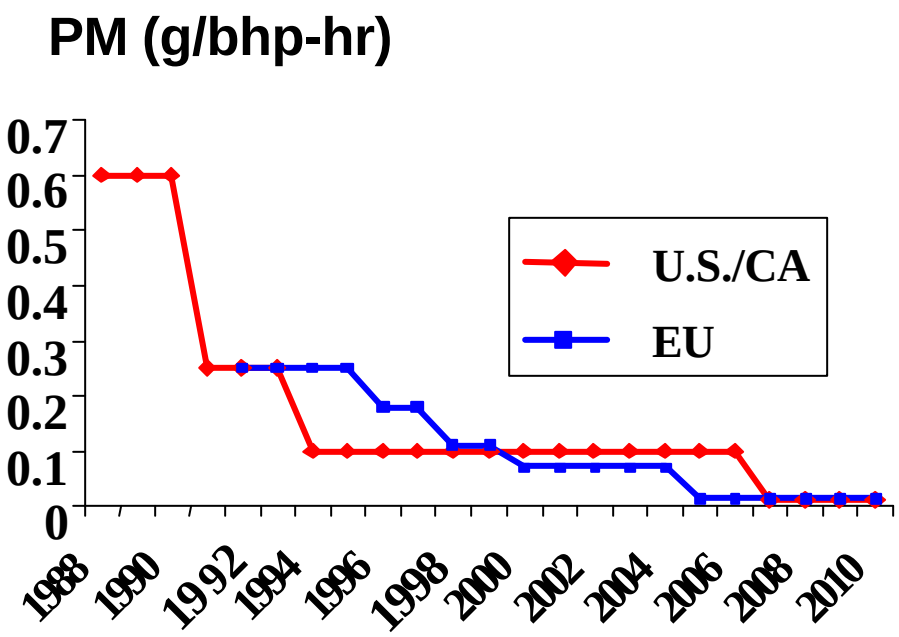
Ambient PM pollution (fine and ultrafine particles) continues to be one of the most formidable air quality and public health issues facing California today

Key Drivers for Action

• Much of the new engine emissions research in US (and California) is driven by the new 2007/2010 standards for heavy-duty on-road engines:

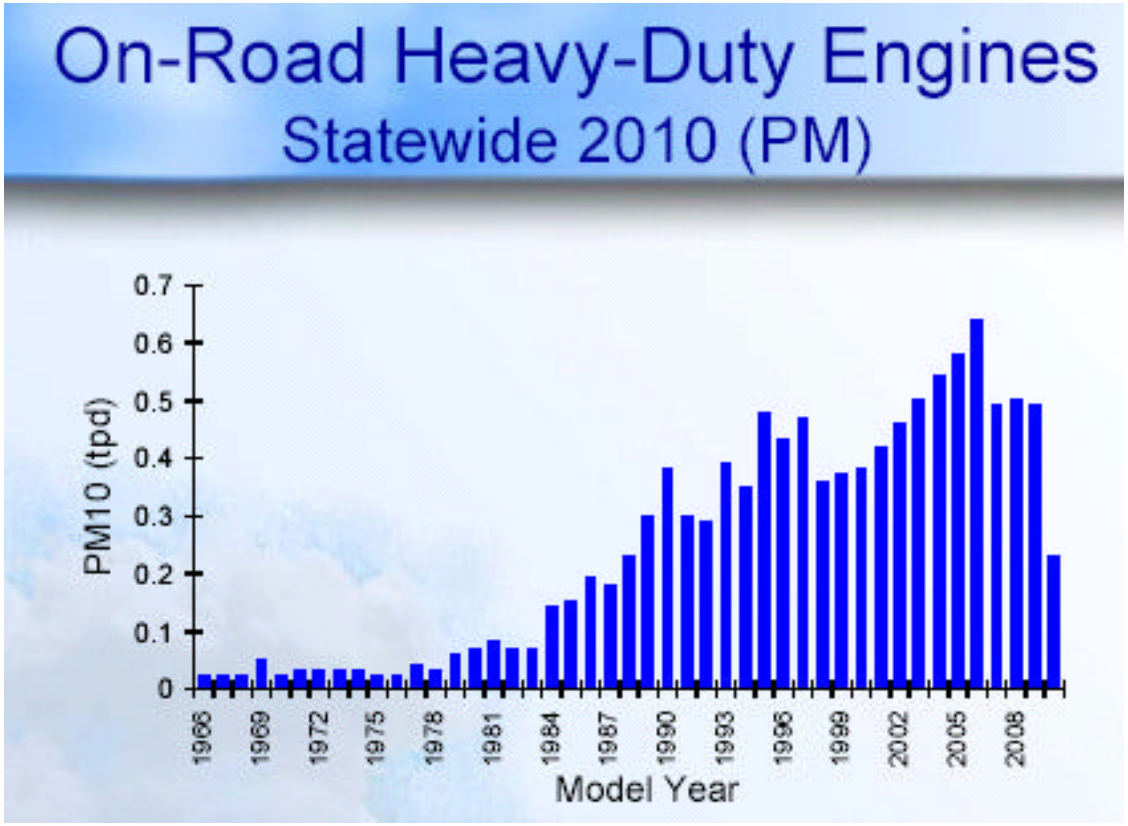
• New engine/fuel/aftertreatment systems will change the chemical and physical composition of PM emissions

• Current research activity into: (1) improved methods for sampling and (2) reassessment of health effects of emissions from new systems



Key Drivers for Action – cont'd

• There is also continued interest in evaluating and finding emission-reduction strategies for the existing HD diesel fleet



Real-time Particulate Matter Emissions

Major Challenge:

- **Definition of particulate matter**

- **Currently PM is defined as everything that is collected on a filter at a given filter face temperature, and then gravimetrically analyzed following a specific equilibration procedure**

Real-time Particulate Matter Emissions

Major Challenge:

- **PM emissions from catalyzed-trap equipped engines consist of ORGANICS, SULFATES, NITRATES**
- **Near absence of elemental carbon; hence, lack of sufficient mass for reliable gravimetric analysis**
- **Mass of PM tunnel background may be comparable to mass emitted from the engine**
- **Other exhaust and sample conditioning and handling procedures pose a challenge:**
  - **Artifacts (Surface reactions, Adsorption and desorption of gases and semi-volatiles, etc.)**

Techniques Available

- **Several techniques/methods are being developed to measure PM in real-time**
- **However, almost all of techniques face several drawbacks**
- **Available techniques (in no specific order):**

2003 EMPA Study reports several techniques
PASS (Photoacoustic Absorption)
Mass Monitor DMM – Dekati
Quartz Crystal Microbalance
TEOM
Flame Ionization Detection Method (Horiba)
Vaporization, Thermal Decomposition & Oxidation- Reduction Methods (Horiba)

Has a Paradox Emerged?

- Research evidence continues to emerge suggesting statistically significant associations between UF particle exposure and a myriad of adverse health effects
- Mobile sources are a key source of UF particles
- Diesel engine emissions are a key suspect
- Reducing total PM mass may or may not reduce UF particle number/surface
- *Yet...no proactive/systematic effort in US/CA to regulate the number of UF particles emitted by IC engines…!*
- But…California is emerging from fiscal crisis with heightened interest in UF particles
- Following European efforts with high interest
- And significant steps are underway to develop technical foundation (i.e., new UF measurement capacity)

Moving Forward

- For total PM emission determination, the measurement approach has been declared: *filter-based gravimetric method with improvements and continued use of engine dynamometer*
  - 40 CFR Part 1064 by US EPA is the technical framework now available for comment

- Non-filter alternatives for PM measurement are also being investigated:
  - Portable Emission Measurement Systems (PEMS) to support Not-to-Exceed regulation
  - These include on-vehicle PM emission measurements

- Harmonization between California and US requirements
- Efforts to harmonize and reach out to the world expert community (i.e., input from PMP)

Status on PM Metrology

- Needed research is too expensive and too complex to do alone
- Most efforts are/will be partnerships
  - Calibration Standards Task Force
  - ACES (Advanced Collaborative Emissions Study)
  - CARB PEMS Project
- All joint filter-based PM metrology work to date is captured in the Draft Part 1065
  - Early 2005 – USEPA publishes final rule
  - California to adopt
  - Industry/Government/Academia efforts with extensive worldwide input/exposure

Status on Metrology - cont'd

- In addition, in US, 2007/2010 PM method verification/improvement currently under study by CRC Project E-66
- Sponsored by CRC, DOE/NREL, EMA, USEPA, and CARB
- Prime contractor = SwRI
- Project will improve prescribed regulatory approach
- 1.5 year effort starting Jan. 04

Objective	Description
1	Improve filter-based PM measurement for 2007 engines
2	Correlate partial flow sampling and CVS sampling of PM
3	Investigate real-time PM measurement option to replace filter based method
4	Develop QAPP for 2007 engines

- Current status: exploring issues related to PM composition and filter media. Testing of trap-equipped engine.

New Work on Health Effects

- Extensive research agenda in California on the adverse health effects of UF particles in ambient atmospheres
- State-of-the-science and new information on source characterization might come from ACES. No other such effort in the horizon
- **A**dvanced **C**ollaborative **E**missions **S**tudy
- EMA is championing ACES
- HEI, CRC, US EPA, CARB, plus many others actively engaged
- Hypothesis: *"Emissions from combined new HD engines, aftertreatment, lubrication, and fuel technologies designed to meet 2007/2010 emission standards will have reduced pollutant levels and reduced endpoint-specific adverse effects in animals relative to earlier technologies"*

California's Progress

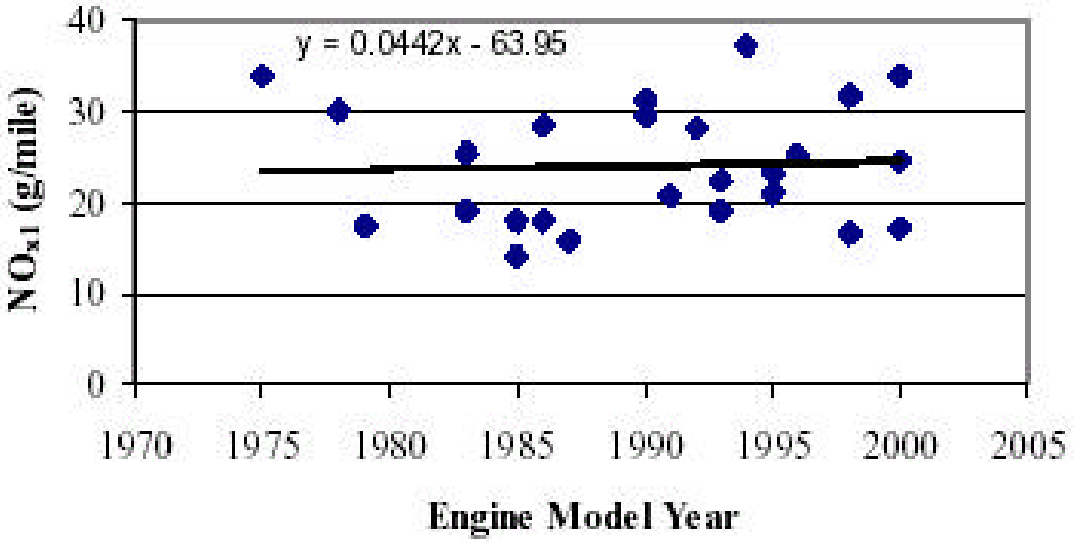
- Key driver is total health burden of air pollution
- Funding in place for incentive programs for replacing older polluting engines with cleaner options
- Technology-forcing PM retrofit program continues underway
  - multiple aftertreatment retrofit options available for on-road and off-road diesel applications
- Retrofit program (i.e., DPFs) = 80% of the total plan benefit to reduce risk associated with diesel PM mass
- International expert input

California's Progress - cont'd

- Latest issue of concern: excess NO_2 emissions from catalyst-based DPFs
  - CARB convened international working group
  - http://www.arb.ca.gov/diesel/no2/no2.htm
- Diesel Plan Regulations on track:
  - Cleaner diesel fuel by July 2006
  - Fleet Rule for Transit Agencies
  - Stationary engines
  - Portable Engines
  - Waste Collection Trucks
  - School Bus Idling Restrictions
  - Transport Refrigeration Units
  - Idling restrictions
- What is next?
  - agricultural engines, other vehicles, harbor craft and ocean going vessels, clean fuel for locomotives

Related Research Agenda

- **(1) Recent work for California HD mobile emission inventory update providing startling results (CRCs E 55/59 Project)**
- **Determination of in-use PM and NOx emission factors is elusive:**



- In-use NOx under transient operation has not decreased over time (MY 1975-2003) and in concert with more stringent standards
- Key issue for PM appears to be maintenance with PM emissions declining in time and in concert with emission standards

Source: Clark, N., et al., "Regulated Emissions from the California Heavy-Duty Truck Fleet Determined in the E55 Emission Inventory Program," 13th CRC On-road Vehicle Emissions Workshop, San Diego, California, April 2003

Related Research Agenda - cont'd

- **What is the correlation between emissions measured during standarized certificaiton test procedure and in-use (real-world) emissions?**
- **In the process of assessing impact on inventory and, most importantly, on State Implementation Plan (SIP)**
- **Extent of SIP impact in a significant issue as CA already facing emission reduction "deficits"**
- **(2) To advance NTE process, CARB deploying PEMS Project to compare leading on-board instruments**
  - Interested in both gaseous and PM measurements
- **Coordinating nationally (USEPA, NYSDEC, equipment vendors,etc) and internationally (MOU between CARB and EC/JRC-IES)**

Related Research Agenda - cont'd

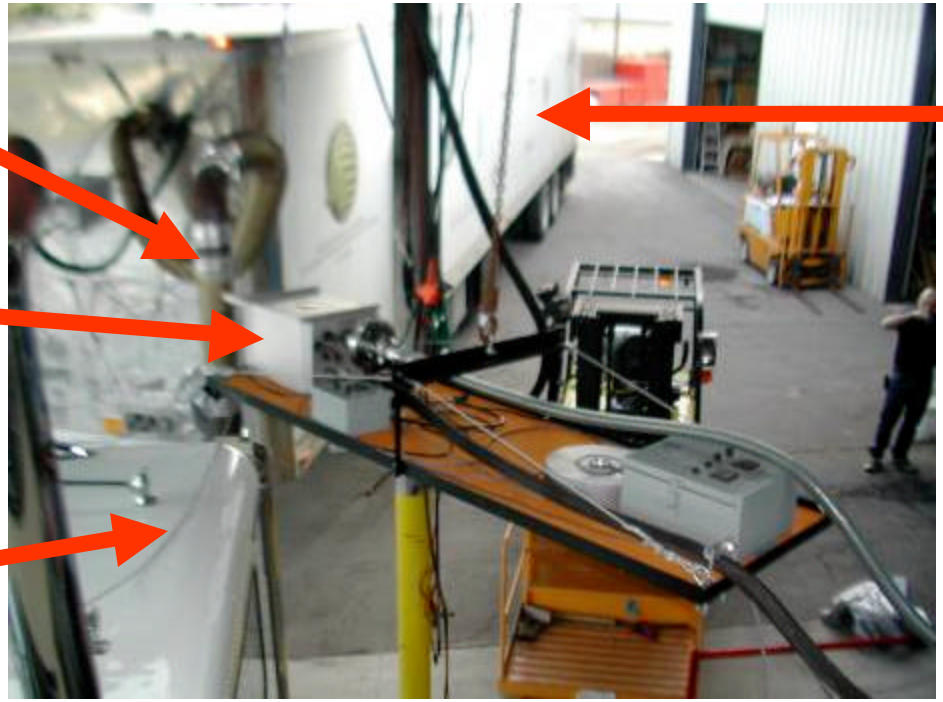
- **(3) Demonstration of advanced PM and NOx retrofit control for meeting 2010 HD emission standards now**
- **CARB working with lead agency: SCAQMD**
- **Technology choices:**
  - (1) trap for PM control
  - (2) SCR and absorber catalyst for NOx
- **Engine OEMs are involved in hardware development/integration**

California developing capacity for improved PM metrology

- **Major effort underway to develop capacity for UF measurement from light-duty and heavy-duty vehicles**
- **Significant investment on methods and hardware**
- **Two heavy-duty emissions laboratories working jointly on multiple issues of policy relevance**
- **Multiple light-duty test cells with UF metrology capacity are envisioned**
- **New capacity for metrology:**
  - full-flow and partial-flow dilution of transient emissions
  - Criteria and toxic emissions plus other: EC mass, size, count, surface area
  - Solid and semi-volatile particles

Heavy Duty Emission Lab # 1

Comparison of radial-inflow diluter against full-flow CVS tunnel



Filter-based assessment

Heavy Duty Emission Lab # 2

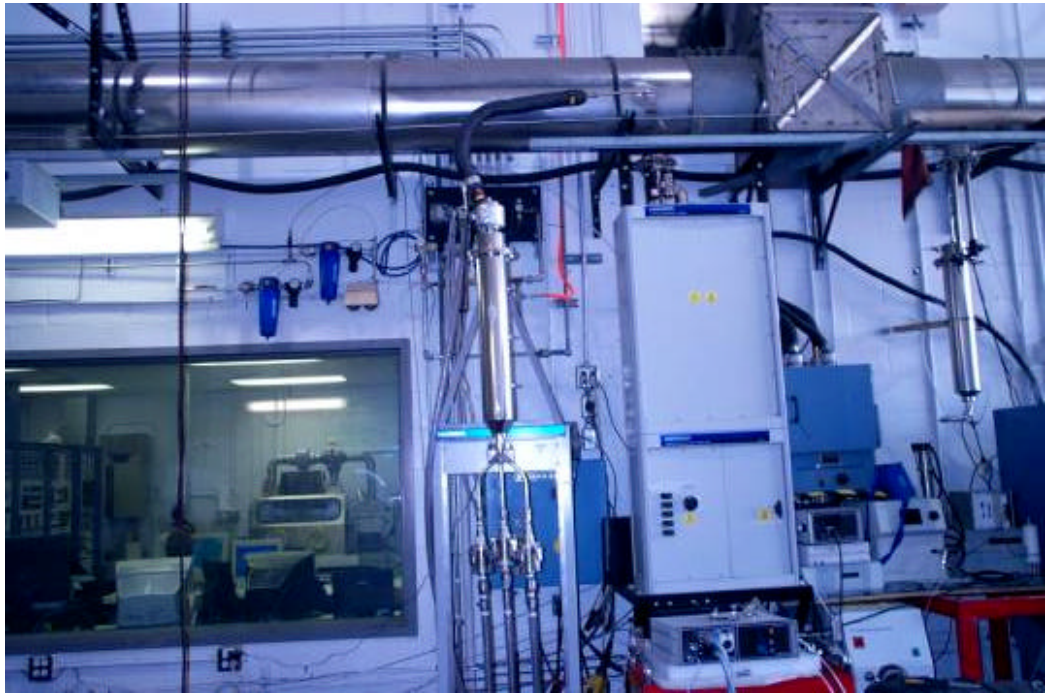
Controlled filter sample collection

Improved gravimetric method

Improvements for 2007/2010 Emissions

Heavy Duty Emission Lab # 2 - cont'd

diluted exhaust



metrology for mass, number, size, surface

raw exhaust

Assessment of measurement alternatives

Light Duty Emission Lab # 1

Aerosol particle characterization (mass and size) from LD diesel car

Final Remarks

- Ambient PM pollution and emissions (including UF particles) continue to be a leading regulatory/health issue
- Emissions research agenda driven by needs for implementing 2007/2010 regulations (new protocols)
- Metrology improvements for total PM emission determination taking center stage
- Additional metrology capacity for on-vehicle PM and UF emission of continued and high interest in California
- *Next year participants can discuss implementation/experiences of 2005 HDIU pilot project and/or alternatives*