7.VERT-Forum, EMPA-Dübendorf 18.March 2016

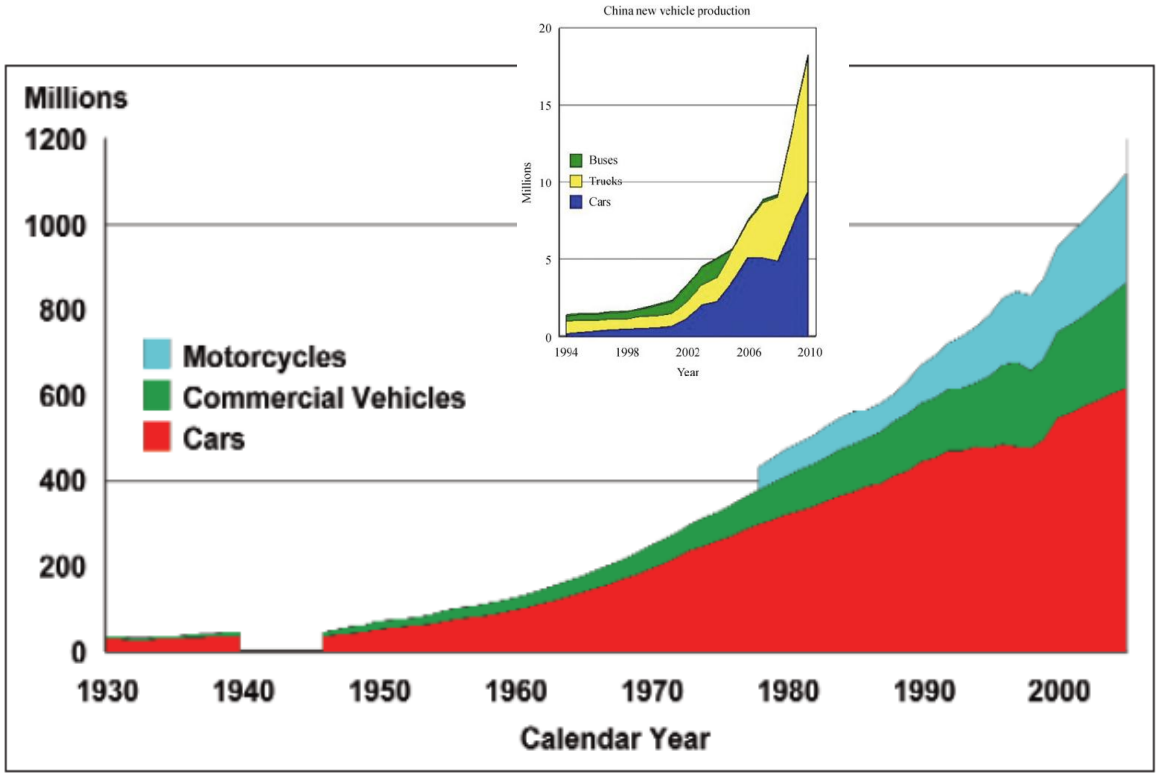
Introduction to block 6a-f

Emission Stability requires a New Concept

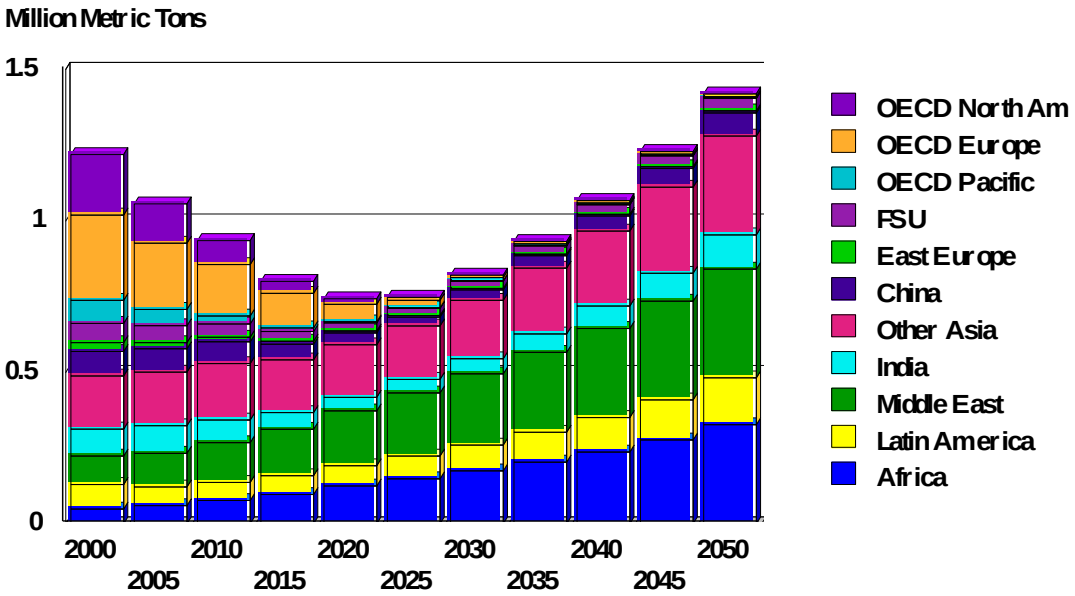
of Periodic Control for all Vehicles
equipped with DPF-DOC-SCR-EGR-LNT-ASC

A.Mayer

Society
needs
Mobility



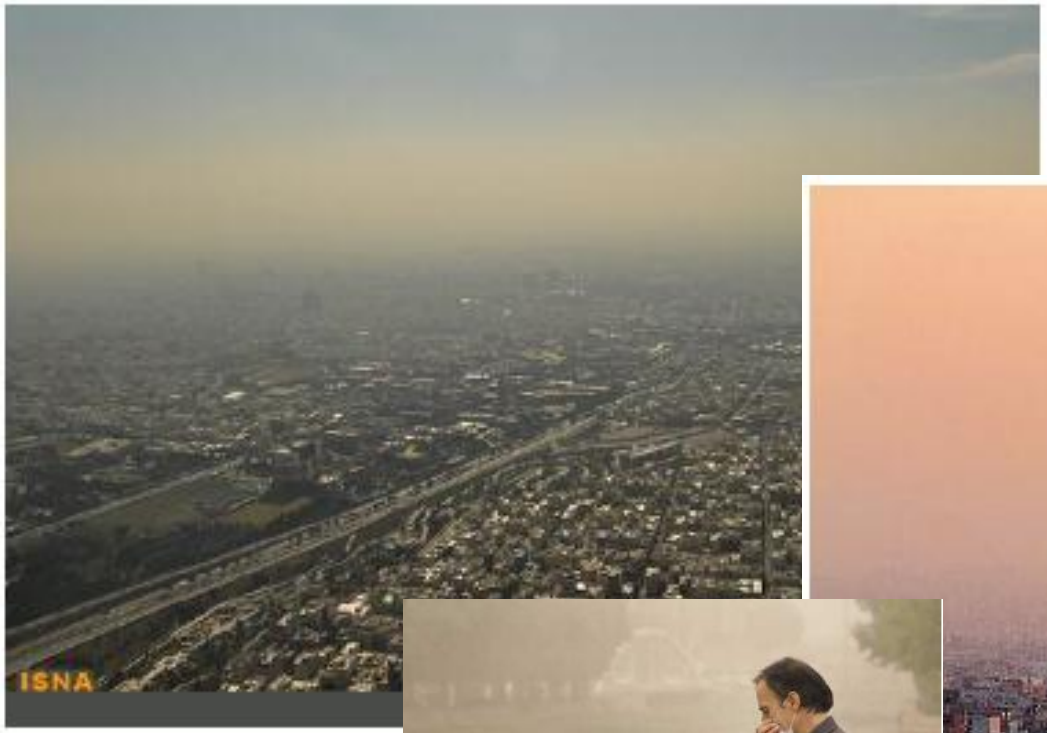
and we have a responsibility to introduce BAT and keep it sustainable



and pollution hotspots need sulutions

VERT-Success in **IRAN**: BAT-DPF from 9/2016

but how to guarantee emission stability

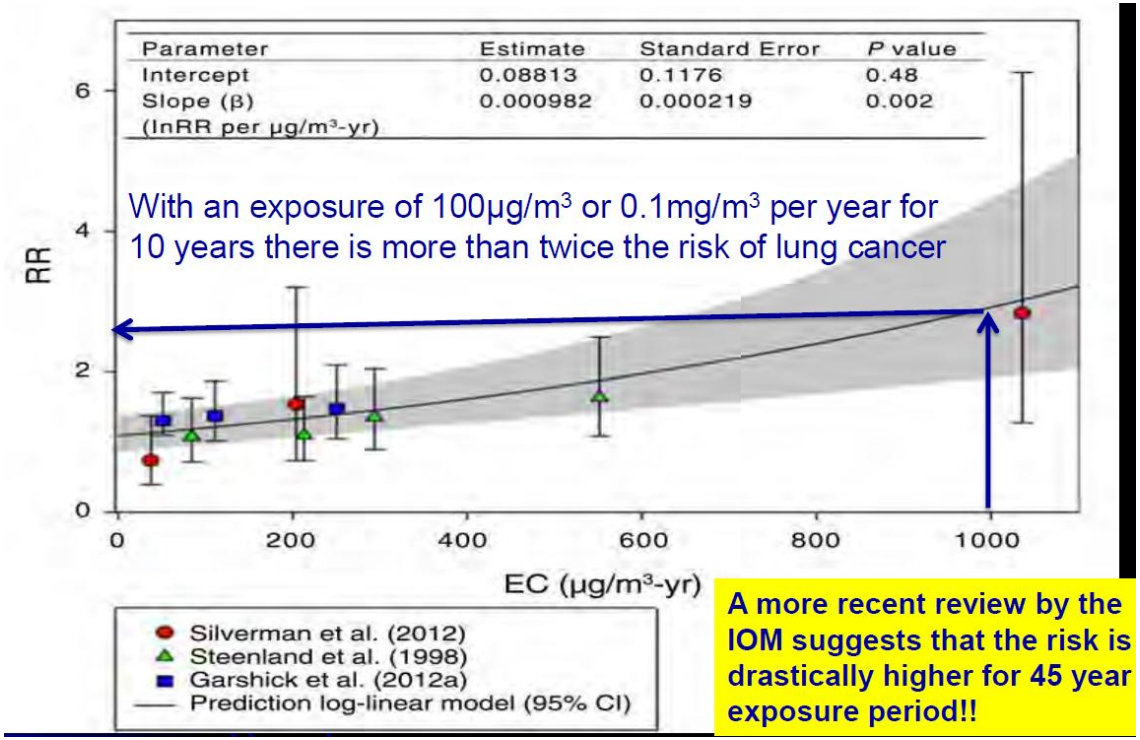


Health Impact

the newest numbers

by WHO 2012
Max Planck
and Harvard 2015

ALRI: acute lower respiratory illness
IHD: ischaemic heart desease
CEV: cerebrovascular desease
COPD: obstructive pulmonary desease
LC: : lung cancer



A more recent review by the IOM suggests that the risk is drastically higher for 45 year exposure period!!

Mortality attributable to air pollution (deaths $\times 10^3$)

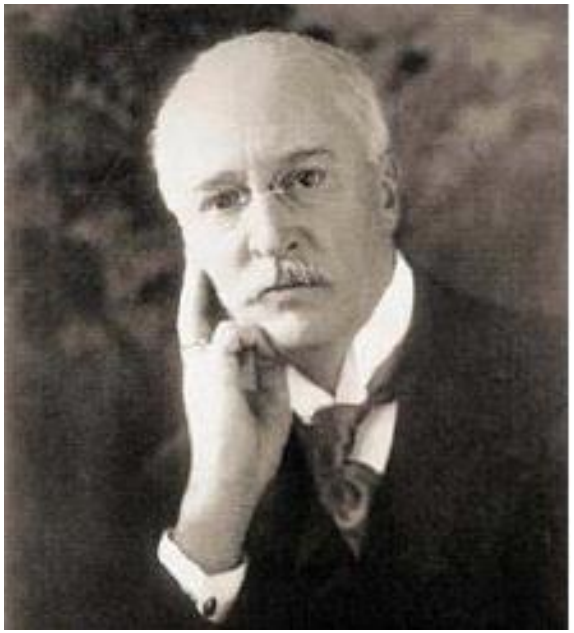
WHO region	Year	Population ($\times 10^6$)	$PM_{2.5}$					O_3	Total
			ALRI < 5 yr	IHD ≥ 30 yr	CEV ≥ 30 yr	COPD ≥ 30 yr	LC ≥ 30 yr	COPD ≥ 30 yr	
Africa	2010	809	90	55	77	11	2	2	237
	2050	1,807	158	185	262	38	5	12	660
Americas	2010	930	0	44	8	4	7	5	68
	2050	1,191	0	75	15	7	11	11	119
Eastern Mediterranean	2010	602	56	115	86	12	5	12	286
	2050	1,021	66	321	246	37	13	40	723
Europe	2010	867	1	239	95	13	27	6	381
	2050	886	1	307	156	18	37	11	530
Southeast Asia	2010	1,762	64	327	250	124	15	82	862
	2050	2,332	104	865	807	419	48	227	2,470
Western Pacific	2010	1,812	19	299	794	209	107	35	1,463
	2050	1,861	16	413	1,120	309	155	57	2,070
World	2010	6,783	230	1,079	1,311	374	161	142	3,297
	2050	9,098	346	2,166	2,604	828	270	358	6,572

PN

NOx

Rudolf DIESEL

1893 Patent - 1.Engine 1897 (26.2 % !)



Diesels is most economic

process to transfer fossil fuel energy to work

- 53 % large ship Diesel (59 % w. Power Turbine)
- 45 % truck Diesel (50 % in reach)
- 35 % car Diesel – 25 % car Petrol
- 42 % steam turbine for electric power station
- 36 % gas turbine for electric power station

2 Problems : Soot Particles + NOx–Emissions
which can not be solved by engine combustion

→ Soot: Air Pollution Substance Nr. 1 - carcinogen

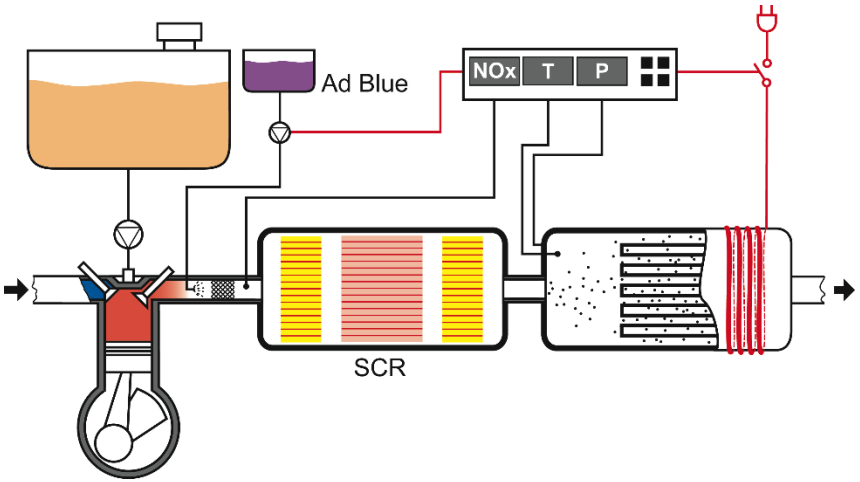
→ Soot: Global Warming Substance Nr. 2

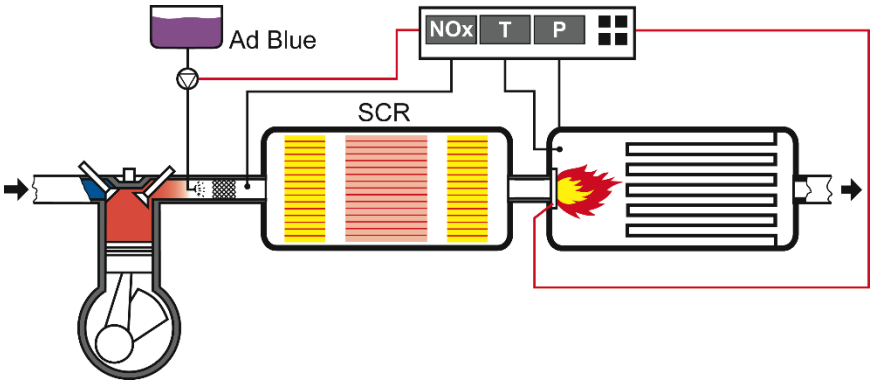
→ NOx: toxic and Ozon-precursor

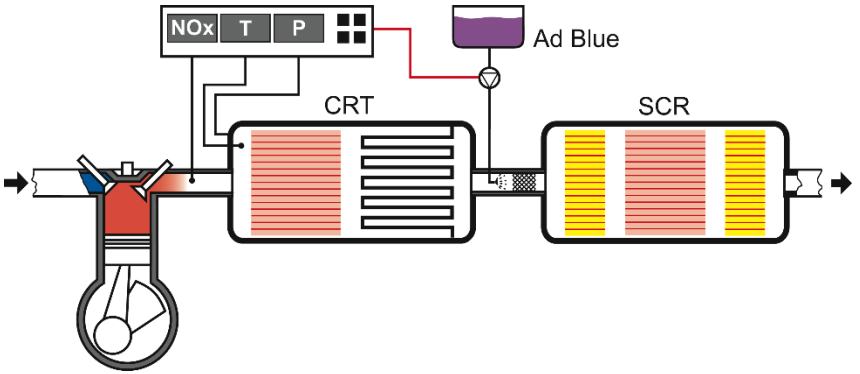
Emission Control by aftertreatment is indispensable

- very efficient > 99%
- but depend on operation profile
- risk of wear, aging and poisoning, pollution
- risk of tampering and manipulation
- potential of intentional deterioration by defeat div.

→ *Control is required*



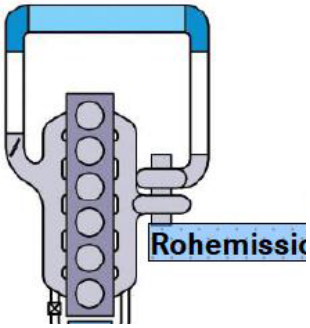




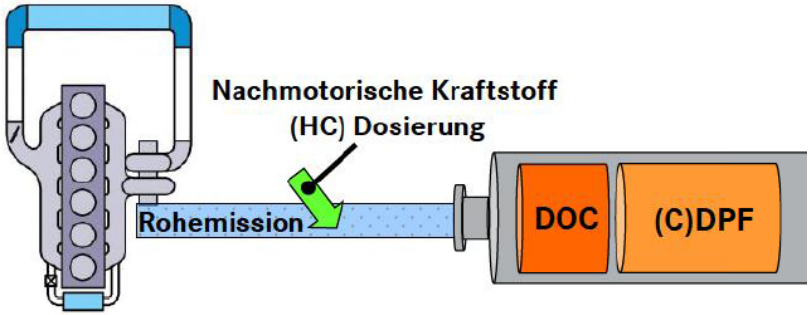
and Aftertreatment masks the Engine

→ **overall tailpipe control might be misleading**

-



Row Emission permits Engine-Diagnosis
by noise, smoke, smell, colour
Free acceleration revealed all problems



DPF and DOC block smell and
smoke, change noise and colour
→engine diagnosis impossible

→ How to Control Section by Section ?

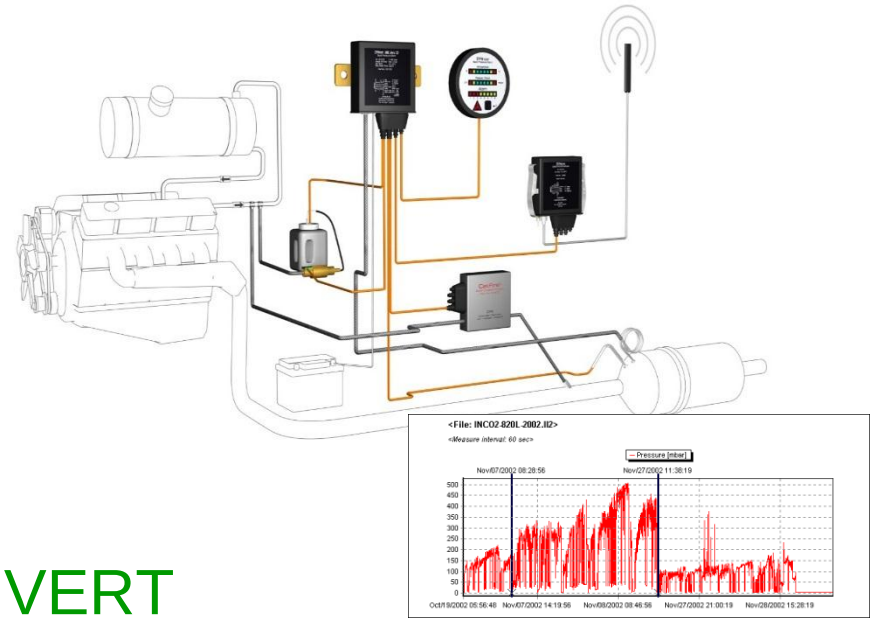
Four Levels of Emission Control

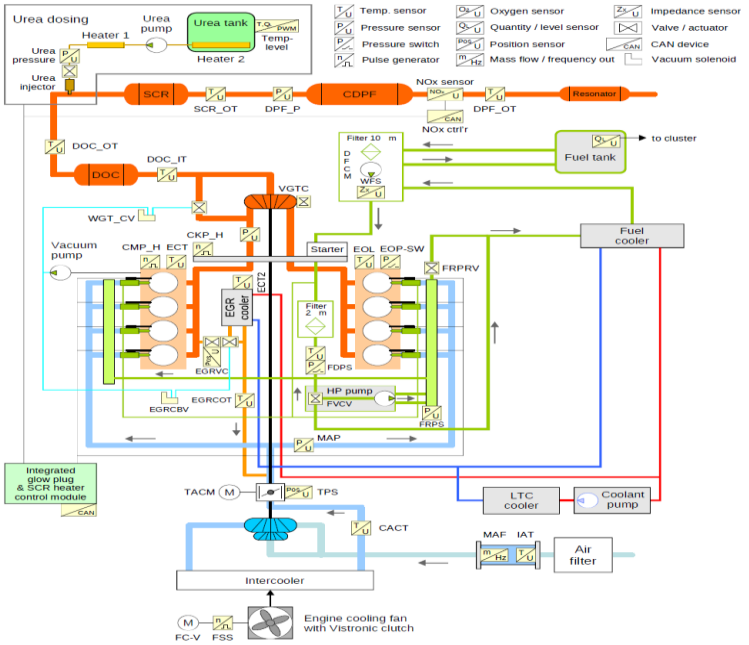
A. On-board Functionality and Safety
B. Homologation of New Engines
C. In Use Compliance and Manufacturing Conformity
D. 100% Periodic Control
of the old and dirty in-use Fleet
with diagostics of engine and all EC-elements

These 4 should never be mixed
nor can any of them be abandoned
for whatever political or financial reasons

A. On-Board Functionality and Safety Control

Interest of the manufacturer – but not enough





VERT
requires on-board electronic DPF-control since 2002

Modern engines use a plurality of sensors and electronic control – no PN sensor yet

This protects functionalty and safety in the interest of the manufacturer and the user but is no guanrantee for sustainable emission level – **as VW and others have demonstrated 2015**

On-Board Functionality and Safety Control-2

Interest of the manufacturer – not enough

VERT

has introduced OBC 2002 to protect filter and engines, controls max. backpressure limit to check regeneration and min. backpressure limit to check filter damage, provides alerts and failure analysis data. OBC needs certification. OBC can not guarantee emission stability.

EU

Is now starting within NRMM to develop DPF-control elements very similar to VERT – (first session 1.3.2016) – and proposes this control tool as a guarantee for emission stability which is a big mistake for two reasons:

- PN-sensors do not exist
- Control must be independent

B.Homologation of New Engines and Filters

Interest of the government and industry – not enough

- For 4 decades government did believe that testing **new engines** in **standard test cycles** would be sufficient – and manufacturers were satisfied
- NGA demonstrated that these cycles do not mirror the reality so do not guarantee clean air for public health
- Now GOV jumped to so-called real driving testing RDE – will this mirror my exposure to toxic exhaust gas?

→Still **new engines only**, what about wear and failures?
→Still tail pipe only ***- why not also check engine-out !!!***
→Still PN not included
→Still not upgrade required to keep up with BAT

C. In-Use Compliance

Interest of the government and industry – not enough

In-use compliance, a statistic test of a small sample of vehicles and **manufacturing conformity** are quality control tools to guarantee constant quality of new vehicles, check deterioration factors.

But they do not supply any information on the emission quality of an individual vehicles nor control proper maintenance

D- Independent 100% Periodic Control

interest of public health –
and mostly against interest of manufacturer+operator

Only Emission Control of **each individual vehicle**

- demonstrates its emission status
- provides information for maintenance and repair
- detects all tampering attempts
- guarantees the enforcement of emission reduction

Needed for all vehicles throughout vehicle life regularly

For new engines with emission control much more important than for earlier engine generations

Must be independent (Montesquieu: la séparation des pouvoirs 1748 - base of our civilization) and cannot be replaced by onboard control – ***see Dieselgate scandal***

we will talk

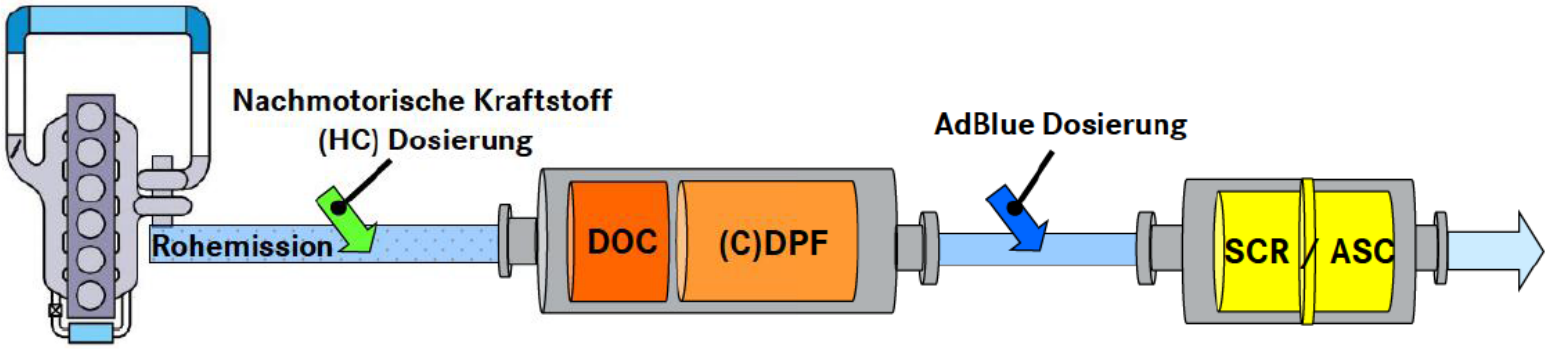
on Public Motivation for Independent Periodic Control

- Follow polluter pays principle
- Equal treatment for all operators
- Bonus for good maintenance and malus for others

we will talk on

Technical Motivation for Independent Periodic Control

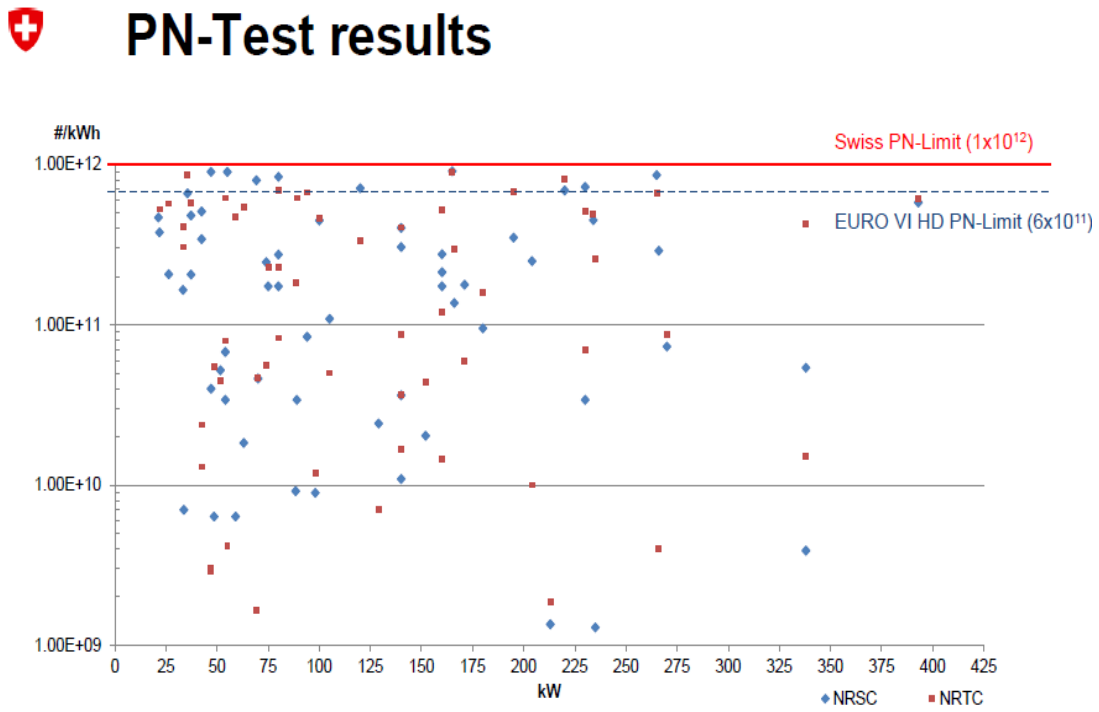
- **Separation of Failures**
- **Quantification of Failures**
- **Preventive Maintenance**



we will talk on

Policy Targets for Periodic Control

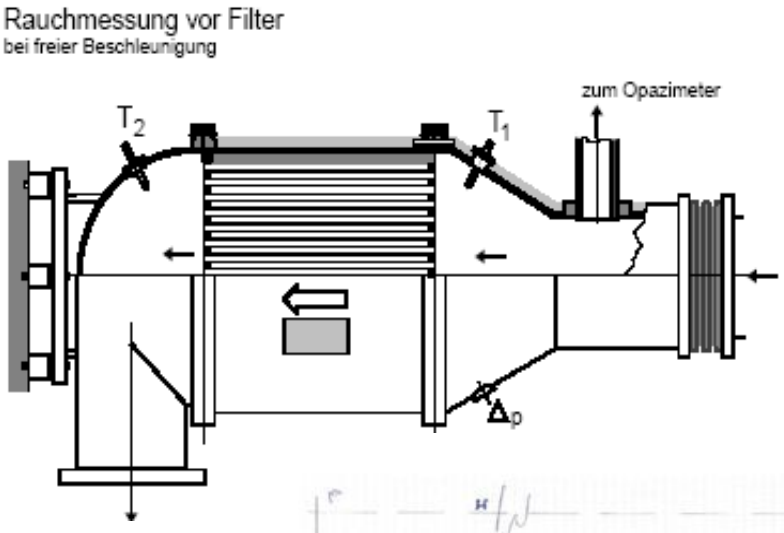
- Make tampering unattractive
- Select upper quality for LEZ
- Phase-out high polluters

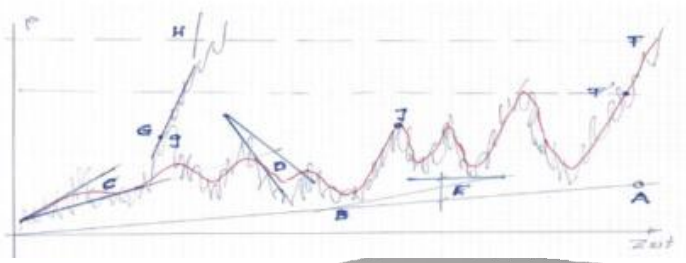


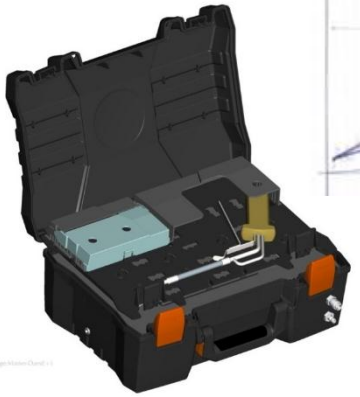
we will talk on

VERT-Tools, Precedures and Experience for Inspection, Maintenance and Repair

to guarantee ultralow emission and clean air







and we will not talk only

we want to influence public consciousnes

demonstrating feasibility of lo emission throughout engine lif by simple I+M tools and low-cost procedures

→ this is why we presented recently this Document to the European Parliament, to the Commission in Brussels, to the German Ministry of Environment
and also to UK-MP

VERT Inspection & Maintenance

Periodic Test of Diesel Vehicle Engines' Emission Stability if equipped with DPF, DOC, SCR-Emission Control Devices

Motivation

Stability of Diesel engine emissions cannot be guaranteed for engines' lifetime; however, it's essential for public health. Apart from wear, aging, and damage of both, emission control hardware and software elements, various kinds of manipulation have been observed, even being offered on the market. Legally required electronic onboard OBD control turned out to be insufficient. Independent 100% periodic inspection ought to be mandatory to guarantee functionality of **Particle Filters (DPF), Oxidation Catalysts (DOC, ASC), Selective Catalytic NOx-Reduction (SCR)** and other emission control systems, also called exhaust after-treatment systems of modern combustion engines.

Testing Procedures

VERT has developed inspection methods for retrofit emission-control devices, which have been proven so efficient, reliable and cost effective that they are to be recommended herewith for all engines and applications:

DPF, Filtration Efficiency: Solid particle number concentration PN is measured upstream and downstream of the DPF, following the PMP protocol. Measuring being done with handheld instruments, measurements can be performed at any load or speed, even low idling is sufficient for very accurately determining the filtration efficiency; failure for this relative value is below 1%; detection limit is $<10^3$ P/cc. Small filter substrate damage of less than 2 % is detectable and easily repairable at low cost. This procedure may be simplified by doing only one measurement downstream, however, at cost of accuracy. Since filtration of solid nanoparticles mainly depends on particle size and space-velocity measuring instrumentation must be highly sensitive for particles in the size range of 20-500 nm.

DOC, Conversion Efficiency: A DOC may be part either of a DPF-system or of an SCR-system or even standing alone. It may be inhibited by thermal or chemical poisoning or contamination. DOC-conversion efficiency depends primarily on temperature: In oxygen rich Diesel exhaust, conversion of CO to CO_2 starts at about 130°C (light-off) and it reaches its full conversion level at about 250°C. By means of a load step at constant rpm, conversion capability of a DOC is determined very accurately and in very short time: Heating the exhaust gas up to 300°C on a simple roller-dyno and measuring the CO concentration curve during cooling down at the tail pipe – or inverse. This procedure reveals the exact status of the DOC within a few minutes.

SCR, Functionality of Selective Catalytic NOx-Reduction: Functionality requires both, proper catalytic conversion of the SCR-catalyst system and the accurate injection of the urea-water solution "Adblue" to be done at the minimum permissible temperature. Again a simple load step at constant engine rpm enables to check all functions in one single run. Either heating the exhaust gas from idling temperature 150°C to 300°C, or following the cooling curve from 300°C to idle with a NOx sensor at the tail pipe reveals, whether urea is injected, whether the right amount is injected, whether it is injected at the right temperature and whether the catalyst conversion is on the expected level. After this simple test, at any engine speed selected all required information is available. An even more precise control test is available by an additional NOx-measurement upstream of the SCR in addition.

Instrumentation

The instrumentation of the handheld PN measurement has been specified by the Swiss VAMV-regulation, first published 8/2012 http://www.admin.ch/ch/d/as/2012/5371.pdf and it includes the EU-PMP protocol to focus on non-volatile particles. Three instruments meeting these specs are already on the marked by TSI, TESTO and AVL. Sensors for measurement of CO and NOx are standard and available by many manufacturers. Test data are stored electronically and fail/pass criteria are evaluated automatically protected against falsification or manipulation.

Application

This inspection method applies to any vehicle or engine, HDV as well as LDV, on-road as well as off-road and is not limited to Diesel engines. Engine control electronics must permit load step testing with emission control functions fully operative. Testing roadside is possible for DPF, also for DOC and SCR if the exhaust gas at test start is above 300°C.

Available Experience, Operation Time and Cost

VERT experience dates back for 2 years in applying this testing method. Required time for a complete test-run is about 10 minutes; cost for instruments will be in the range of opacity meters as used in the past, provided the production volume is equally high.

Andreas Mayer, VERT Scientific Officer
29.January 2016

since what is done and in process is by far not enough