



BUILDING AMERICASM

Diesel Particulate Filter (DPF) Technology for New & Retrofitted Locomotives in the US and Europe

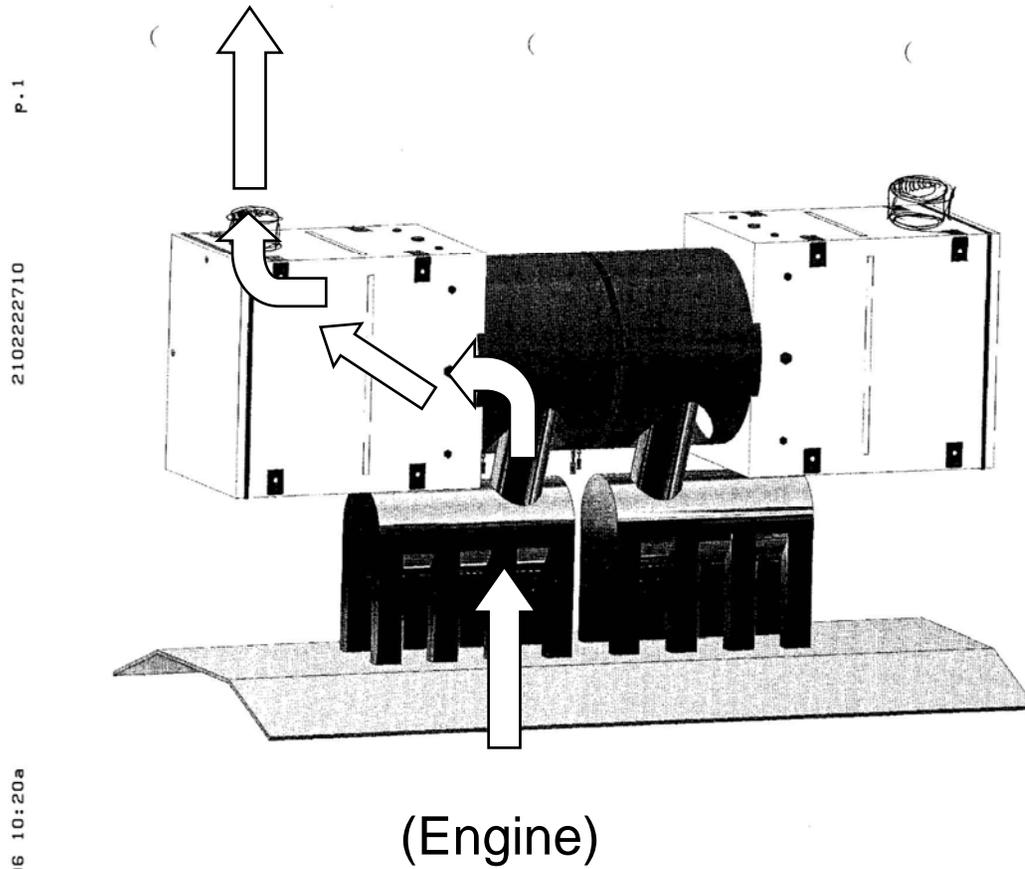
BNSF-UP-SWRI meeting with CARB staff

Sacramento, CA, December 7, 2006

(revised for EPA-Ann Arbor, December 19, 2005)

(revised for CARB hearing, Sacramento, July 13, 2006)

Diesel Particulate Filter (DPF)



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Known US DPF investigations~Europe

→ February 2005:

- ✦ BNSF-UP-SWRI trip to Switzerland & Germany ... Anderson-BNSF, Iden-UP, Fritz-SWRI ... visited Hug Engrg. (Winterthur CH), L'Orange Injection (DE), MTU Engine (Friedrichshafen DE), SBB Cargo (Biel CH) & Vossloh Locomotive (Kiel DE)

→ August 2005

- ✦ SCAQMD trip to Switzerland ... Dr. Liu-SCAQMD ... visited Hug and SBB Cargo

→ November 2005

- ✦ UP-SWRI trip to Switzerland, Germany & UK ... Iden-UP and Fritz-SWRI ... visited SBB Cargo (Basel CH), MTU Engine and Eurotunnel (Folkestone UK)

→ May 2006

- ✦ CARB-SCAQMD-UP trip to Switzerland ... Iden-UP, Semeroth & White-CARB, Hogo & Depankar-SCAQMD ... visited Hug Engrg., VERT institute & SBB Cargo (Biel, CH)

New Locomotives

Category	U.S.	Switzerland	Other Europe
Road Power 3600-6000HP	<p><u>EMD/GE</u> investigating DPF technology for potential Tier 3 use. Utilizing data from CEP.</p> <p><i>OxyCat being researched for Tier 3 (see <u>EPA-SWRI-UP</u> test on retrofit page).</i></p>	<p>No Swiss diesels in this HP range.</p> <p>All higher-HP Swiss road freight locos (450) are electric up to 10,000HP</p>	<p>1 prototype 3600HP <i>with factory-applied DPF</i> (none ordered or delivered yet).</p> <p>4000HP “Euro4000” (~EMD Tier 2) engine to be introduced in '06. <i>No DPF planned now.</i></p>
Local 2000-3000HP	<p>None being manufactured in US</p>	<p>Am843 (2000HP)</p> <p>73 new units operating w/ <i>Hug DPF</i>, 0-2 yrs old.</p>	<p>Same Am843 as in Switzerland <i>without Hug DPF Filter</i></p>
Switch 1200-2000HP	<p>No traditional switchers mfr'd since early-1980s.</p> <p>UP genset switcher being tested, 158 units in production.</p> <p>~ 21 Hybrid units in-service.</p>	<p>Am841 (1200HP)</p> <p>40 units in fleet, ~10-12 years old.</p>	<p>Comparable switchers <2000HP throughout Europe compliant with UIC II/EC standards <i>with no DPF.</i></p>
Other 150-600HP	<p>Not used in US</p>	<p>All new Swiss locos of this type will be mfr'd with DPF.</p>	<p>Comparable switchers <600HP throughout Europe compliant with UIC II/EC standards <i>with no DPF</i></p>

Existing Locomotives (DPF retrofits)

Category	U.S.	Switzerland	Other Europe
Road Power 3600-6000HP	<p>General consensus: not enough space for DPF.</p> <p>EPA-SWRI-UP test of diesel oxidation catalyst (DOC) inside exhaust manifold on (1) 3800HP SD60 in LA Basin in 2Q'06</p>	<p>No Swiss diesels in this HP range.</p> <p>All higher-HP Swiss road freight locos (450) are electric up to 10,000HP.</p>	<p><i>No DPF retrofit developments known.</i></p>
Local 2000-3000HP	<p>General consensus: not enough space for DPF.</p>	<p>Am843 2000HP</p> <p>(All Swiss Am843s are NEW locomotives.)</p>	<p><i>No DPF retrofit developments known.</i></p>
Switch 1200-2000HP	<p>CEP Program evaluating DPF for application on 2-to-3 1500HP roots blown EMD switchers.</p> <p>Will use Hug DPF technology (same as in Switzerland).</p> <p>In-service testing by 2Q'06.</p>	<p>Am841 1200HP</p> <p>40 existing diesel units operating.</p> <p>6-of-the-40 units <i>with Hug DPF retrofits.</i></p>	<p><i>No DPF retrofit developments known.</i></p>
Other 150-600HP	<p>Not used in US</p>	<p>201 existing diesel Units</p> <p>All have been <i>retrofitted DPF.</i></p>	<p><i>No DPF retrofit developments known.</i></p>

What's Different: Europe v California?

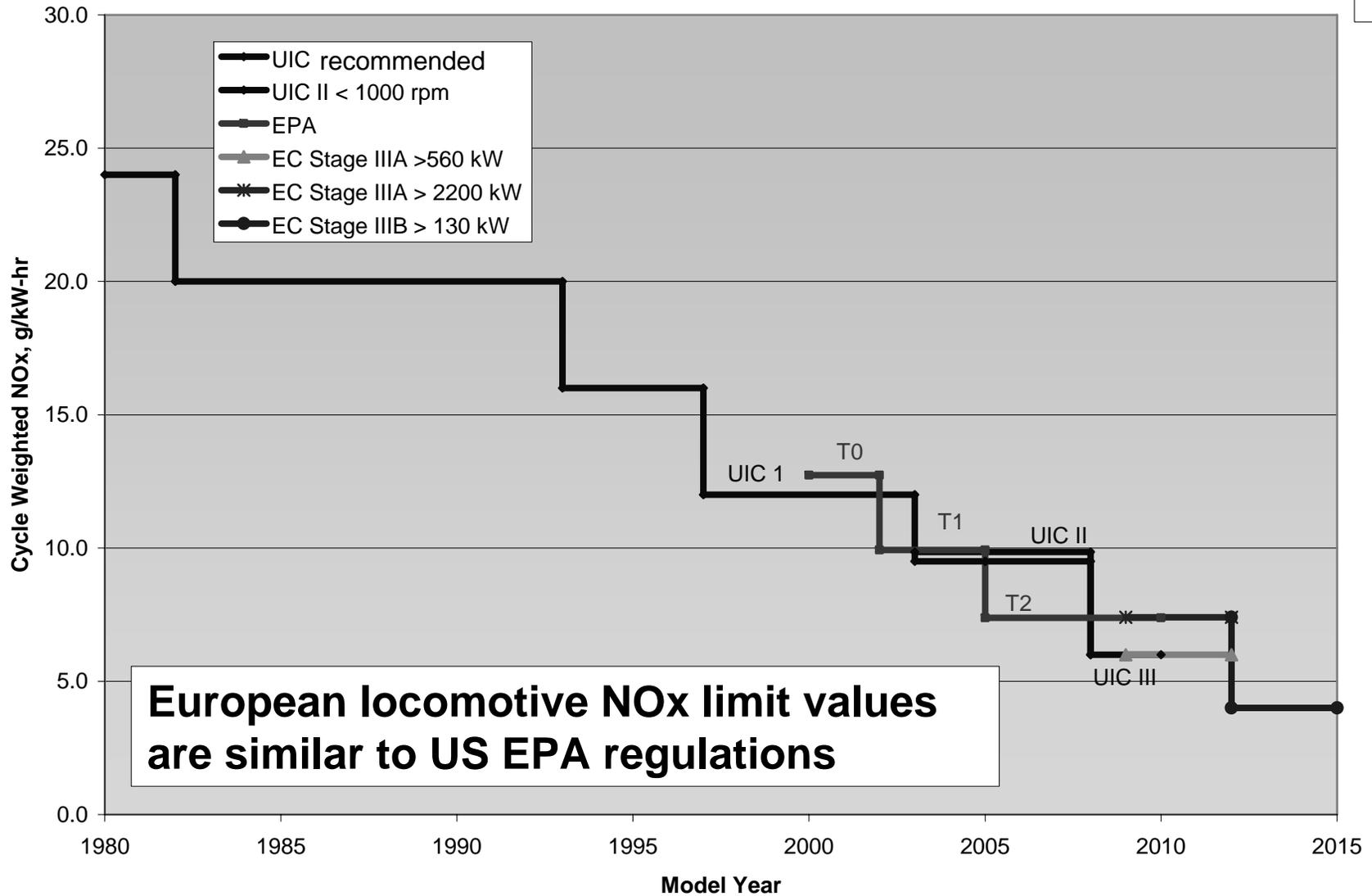
→ New locomotives, i.e., original equipment installation

- ✦ Switzerland: running 73 new 2000HP switcher locomotives with Hug filters.
- ✦ Germany: 1 new demo on 3600hp. None ordered or delivered.
 - European Community stage IIIA ~ US EPA Tier 2
- ✦ ... suspect this model may be superceded by new design using EMD EPA Tier 2-equivalent engine without DPF!
- ✦ US:
 - Diesel genset switchers, likely ULELs.
 - Diesel-battery hybrids (“Green Goats”), likely ULELs.
 - LNG switchers.

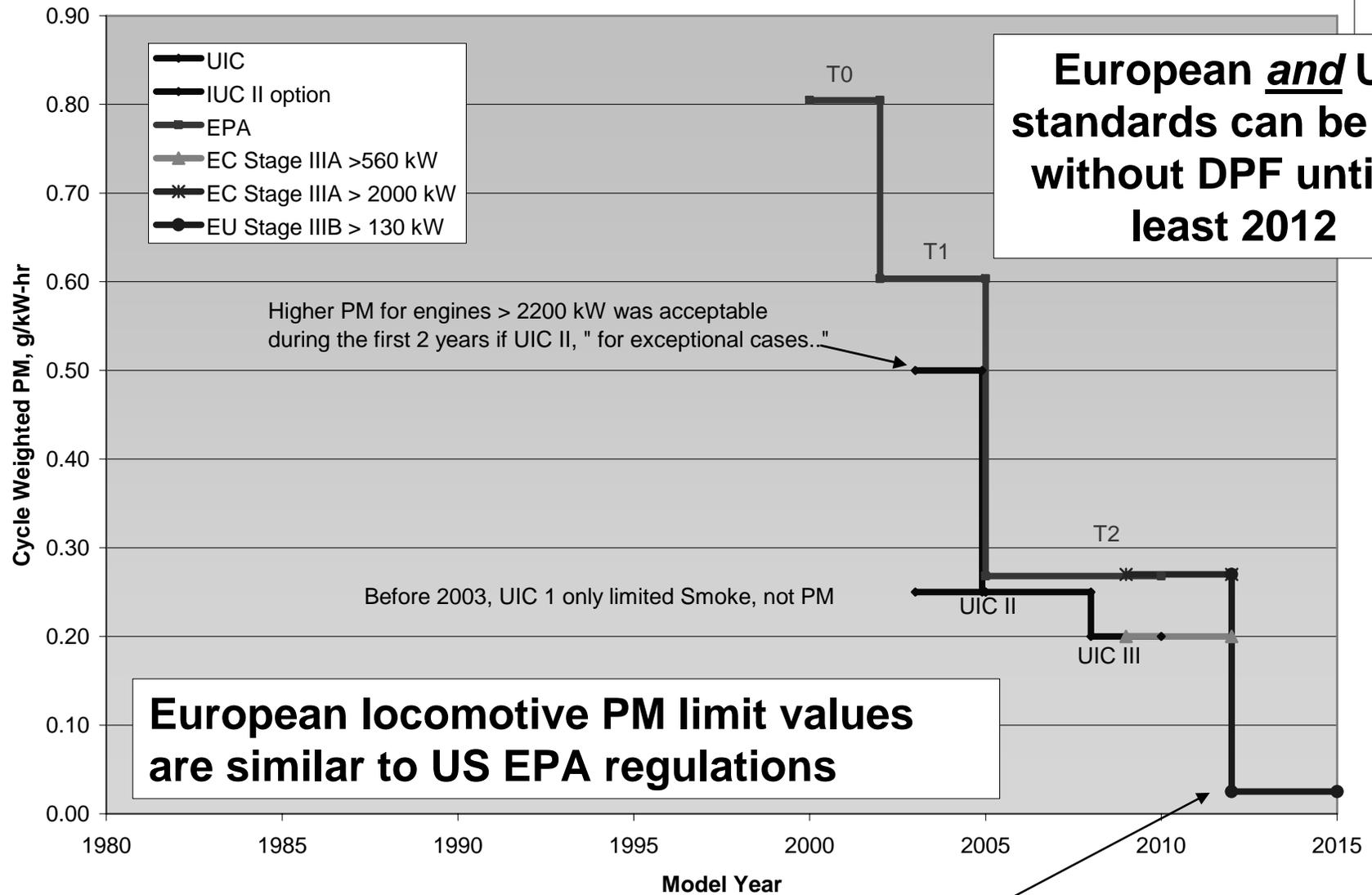
→ Retrofit locomotives

- ✦ Switzerland: retrofit 6 1200hp switcher locomotives with Hug filters.
- ✦ Europe: Euro Standard = US standard, no requirement in Europe to retrofit or rebuild to lower emissions, e.g. EPA Tier 0 upgrade.
- ✦ US: California Emissions Project will retrofit and field test (3) 1500HP switchers in southern CA with Hug filters, 2006
Oxy Cat test on 3800HP UP 2Q'06

Progression of Loco NOx Reg's



Progression of Loco PM Reg's



European *and* US standards can be met without DPF until at least 2012

Proposed 2012 PM limit of 0.025 g/kW-hr to be reviewed in 2008

DPF performance: Switzerland

- 1-2 years service on 73 “new” Am843 2000HP locos & 6-of-40 retrofitted Am841 1200HP**
 - ↘ Requires use of synthetic engine lube oil (low-ash).**
 - ↘ Low-sulfur (<300 ppm) fuel.**
 - ↘ SBB has had no DPF maintenance responsibility until warranty expires (oldest units ... December ‘05 expiration).**
- Various “unknowns” regarding ash cleanout cycles, etc.**
- VERT-approved, however, no in-service DPF emissions testing made or planned**

DPF performance: US

→ California Emissions Program ...

→ 3 years “engine reconfiguration & filter screening” work at SWRI

- ✦ SWRI screened >12 DPF candidates on 2-stroke EMD engine (*not Cat or MTU 4-stroke engines as used in Switzerland*)
- ✦ Conventional non-synthetic lube oils & low-oil-consumption power assemblies (*Swiss DPF apps use synthetic oil*)
- ✦ Tested for performance and durability in engine cell
- ✦ Hug DPF technology is best candidate (*same technology used in Switzerland*)
- ✦ 2-to-4 1500HP switchers to be retrofitted for revenue testing in southern CA in 2006

Very similar progress: Swiss & US

→ There is no different technology being utilized in Europe that is not being investigated in the U.S.!

→ New locomotives

✦ Switzerland is ahead of US on implementing Hug DPF filters ... but only on 73 new 2000HP switcher locomotives.

✦ *US focus for new switchers has shifted to ultra-low-emissions hybrids and genset switchers, both using low-emissions truck-derivative diesel engines.*

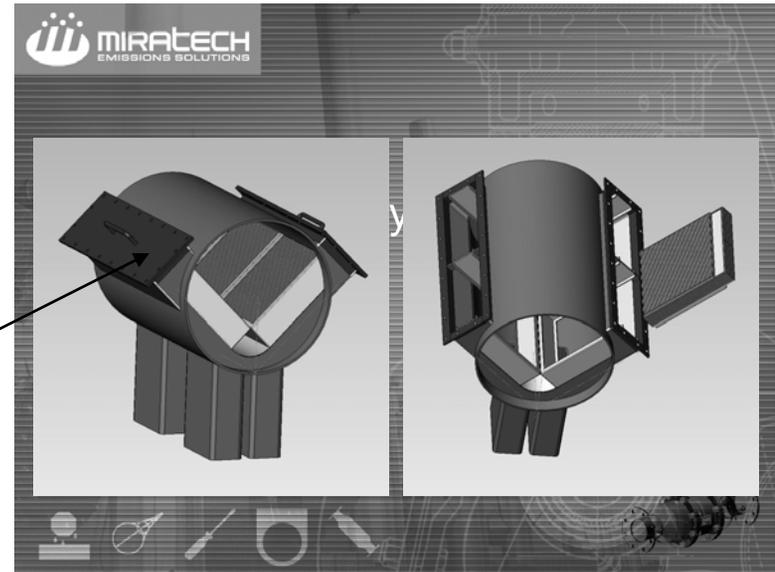
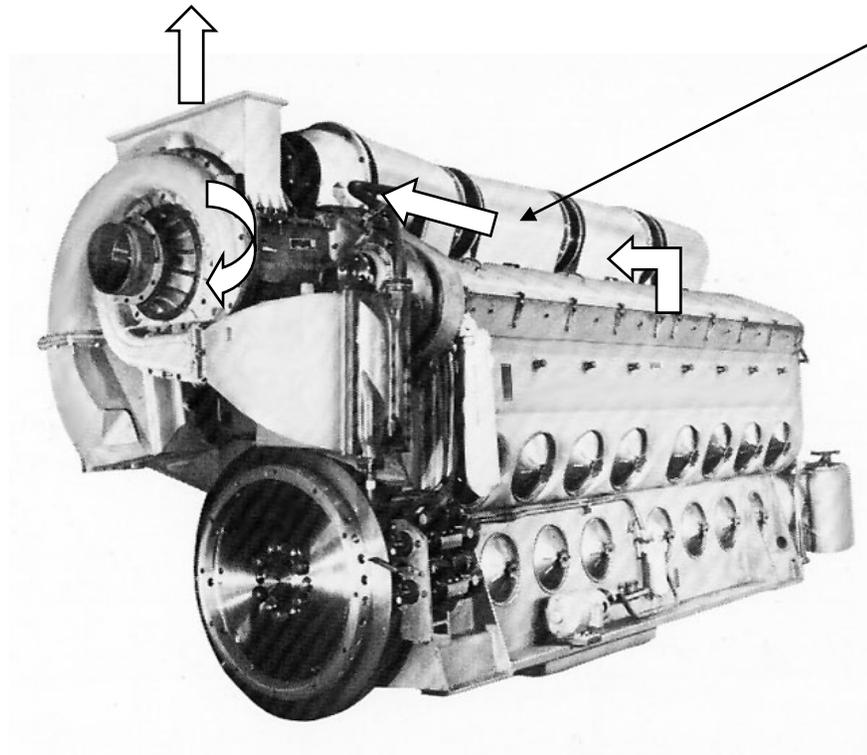
✦ For high horsepower, there is only 1 prototype new locomotive with DPF in Europe.

✦ *But ... European manufacturer is now partnering with EMD to use US Tier 2 type engine without DPF.*

→ Retrofits: only 6 in Switzerland completed, 2-to-4 to be completed in US in '06

EPA-SWRI-UP-Miratech oxicat test

US EPA-funded field test of a pre-turbocharger oxidation catalyst (“oxicat”) to reduce Soluble Organic Fraction particulates (primarily oil-droplet related)



One UP SD60M with a Tier 0 overhauled-engine to be equipped in Feb. '06 ... returned to service inside LA basin for 1 year of service and assessment.