

Future Considerations for Diesel Retrofit Technologies

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Types of Verified Diesel Retrofit Technologies

PM Reduction

- Diesel Particulate Filter
 - Wall-flow device that physically traps PM in exhaust stream on surface of substrate; PM burned off through regeneration (passive or active); >85% PM reduction
- Diesel Oxidation Catalyst
 - Flow-through device with catalytic coating on substrate that oxidizes soluble organic fraction of PM; 25-50% PM reduction
- Closed Crankcase Ventilation System
 - Replaceable filter that reduces engine blow-by emissions; >90% PM reduction (crankcase emissions)

NOx Reduction

- Selective Catalytic Reduction
 - Flow-through device that reduces NOx with injection of a reductant (urea) over the catalyst; 60-90% NOx reduction
- Lean NOx Catalyst
 - Flow-through device that reduces NOx with injection of a reductant (diesel fuel) over the catalyst; 25-40% NOx reduction

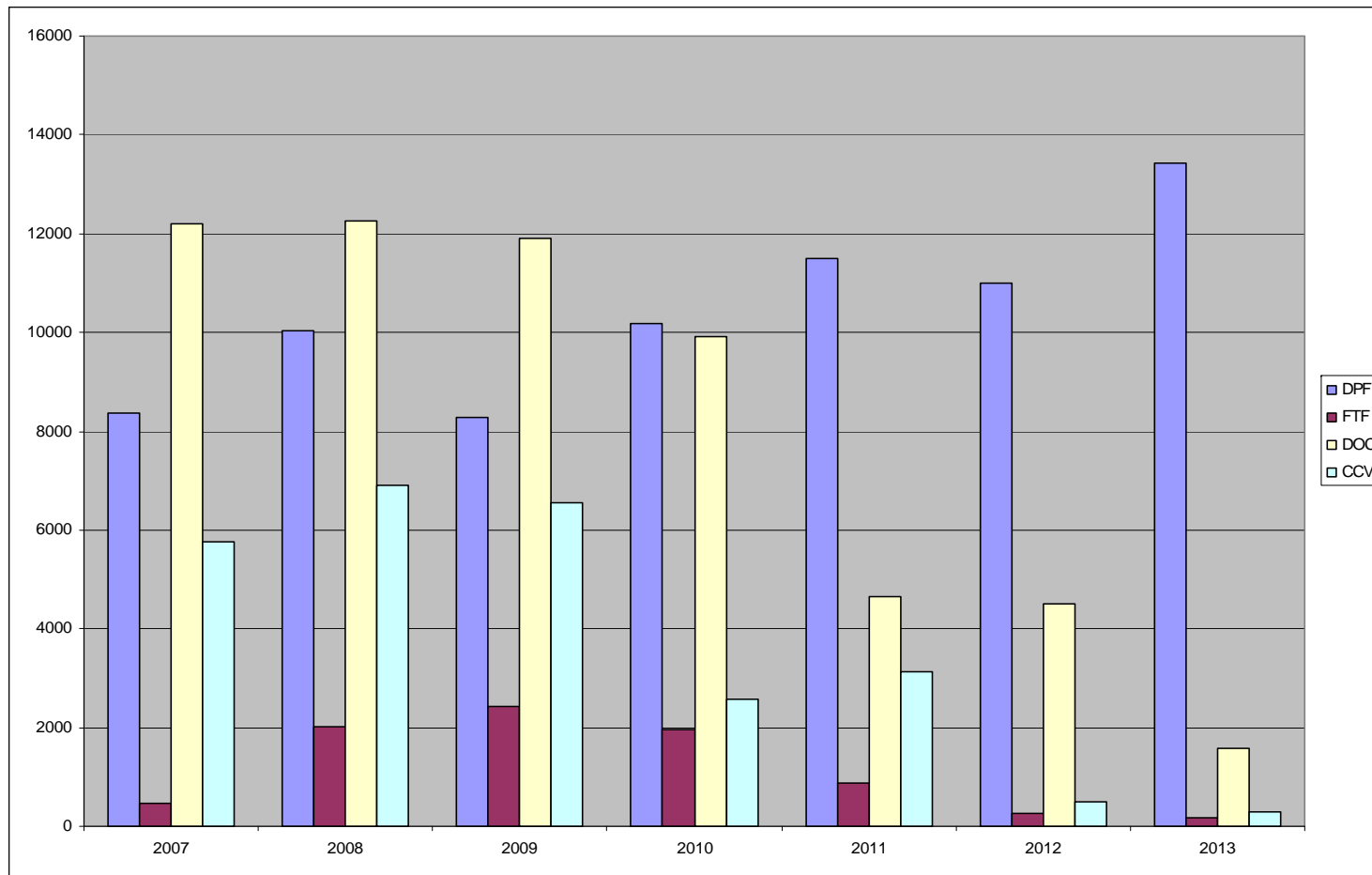


List of Available EPA-/ARB-Verified Level 3 Retrofit Technologies Continues to Expand (as of September 2014)

- U.S. EPA (epa.gov/cleandiesel/verification/verif-list.htm)
 - 6 on-road passive DPFs (includes 2 DPF+SCR)
 - 2 on-road active DPFs
 - 1 off-road passive DPF
 - 1 off-road SCR (NO_x control)
 - 1 locomotive SCR (NO_x control)
- California ARB (www.arb.ca.gov/diesel/verdev/vt/cvt.htm)
 - 13 on-road passive DPFs (includes 1 DPF+LNC and 1 DPF+EGR)
 - 9 on-road active DPFs
 - 1 off-road passive DPF
 - 4 off-road active DPFs
 - 7 Level 3 devices for TRUs or APUs
 - 11 Level 3 devices for stationary engines



MECA Diesel Retrofit Sales Survey Results (Total U.S. – On-Road and Off-Road)



Total of
26,863

Total of
31,283

Total of
29,180

Total of
24,640

Total of
20,177

Total of
16,262

Total of
15,467



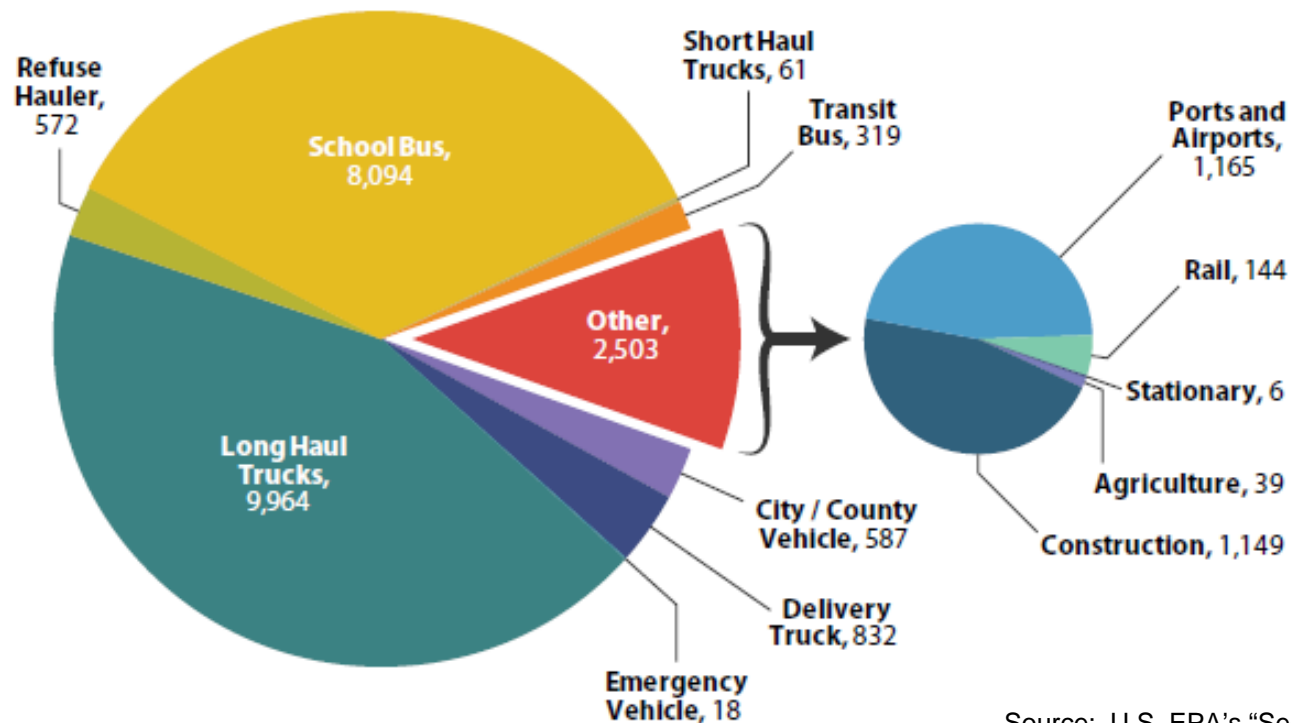
Significant Retrofit Experience in U.S.

- >100,000 on- and off-road DPF retrofits in U.S. since 2001
- >55,000 on- and off-road DPF retrofits in California since 2002
- >1 million DOC retrofits worldwide
- Extensive experience with retrofit technologies exists for on-road vehicles
 - School buses, transit buses, long- and short-haul trucks, refuse haulers, utility vehicles
- Retrofit experience continues to grow for many off-road applications
 - Construction equipment, port vehicles/equipment, marine engines and locomotives, stationary IC engines



Extensive On-Road Retrofit Experience, Off-Road Experience Growing

Figure 2. Equipment Retrofitted, Replaced, or Repowered by DERA 2008 and 2009/2010 Grants



Source: U.S. EPA's "Second Report to Congress: Highlights of the Diesel Emissions Reduction Program," April 2013



Active DPF+SCR Tugboat Retrofit at Port of LA

- Powered by two Detroit Diesel 525 hp, 14 liter, 2-stroke turbocharged & supercharged engines rebuilt to EPA Tier 2 emission levels
- Each engine retrofit with catalyzed DPF+SCR system; DPF regeneration managed by in-line diesel fuel burner
- Using ULSD, PM reduced by >95% (ca. 5-7 mg/kWh PM after ca. 200 h service); NOx reduced by >90%



Passive DPF Locomotive Retrofit Completed in California

- Tier 2 locomotive powered by three 19 liter, 522 kW Cummins gensets, each retrofit with DOC+catalyzed DPF (passive regeneration)
- Operated 3000 hours in switcher rail service with ULSD
- PM levels reduced by ca. 80% (19 mg/bhp-hr PM measured after 3000 h of service; below EPA Tier 4 PM limit of 30 mg/bhp-hr)



Solutions for Broadening Retrofit

- Increased and sustained DERA funding needed
 - EPA received only \$20 million in DERA funding for FY 2014; DERA funding eliminated in President's FY 2015 budget proposal in March (House proposed \$30 million in July, Senate proposed \$6.25 million in August)
- EPA DERA Rebate Program
 - Targets specific types of diesel vehicles/equipment
 - School buses in FY 2012, construction equipment in FY 2013, school buses in FY 2014
- EPA five-year in-use clean diesel strategy
 - Targets areas with high PM exposure areas (e.g., ports)
- CMAQ funding: \$4.44 billion for FY 2013-14
 - Approximately \$325 million set aside for PM_{2.5} projects in nonattainment areas in both FY 2013 and FY 2014
 - More funds need to be directed specifically towards retrofit
 - Better guidance needed from FHWA for state DOTs/MPOs



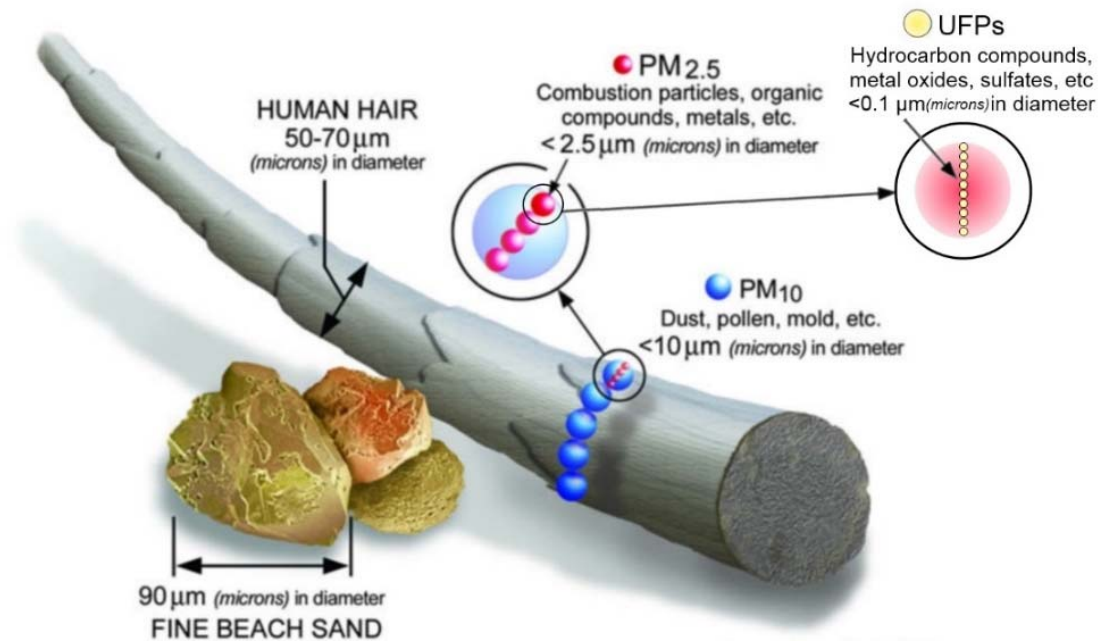
Solutions for Broadening Retrofit

- Timely implementation and effective enforcement of regulations
 - ARB diesel fleet rules
- More state-supported clean diesel programs
 - California, Illinois, Massachusetts, New Jersey, New York, Texas, Washington
- Supplemental environmental projects (SEPs)
 - More funds directed towards retrofit projects
- Clean construction initiatives
 - Contract specifications to promote use of emission controls
 - Federal showcase project for construction retrofits?
- Expansion of SmartWay
 - Renewed interest at getting criteria pollutant reductions from truck fleets in addition to improving fuel-efficiency



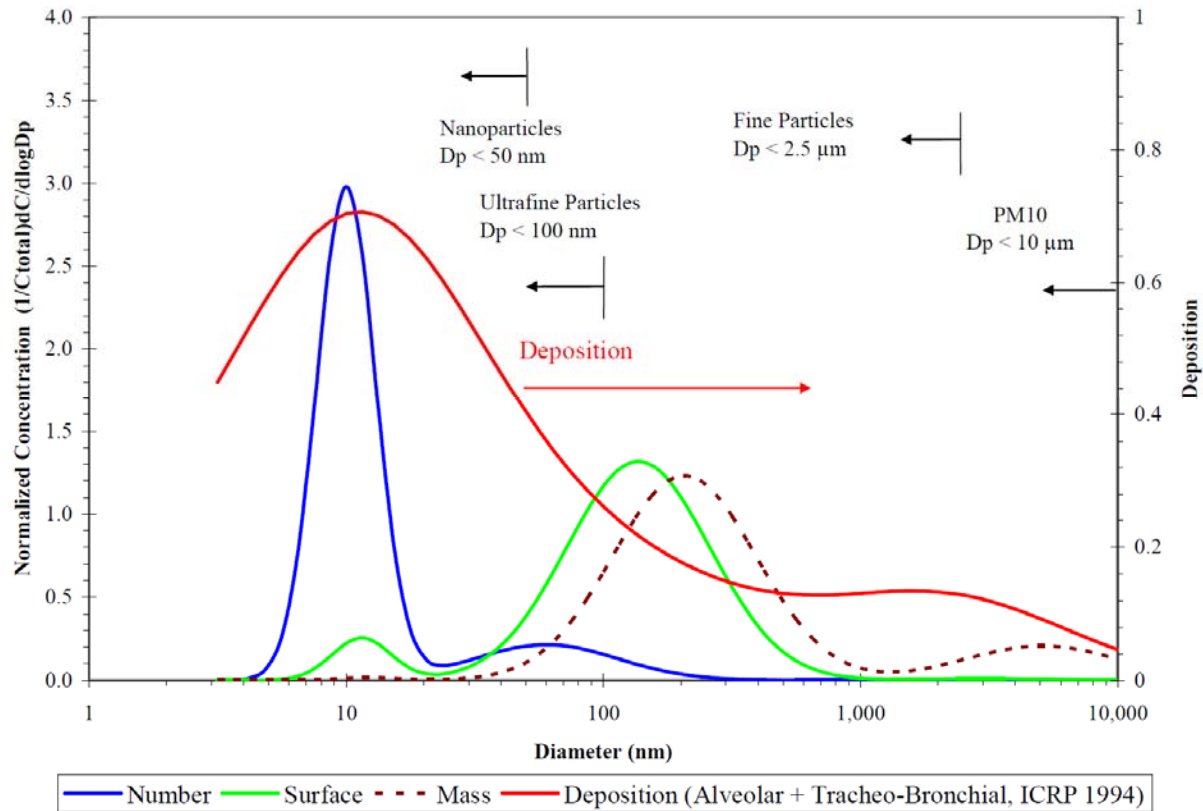
Growing Concern About Contribution of Ultrafines to Health Impacts of PM

- UFPs small enough to evade respiratory defense mechanisms and lodge in deepest recesses of lungs
- New studies suggest UFPs may be more toxic than elemental carbon that makes up most of engine PM mass emissions
- WHO/IARC classified air pollution/particles as cancer agents in October 2013



Engine Exhaust Particles Dominated by UFPs

- Greatest number of particles and greatest amount of lung deposition occurs in ultrafine particle size range

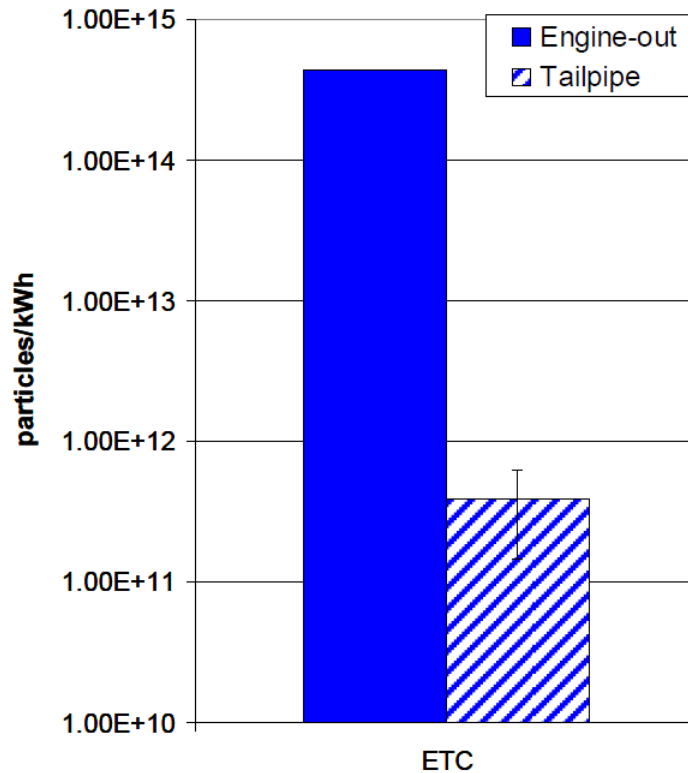


Particle size distribution of typical engine exhaust PM
(Kittelson, 2006)

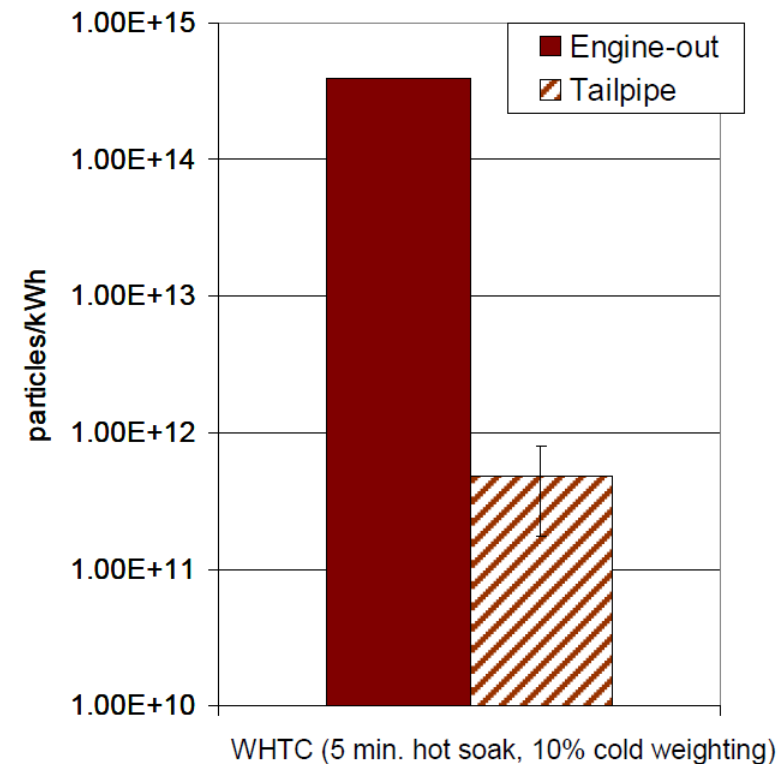


DPFs Have High Particle Number Filtration Efficiency

- ETC tailpipe emissions $\sim 4 \times 10^{11}/\text{kWh}$
- DPF Efficiency $> 99.9\%$



- WHTC tailpipe emissions $< 5 \times 10^{11}/\text{kWh}$
- DPF Efficiency $> 99.8\%$



- Filters capture ultrafine particulate matter
- Filters reduce black carbon emissions

Future Retrofit Considerations

- New off-road diesel engines meeting Tier 4 limits without filters
 - As clean as off-road engines with filters?
- Potential health concerns regarding other mobile sources without filters
 - Tier 4 diesel locomotives
 - Gasoline direct-injected light-duty vehicles
 - Heavy-duty, spark-ignited stoichiometric natural gas engines
- Particle number emission standards may need consideration to ensure reduction of ultrafine particulate matter and use of best available controls

Future Retrofit Considerations

- Need to preserve benefits of diesel vehicles certified with emission control devices
 - 2007 and newer on-road trucks; Tier 4 off-road equipment with DPFs; over 380 engine families certified between 1994 and 2009 with DOCs
 - Market opportunity for diesel emission control replacement parts for 2007 and newer trucks
 - ARB taking lead in developing protocol to approve diesel aftermarket parts; targeting proposal in 2016
- Need for more effective state heavy-duty I/M programs
 - High emitters have significant impact on emissions
 - DPFs being compromised and/or tampering issues (DPFs removed)
 - More stringent opacity cutpoints needed for trucks with filters
 - States seeking SIP credit for heavy-duty I/M programs; how correlate opacity to PM mass?



Future Retrofit Considerations

- Effort by UN Climate and Clean Air Coalition to retrofit trucks and buses in developing world
 - Focus on reducing climate and health impacts of black carbon emissions
 - Concerns with age of vehicles, availability of low sulfur fuel

Summary

- Over 14 years of progress but still millions of legacy diesel engines operating across U.S.
- Manufacturers continue to invest and expand retrofit technology options available for reducing PM and NOx emissions from existing diesel engines
- Need effective policies/strategies to increase interest in retrofit projects
- UFP health concerns show importance of filters
- Need to preserve benefits of new diesel engines
- Defined window of opportunity for retrofitting legacy fleet



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Diesel Retrofit

The purpose of this section of the website is to provide useful information related to diesel retrofit emission control technology. By making this information available, MECA hopes to assist interested stakeholders in establishing and operating more effective diesel retrofit programs.

- What Is Retrofit**
Summary of the various types of diesel retrofit technologies
- Manufacturers**
List of MECA companies who sell diesel retrofit technologies
- Funding**
List of notable funding sources for diesel retrofit projects
- Resources**
Reports, fact sheets, and presentations on diesel retrofit technology
- Diesel Retrofit News**
News related to diesel retrofit technology (2013-2010)
- Helpful Links**
List of websites related to diesel retrofit technology

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