



BUILDING AMERICASM



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

**→ BNSF-UP-SWRI meeting with CARB staff
Sacramento, CA
December 7, 2006**

Known US DPF investigations~Europe

→ February 2005:

↗ BNSF-UP-SWRI trip to Switzerland & Germany

- Jennifer Anderson-BNSF, Mike Iden-UP, Steve 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. Chung S. 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)

Nomenclature

- ➔ **AAR** Association of American Railroads
- ➔ **Am841** Vossloh loco. w/ MTU 396 1200HP engine in Switz. & Europe
- ➔ **Am843** Vossloh loco. w/ Cat 3512 2000HP engine in Switz. & Europe
- ➔ **CEP** Ca. Emissions Program (ARB-BNSF-UP-SWRI DPF testing)
- ➔ **DOC** Diesel Oxidation Catalyst (PM control)
- ➔ **DPF** Diesel Particulate Filter (PM control)
- ➔ **EC** European Commission (sets diesel engine emissions reg's for Europe)
- ➔ **EMD** Electro-Motive Diesels, Inc. (former Electro-Motive Div. of GM)
- ➔ **Euro4000** EMD-Vossloh loco. w/ EMD 710 4000HP engine, '06 Europe sales
- ➔ **GE** General Electric
- ➔ **Hug** Hug Engineering (DPF manufacturer in Switzerland)
- ➔ **MaK2000BB** Vossloh prototype loco w/ MTU 3600HP engine w/ Hug DPF
- ➔ **MTU** German diesel engine mfr, subsidiary of DaimlerChrysler
- ➔ **SBB** Swiss Railways (recently privatized)
- ➔ **UIC** International Union of Railways ("AAR for rest of the world")

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 EPA-SWRI-UP 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. No DPF planned now.</p>
Local 2000-3000HP	<p>None being manufactured in US</p>	<p>Am843 (2000HP)</p> <p>73 new units operating <i>with Hug DPF.</i></p>	<p>Same Am843 as in Switzerland without Hug DPF Filter</p>
Switch 1200-2000HP	<p>No traditional switchers mfr'd since early-1980s.</p> <p>UP genset switcher being tested.</p> <p>Hybrid units in-service.</p>	<p>Am841 (1200HP)</p> <p>No “new” units in fleet.</p> <p>40 electric switchers</p>	<p>Comparable switchers <2000HP throughout Europe compliant with UIC II/EC standards with no DPF.</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 with no DPF.</p>

Existing Locomotives (DPF retrofits)

Category	U.S.	Switzerland	Other Europe
Road Power 3600-6000HP	General consensus: not enough space in carbody for DPF. EPA-SWRI-UP test of diesel oxidation catalyst (DOC) inside exhaust manifold on (1) SD60 in LA Basin in 2Q'06	No Swiss diesels in this HP range. All higher-HP Swiss road freight locos (450) are electric up to 10,000HP.	<i>No DPF retrofit developments known.</i>
Local 2000-3000HP	General consensus: not enough space in carbody for DPF.	Am843 2000HP (All Swiss Am843s are NEW locomotives.)	<i>No DPF retrofit developments known.</i>
Switch 1200-2000HP	CEP Program developing DPF for application on 2-to-3 1500HP roots blown EMD switchers. Will use Hug DPF technology (same as in Switzerland). In-service testing by 2Q'06.	Am841 1200HP 40 existing diesel units operating. 6 diesel units <i>with Hug DPF retrofits.</i> 40 electric switchers	<i>No DPF retrofit developments known.</i>
Other 150-600HP	Not used in US	201 existing diesel Units 0 units operating <i>with retrofitted DPF.</i>	<i>No DPF retrofit developments known.</i>

What's Different: Europe v California?

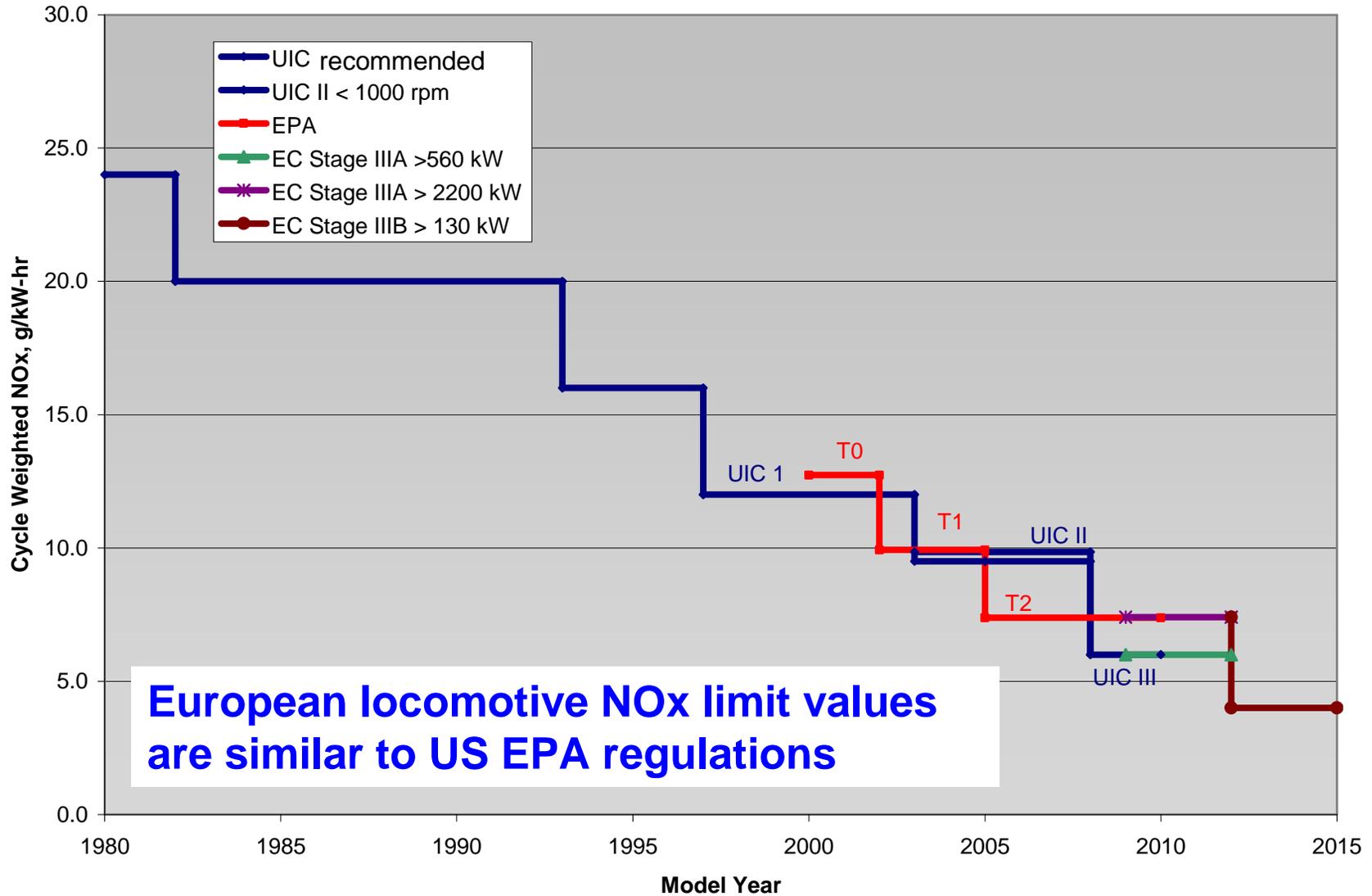
→ New locomotives, I.e., original equipment installation

- ✦ 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
- ✦ ... will likely be superseded by new design using EMD Tier 2 engine without DPF!
- ✦ US:
 - Diesel genset switchers, likely ULELs.
 - Diesel-battery hybrids (“Green Goats”), likely ULELs.
 - LNG switchers.

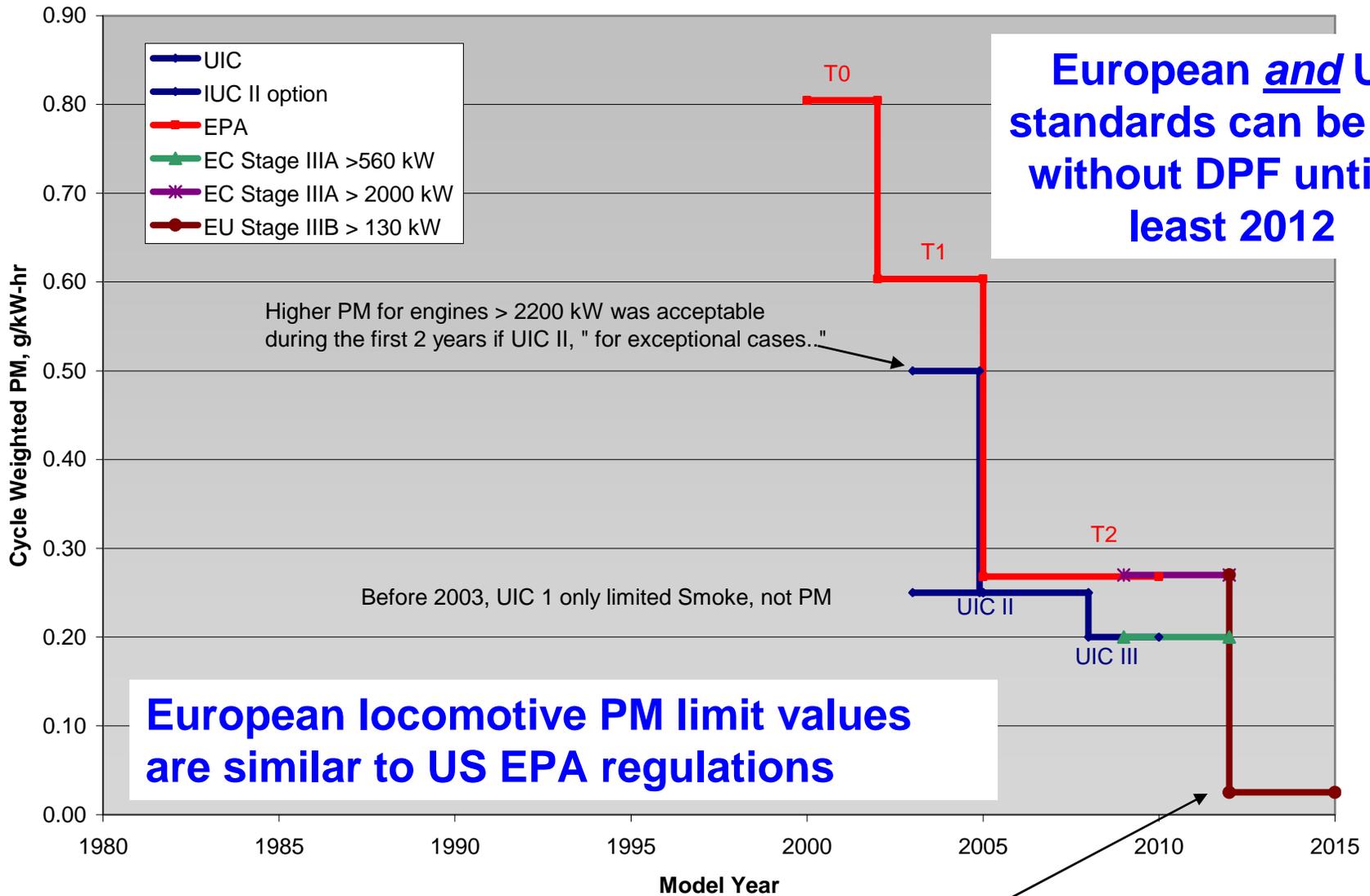
→ Retrofit locomotives

- ✦ Switzerland: retrofit 6 1200hp switcher locomotives with Hug filters.
- ✦ Europe: Euro Standard = US standard
- ✦ 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

Higher PM for engines > 2200 kW was acceptable during the first 2 years if UIC II, " for exceptional cases."

Before 2003, UIC 1 only limited Smoke, not PM

European locomotive PM limit values are similar to US EPA regulations

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
 - ↘ Only 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 disposal, ash cleanout cycles, etc.
- 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

More than 300 Vossloh 2000HP locomotives without Hug DPF

Same Vossloh 2000HP locomotive but with \$100,000 Hug DPF



vossloh

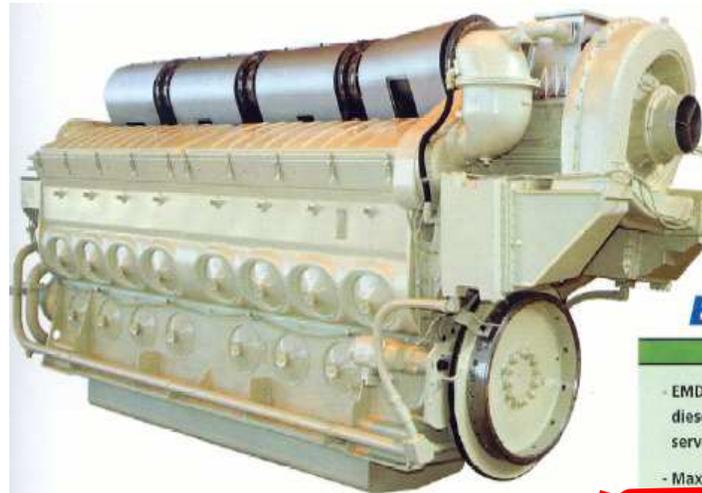


Introducing the EURO 4000

Europe's most powerful diesel-electric locomotive. powered by **ELECTRO MOTIVE**

In line with all European standards

The EURO 4000 was designed by the world's leading specialists in the railway sector – Vossloh and EMD. These two companies have already supplied hundreds of customers around the world with diesel locomotives that guarantee a high degree of availability, optimum life-cycle cost and the added assurance of a ready supply of spare parts for the rest of the locomotive's service life. The EURO 4000 naturally also complies with all European norms (for example: emissions, noise, crash, fire), is suitable for UIC-gauge lines and capable of running on all European railway networks.



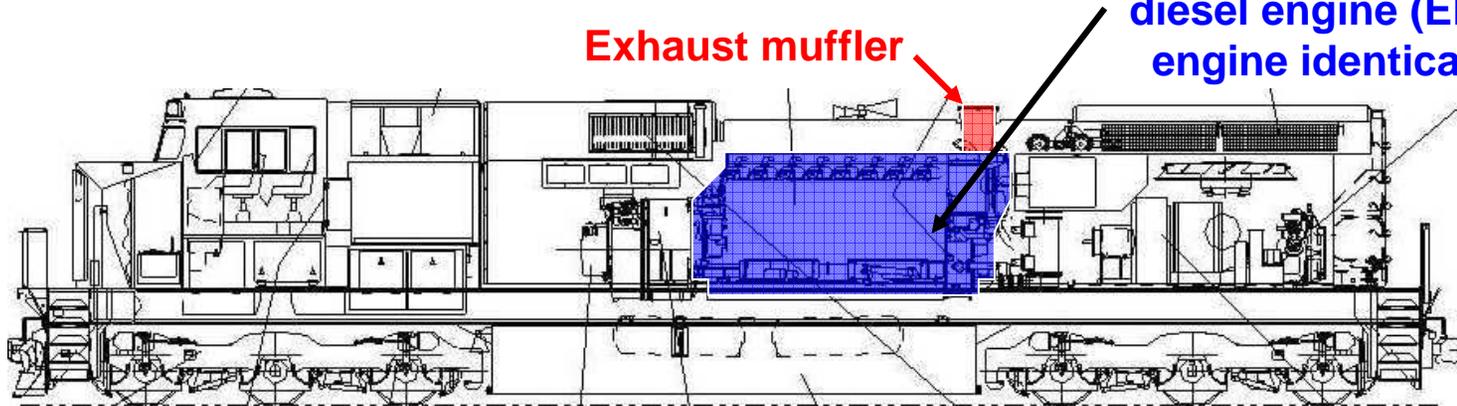
powered by **ELECTRO MOTIVE**

- EMD's most fuel efficient turbocharged 16-V two stroke diesel engine (16-710) with electronic fuel injection serves to power the locomotive with 4,250 HP DIN
- Maximum speed of 120 km/h; six D43 traction motors
- Exhaust emissions remain below the levels stipulated by EU 97/68, stage IIIA

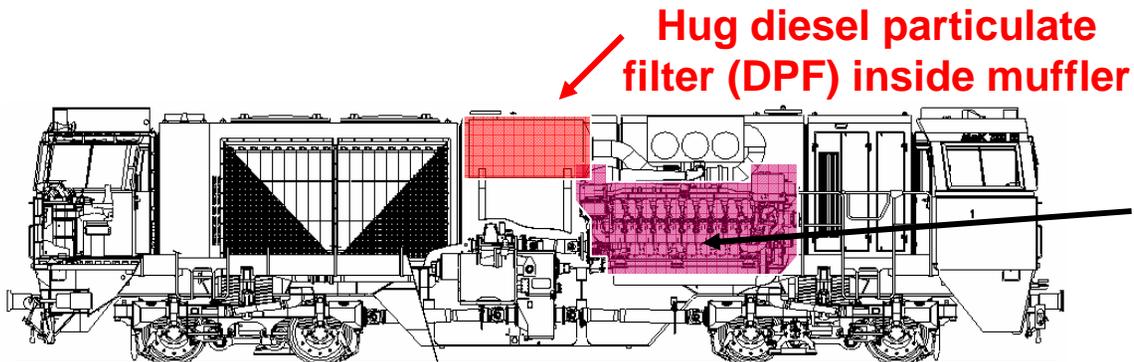
http://emdiesels.com/pdf_files/2.4.1%20EURO%204000%202005-09-30.pdf

GE 4400 HP diesel-electric AC locomotive

GE Evolution-series
medium-speed 4400 HP
diesel engine (EMD 710
engine identical size)



420,000 pound weight
76' long



MTU high-speed 4000 HP
diesel engine

200,000 pound weight
57' long

Vossloh MaK 2000BB 4000 HP diesel-hydraulic locomotive



**SBB Am841 1220HP
w/ retrofitted Hug filter
(1 of 6)**



**SBB Am843 2000HP
w/ new Hug filter
(1 of 73)**



**Vossloh MaK2000BB
3600HP w/ new Hug filter
(1 of 1)**

ARB-BNSF-UP
1500HP EMD
switchers with
retrofitted Hug
DPF

EPA-SWRI-UP
3800HP SD60
with retrofitted
DOC

Lets Be Clear!

→ 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 on 73 new 2000HP switcher locomotives.
- ✦ US focus for new switchers has shifted to hybrids and genset switchers, both using 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

Visit to Eurotunnel: *not promising!*



Vossloh G1206 locomotive (same as Swiss Am843) without DPF



**Water scrubber
tender car**



Questions & Comments