CAPABILITY ENHANCEMENT OF ELECTRONICS AND SOFTWARE

Module 2 - Exhaust After Treatment system Basic architecture and functions (Part 1)

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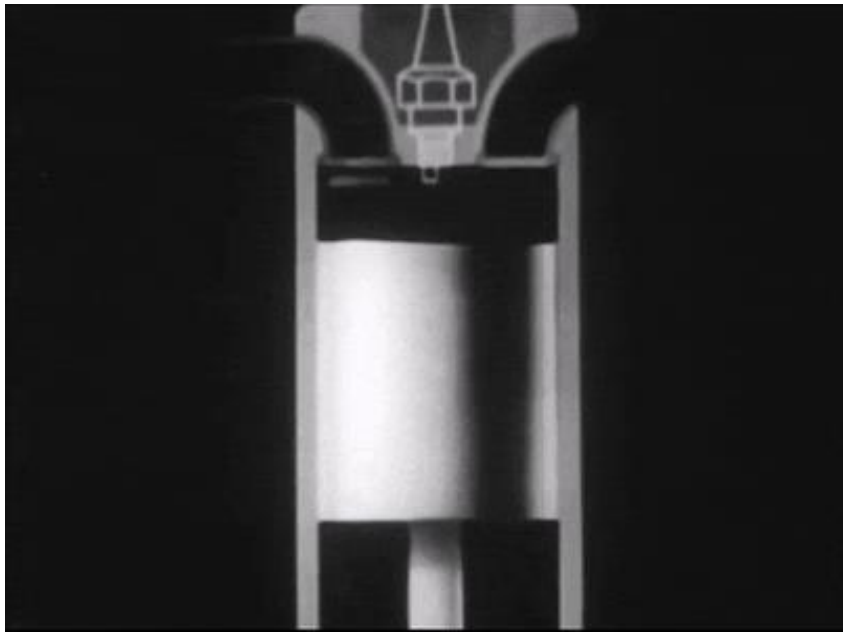
Why exhaust after treatment system ?

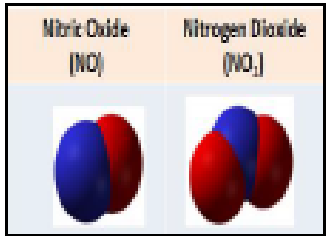
4 Stroke combustion engine



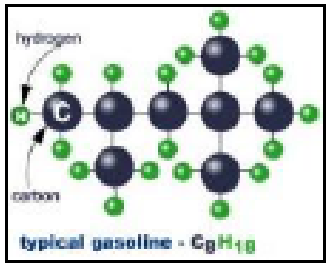
Air pollution

Emission elements and Norms

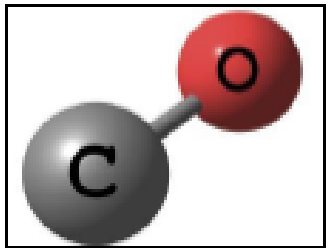
No_x – Oxides of Nitrogen



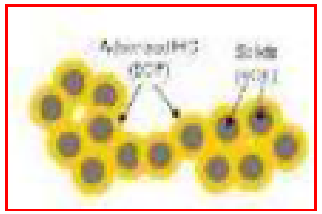
HC – Unburnt Hydro carbon

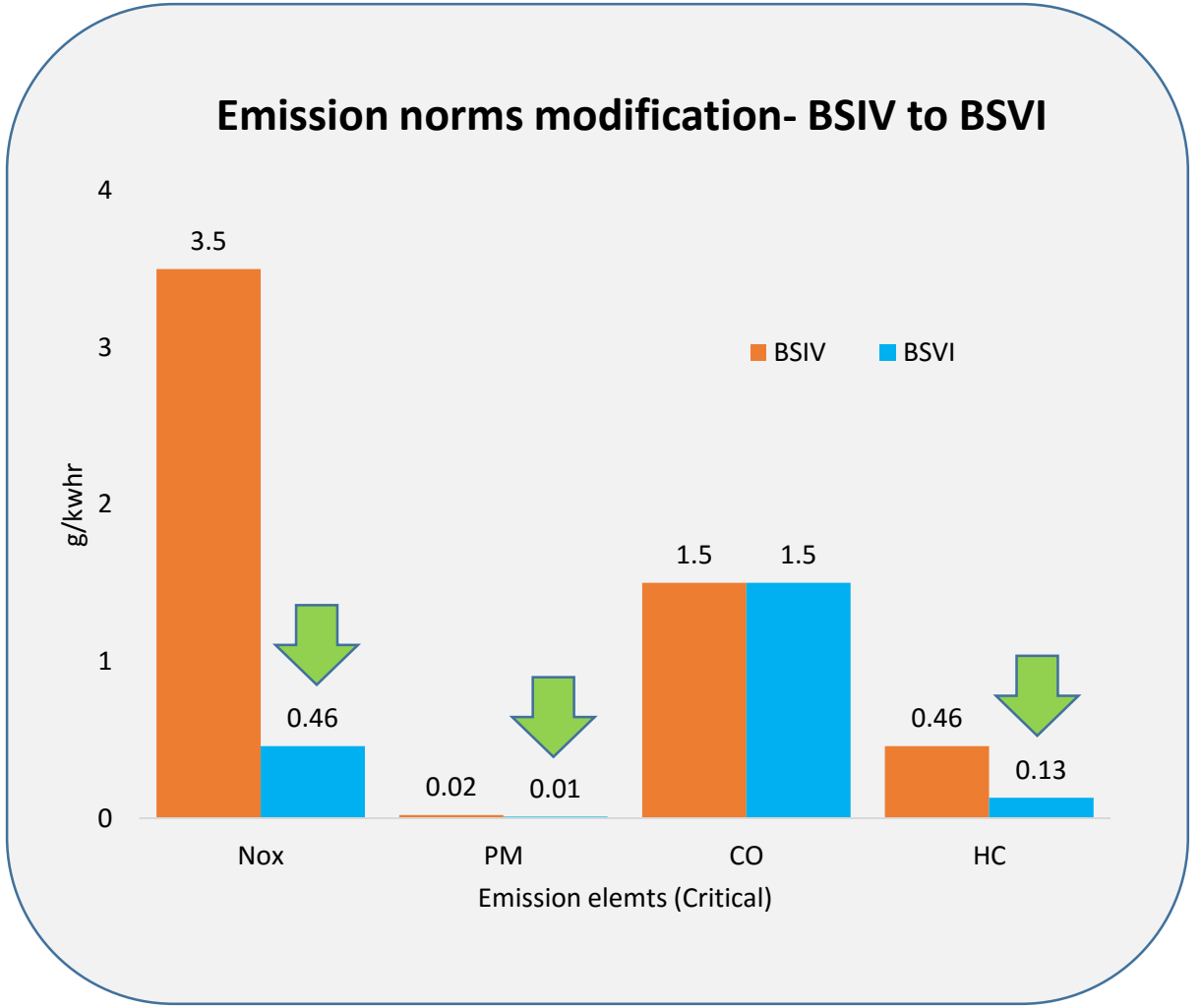


CO – Carbon Monoxide

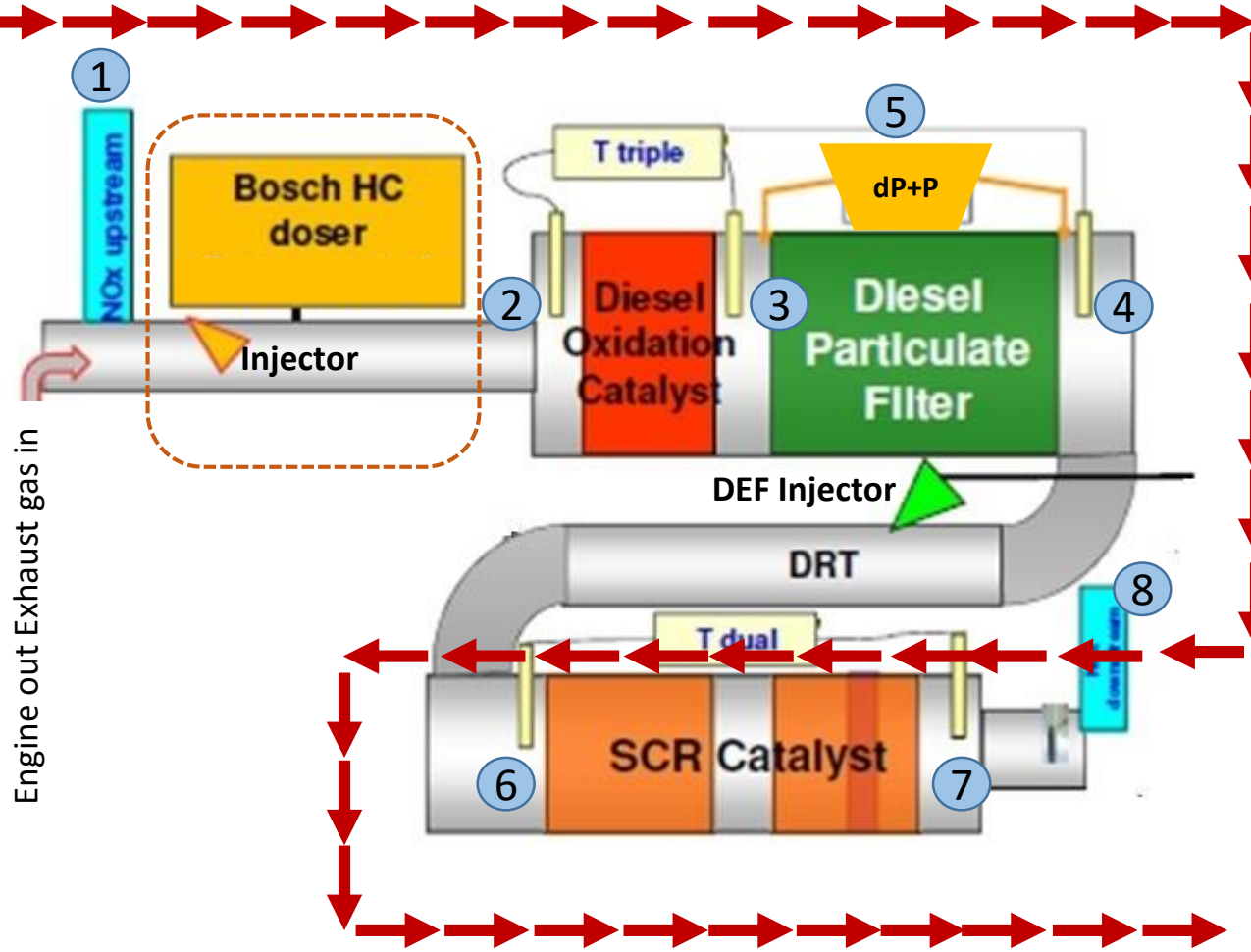


PM – Particulate Matter





Compact S type architecture- H6, A4 and A6



DEF : Diesel Exhaust fluid (Urea/AdBlue)
DRT : Decomposition Reactant Tube
dP : Delta pressure
SCR : Selective Catalyst Reduction
HC : HydroCarbon

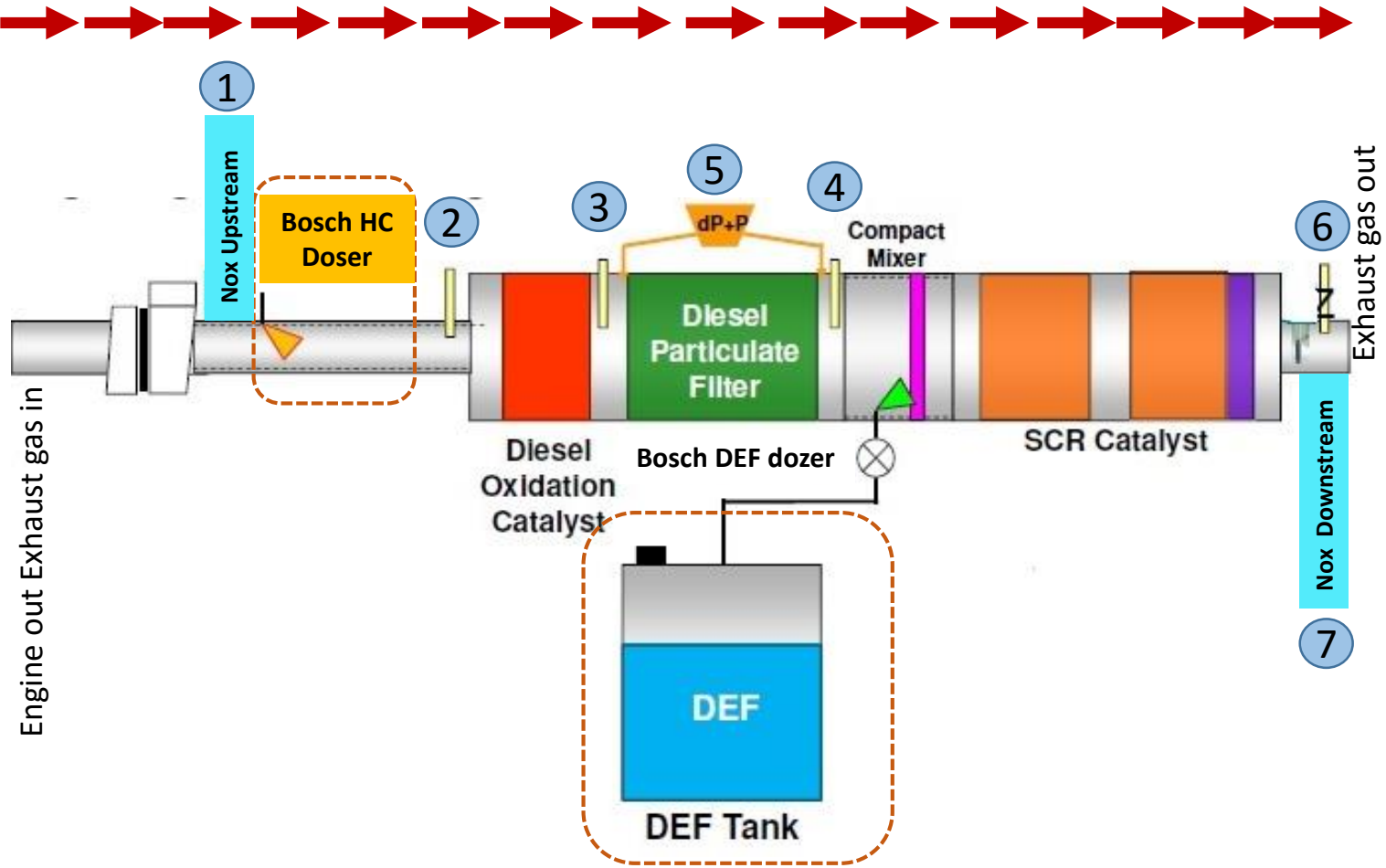
1 Nox Sensor- Engine out

8 Nox Sensor- Tailpipe out

2 3 4 6 7 Exhaust Gas temperature sensors

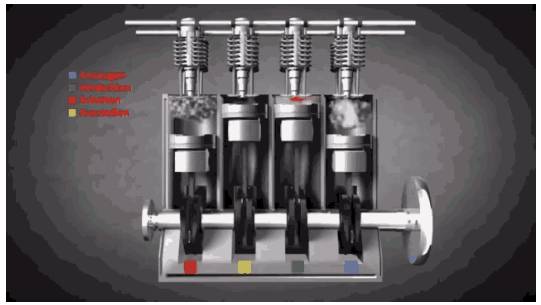
5 Delta pressure sensor

Compact Linear type architecture- H4



1. **NOx (Nitrogen Oxide) sensor**
   To measure the NOx coming out Engine(ppm)
2. **Temperature sensor- T1**
   To measure DOC inlet temperature or Engine outlet temperature
3. **Temperature sensor-T2**
   To measure DOC outlet temperature or DPF inlet temperature
4. **Temperature sensor- T3**
   To measure DPF outlet temperature or SCR inlet temperature
5. **Delta pressure sensor**
   Measure Delta pressure across the DPF to estimate Soot load collected in DPF
6. **Temperature sensor-T4**
   To estimate SCR bed temperature
7. **NOx sensor- Tail Out**
   To measure the tail out NOx after reduction from SCR

Basic function of Exhaust After Treatment system



Engine

Engine outlet emission
HC
CO
PM
Nox

EATS

DOC	DPF	SCR	ASC
HC (0.13g/kwhr) CO (1.5g/kwhr)	PM (0.1g/kwh)	Nox (0.4g/kwhr)	NH3(0.10ppm)

HC	: Hydrocarbons
CO	: Carbon monoxide
PM	: Particular Matter
NoX	: Nitric oxides
NH3	: Ammonia

DOC	: Diesel Oxidation Catalyst
DPF	: Diesel Particular Filter
SCR	: Selective Catalyst Reduction
ASC	: Ammonia Slip Catalyst

Diesel Oxidation Catalyst- DOC

The diesel oxidation catalyst (DOC) promote oxidation of exhaust gas components by oxygen.

Functions of Diesel Oxidation Catalyst

- **Emission control of Hydrocarbons (HC) and Carbon monoxide(CO)**

  $[Hydrocarbons] + O_2 = CO_2 + H_2O$

  $2CO + O_2 = 2CO_2$

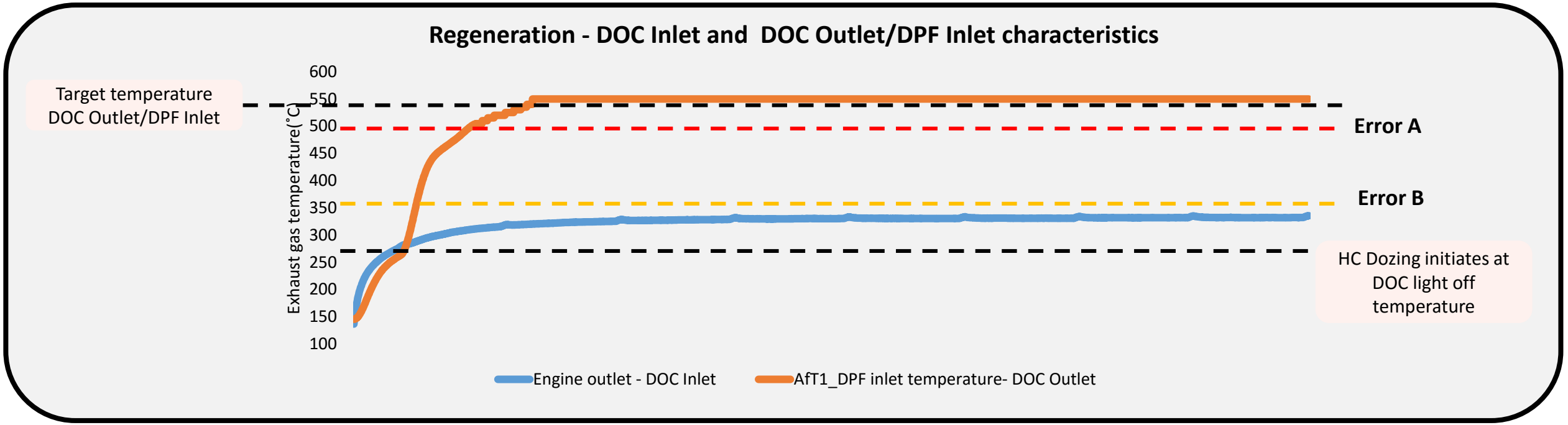
- **Active regeneration**: Oxidization of hydrocarbons—introduced via **diesel fuel injection** into the exhaust system or **post-injection** in the engine—to increase the exhaust gas temperature and facilitate active DPF regeneration

- **Passive regeneration**: An increased NO_2/NOx ratio promotes passive DPF regeneration.

- **Noxidation**: an important function of the DOC is to oxidize nitric oxide (NO) to *nitrogen dioxide* (NO_2)—a gas needed to support the performance of diesel particulate filters and SCR catalysts used for NOx reduction

  $2NO + O_2 = 2NO_2$

DOC – Exothermic process for regen and Performance related diagnostics



DOC Performance related diagnostics

3 Byte Pcode	Fault Code Description	Thresholds for triggering error
P0421-00- **Error A**	DOC Conversion efficiency	10% drop in efficiency
P0420-00- **Error B**	DOC Missing	90% drop in efficiency

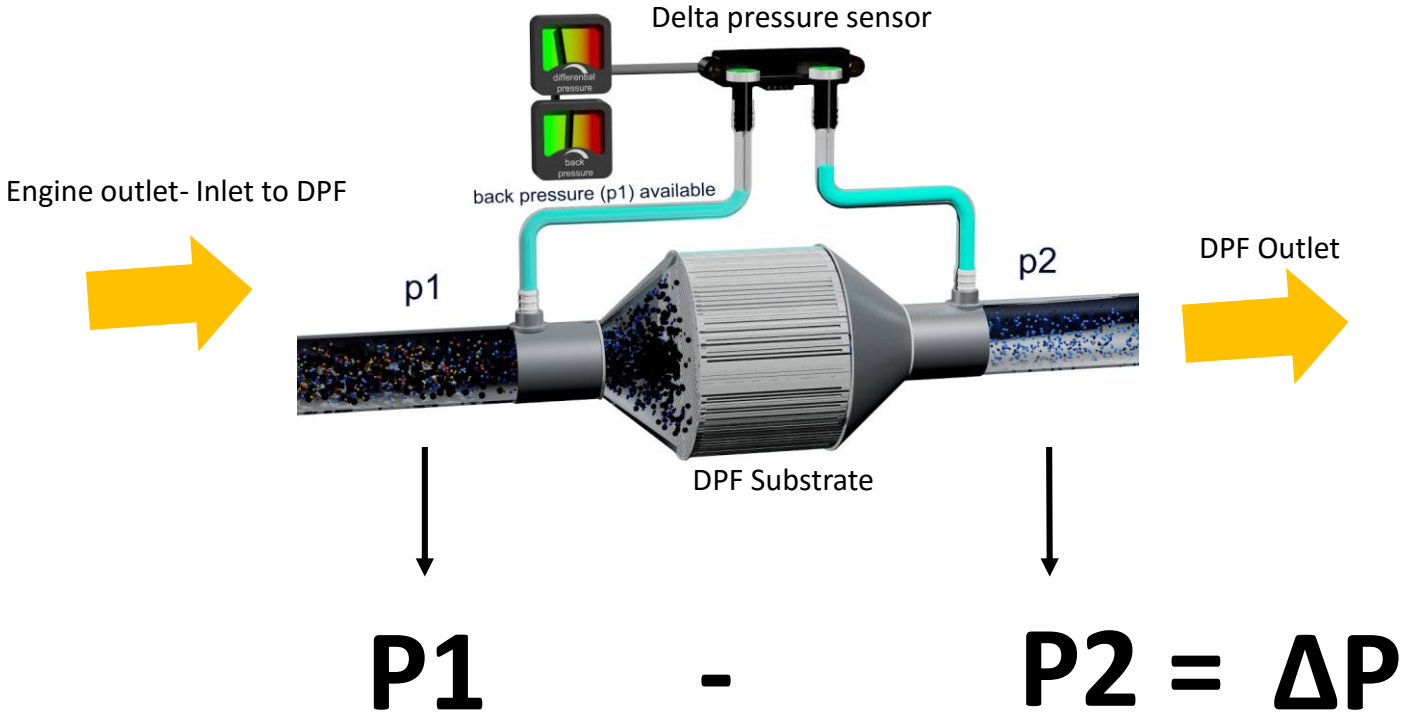
Diesel Particulate Filter- DPF

What is DPF?

- DPF is an exhaust after treatment component that traps particulate matter such as soot and ash.
- A DPF typically uses a substrate made of a ceramic material that is formed into a honeycomb structure.

DPF Substrate

DPF Soot load estimation- Delta pressure sensor based

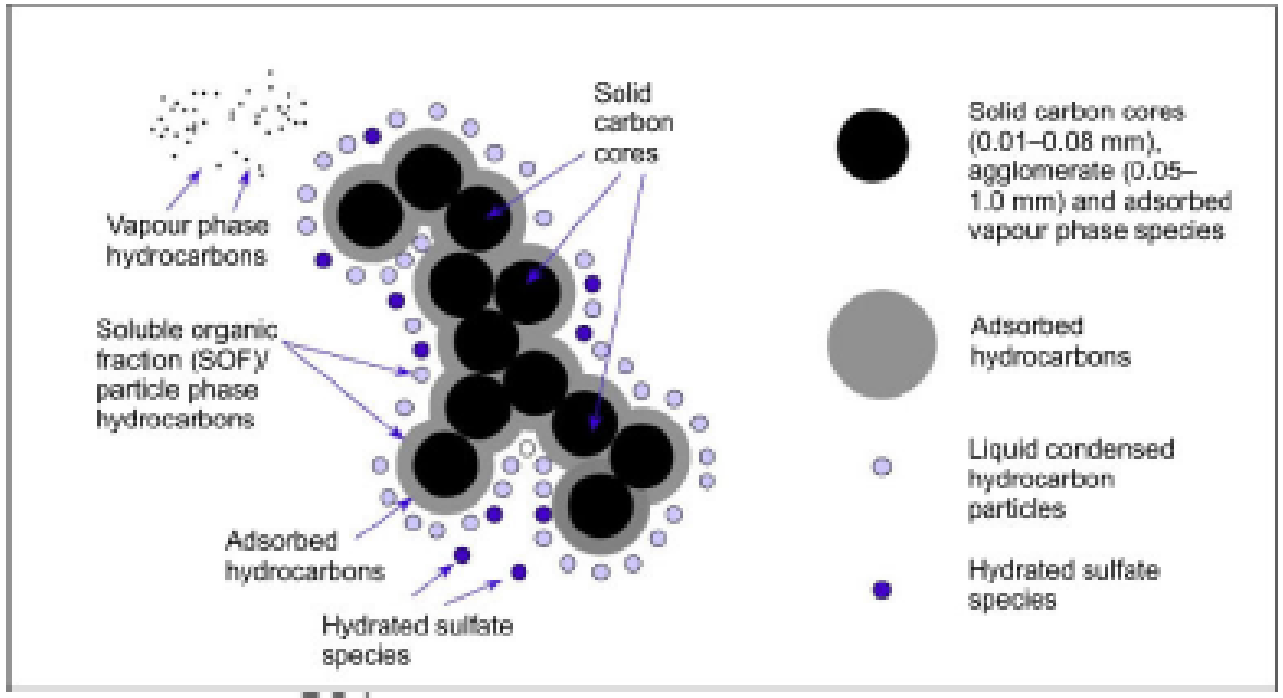


P1 - P2 = ΔP

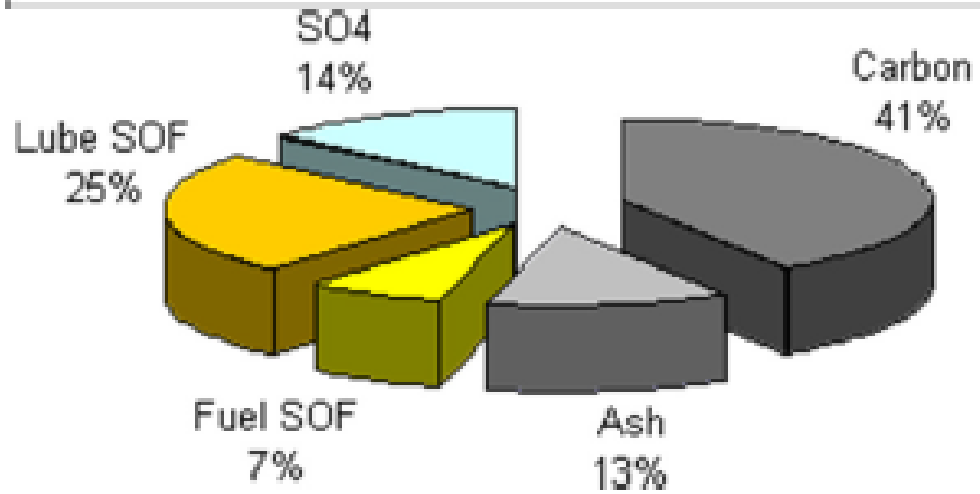
ΔP Increases with increase in Soot load and vice

The ΔP signal is then used by the ECU to estimate soot mass inside the filter using calibration maps.

Soot - Composition



- Adsorbed HCs (soluble organic fractions, or SOF)
- "Dry carbon"
  - Primary particles: ~20-40 nm
  - Agglomerated to ~0.1 – 1 µm
  - From fuel or lube oil
- Inorganic materials
  - Ash/precursors, H_2SO_4, HNO_3, H_2O



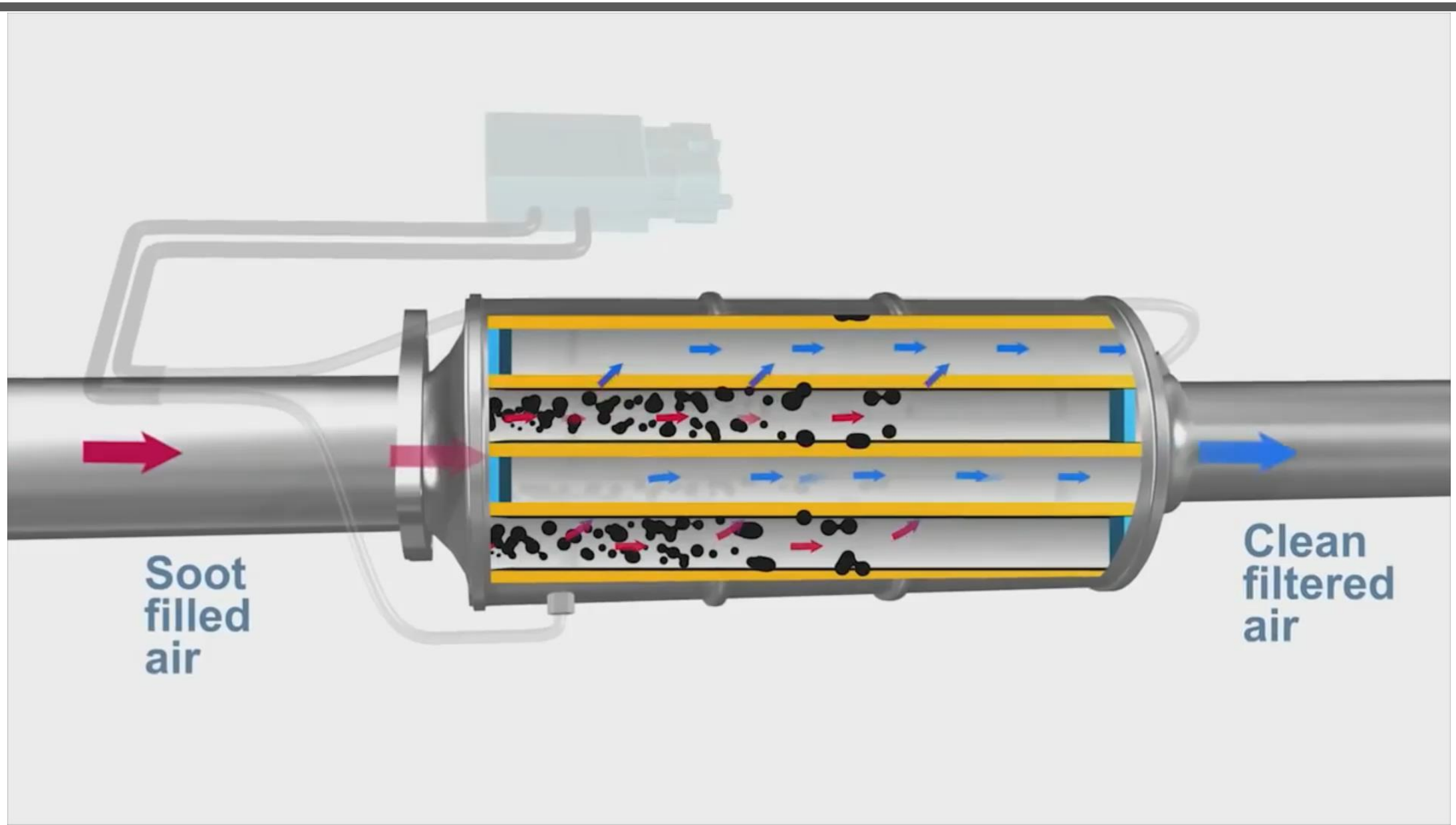
Solids (carbon +ash) - 54%

SOF (fuel + lube) - 32%

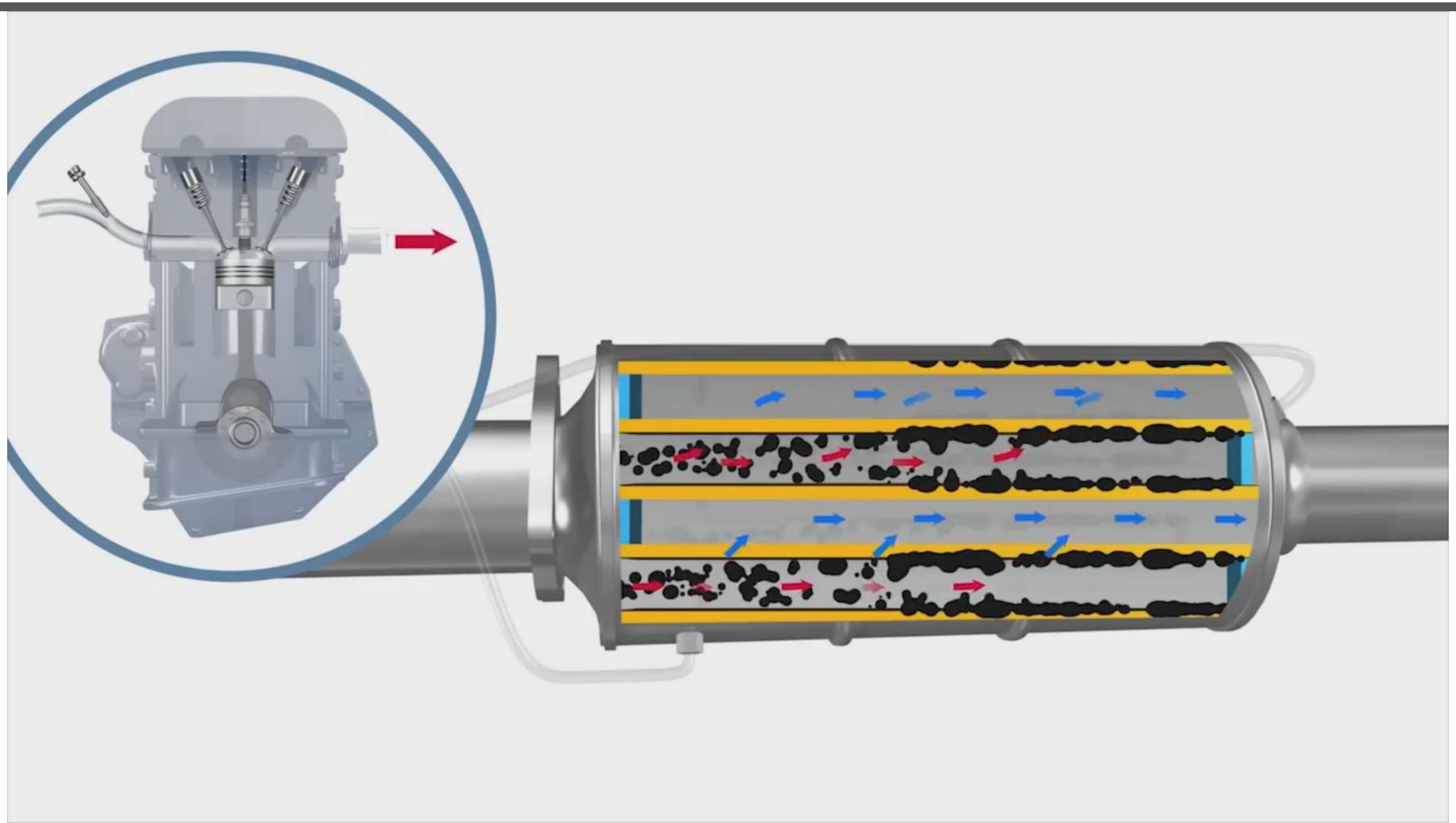
SO4 (sulfate + water) - 14%

Note: Particulate composition depends on engine condition, operating point, dilution conditions and fuel type

DPF Soot accumulation

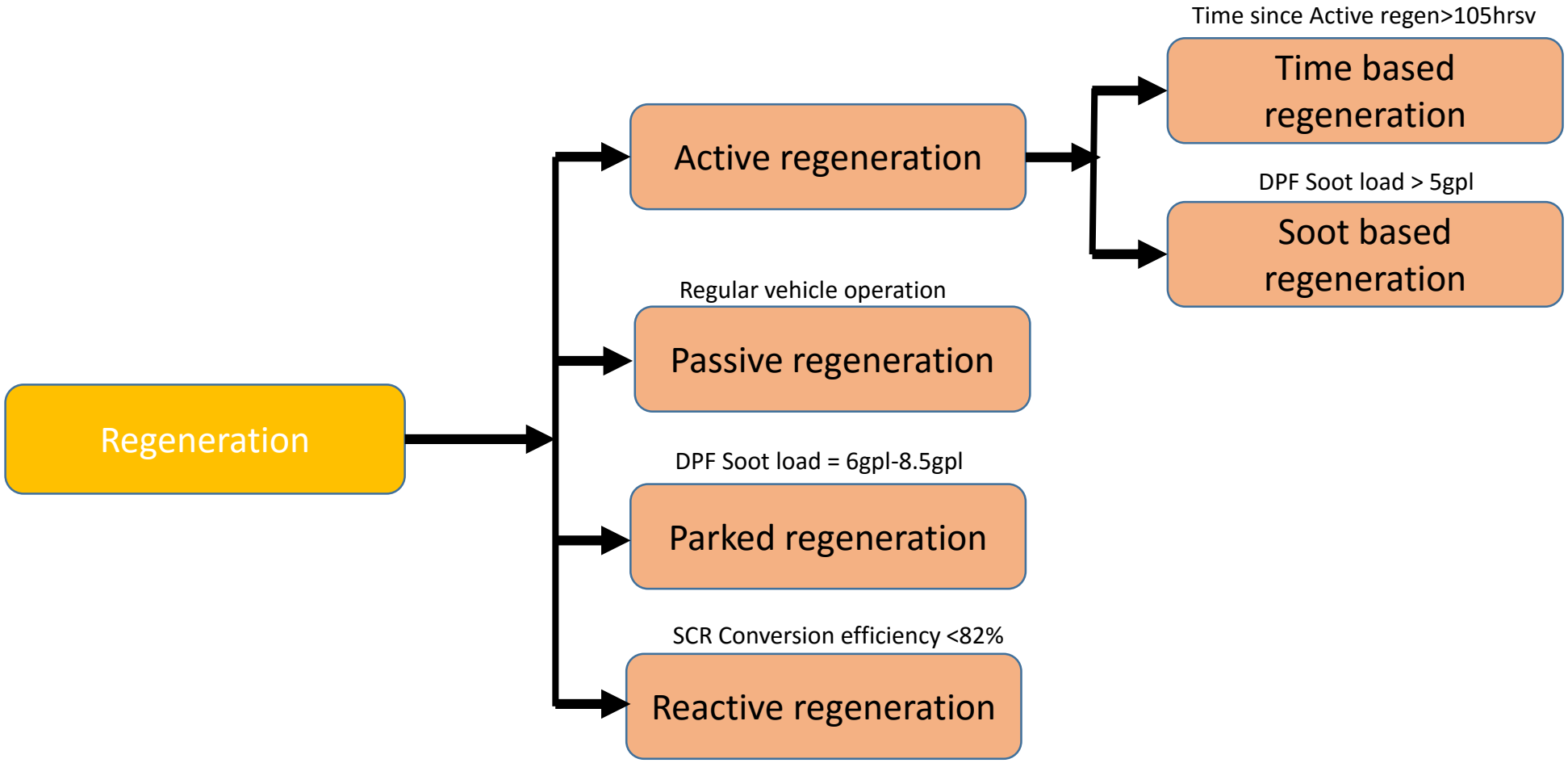


DPF Regeneration



Regeneration- Types

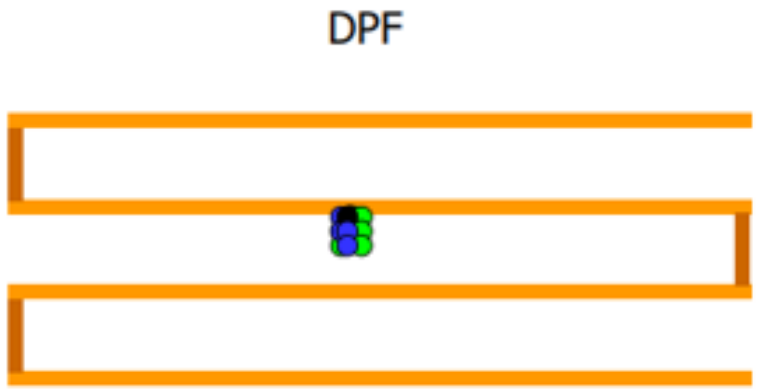
Regeneration is the process of restoring the performance of DPF and SCR Catalysts. Various types of Regenerations features are available in the system which triggers based on the Time, Soot and SCR Conversion efficiency conditions



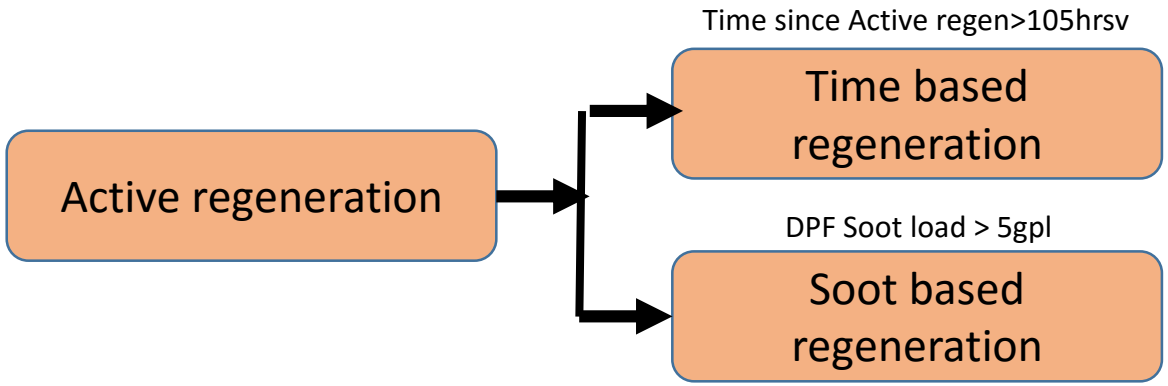
1. Active regeneration

Active Regeneration

Hydro Carbon injects in the Exhaust gas channels and subsequent oxidation of these hydrocarbons takes place at DOC. High temperature from the DOC outlet is using for Soot burning.

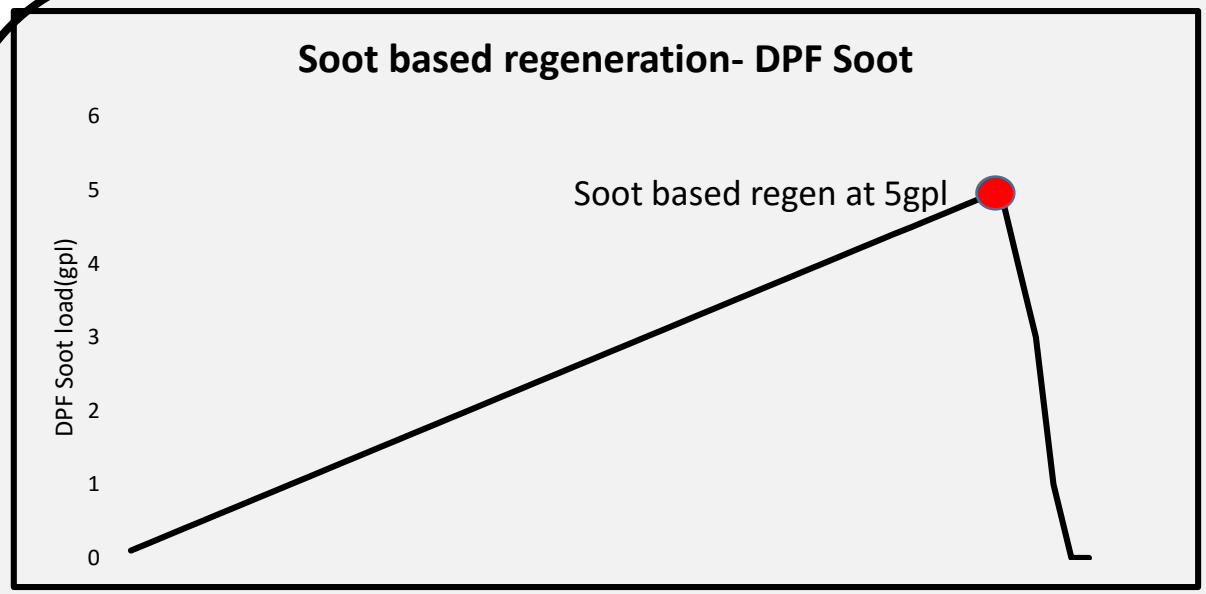


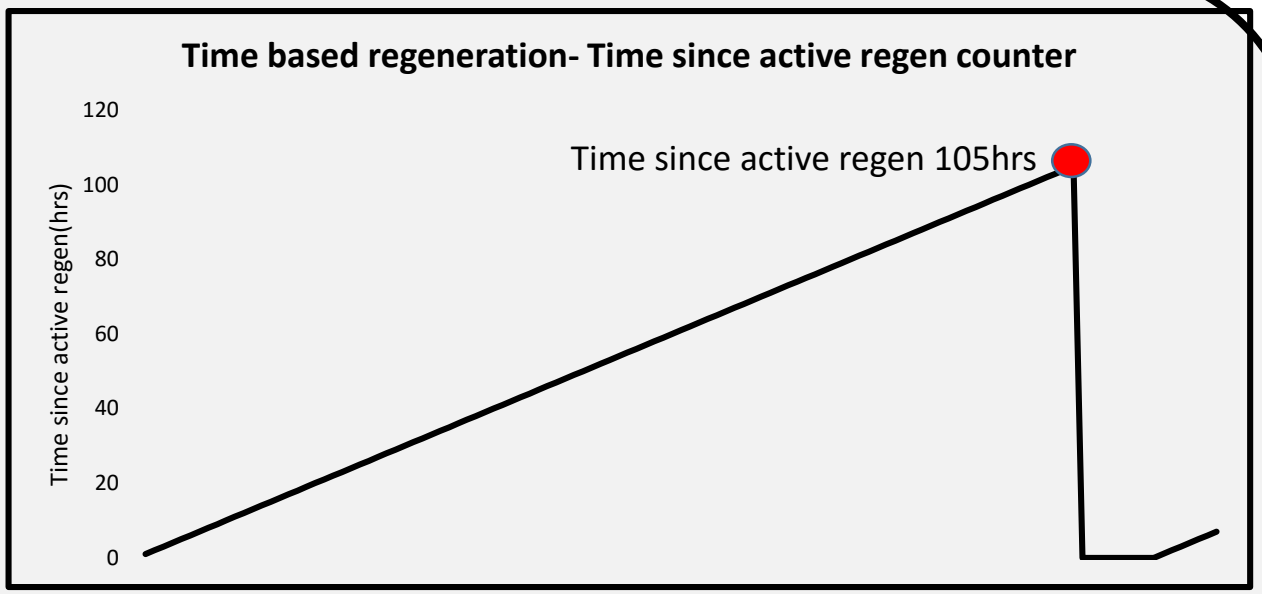
$$C + O_2 \xrightarrow{\sim 500^{\circ} C} CO_2$$



Soot can be burnt in presence of O_2 at very high temperature. The required temperatures are achieved through HC dosing

Active regeneration- Type and Logic





Soot based regeneration: An Active regeneration triggers at 5gpl of soot load to burn the accumulated soot.

Necessity: To remove excessive soot from the DPF before filtration ability is hampered and risk of uncontrolled exothermal increases

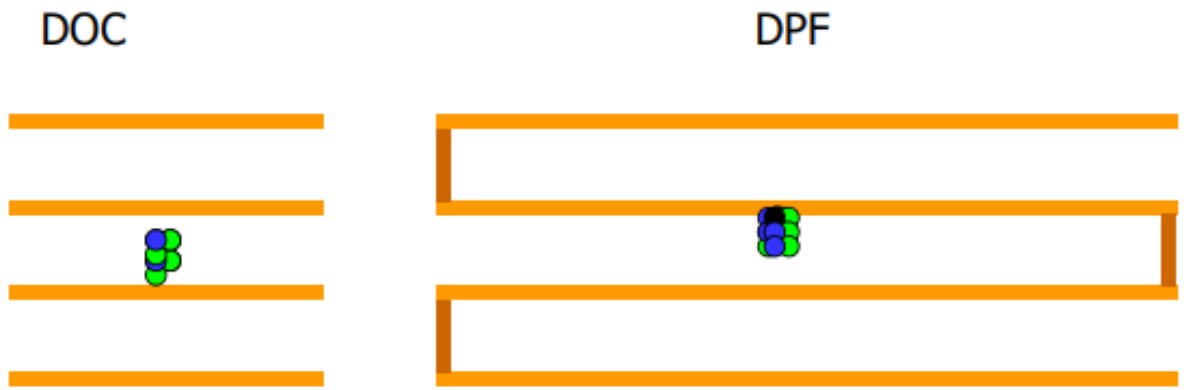
Time based regeneration: A time based regeneration triggers every 105hours since last active regeneration.

Necessity: As time without regen increases, soot tends to get caked on the periphery of the DPF. This is hard to remove later since temperature at the periphery may not be high enough to burn all the soot collected.

2. Passive regeneration

Passive Regeneration

Takes place in presence of High exhaust gas temperature and Nox from the engine outlet. An external hydrocarbon dosing is not required for the phenomenon to occur. Passive regeneration happens at the favorable conditions.



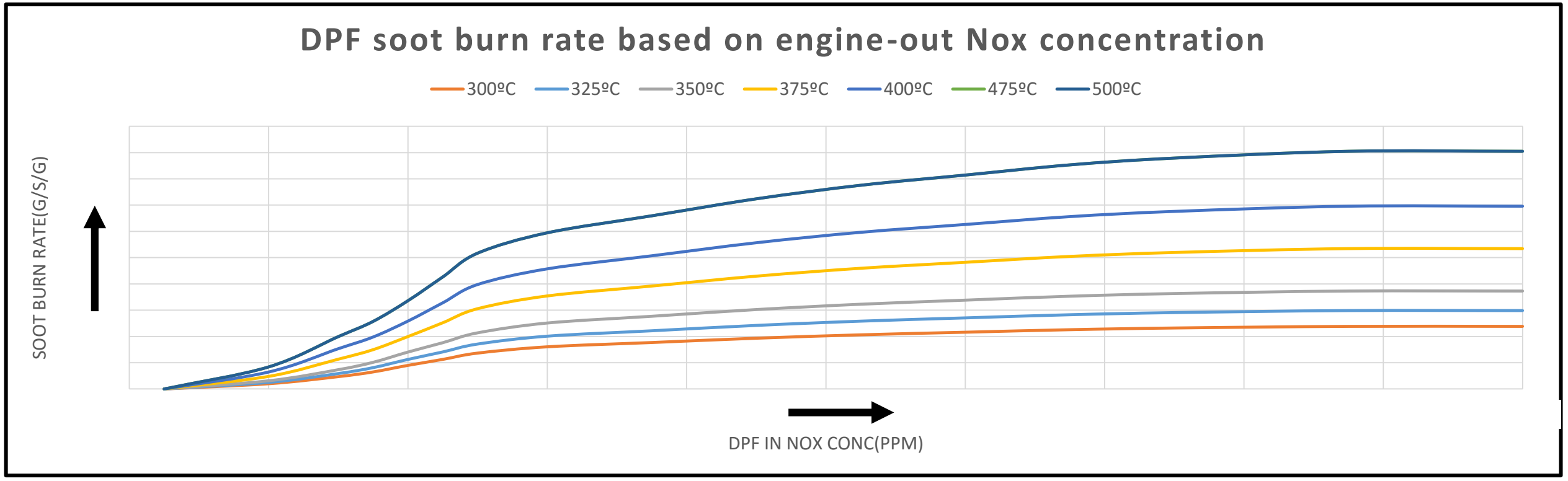
$2NO+O_2 \rightarrow NO_2$

$C+2NO_2 \xrightarrow{>235^{o}\ C} C0_2+ 2NO$

NO_2 being a better oxidizing agent assists soot burning and can burn soot at relatively lower temperatures.

2. Passive regen - Characteristics

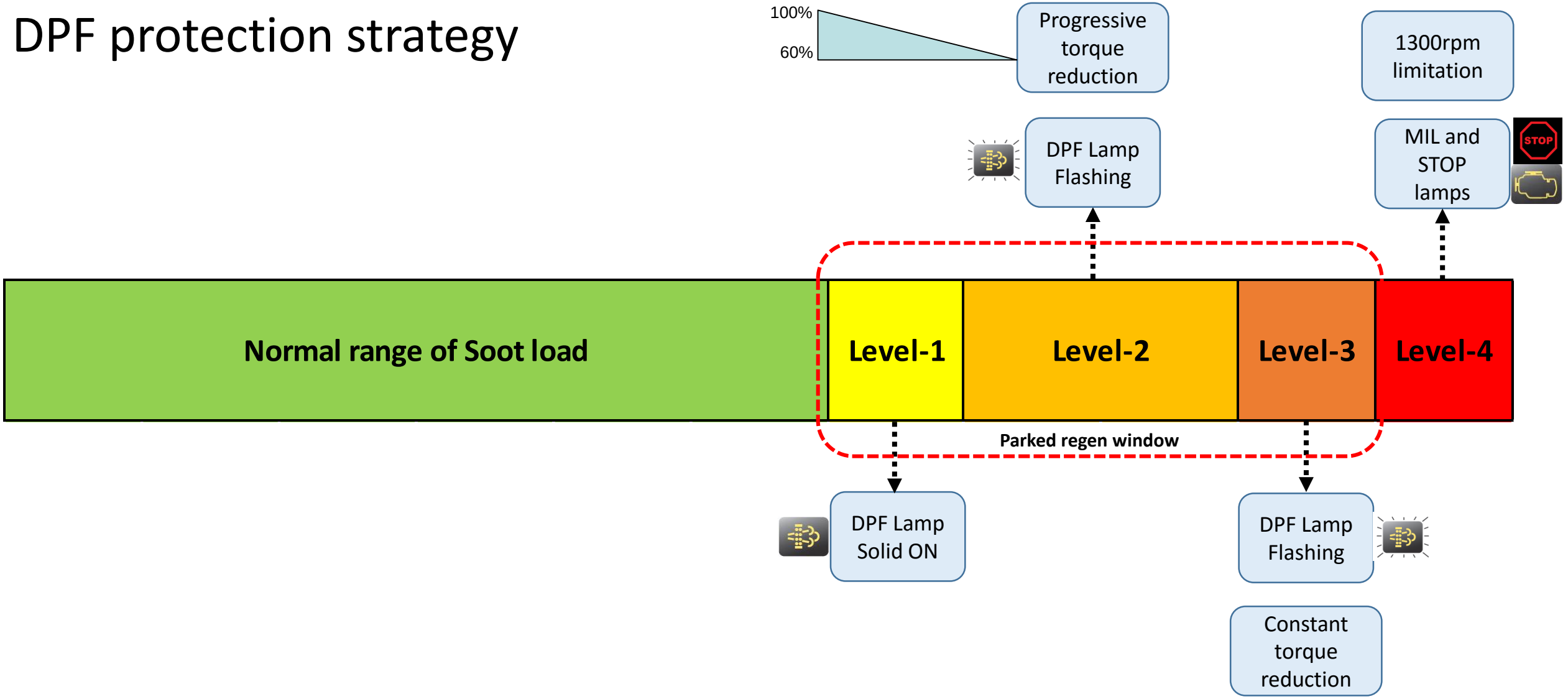
Passive regeneration- Correlation with Engine outlet Nox concentration is explained in the below graph



- Soot burn rate increases with increase in IN Nox Concentration
- Soot burn rate increases with increase in temperature
- Soot burn rate is higher at higher soot load as soot oxidation process is an exothermic process releasing heat which in turn provides the temperature to burn more soot. Hence soot burn rate is indicated in **Grams per second/ Gram of soot present in DPF**

3. Parked regeneration

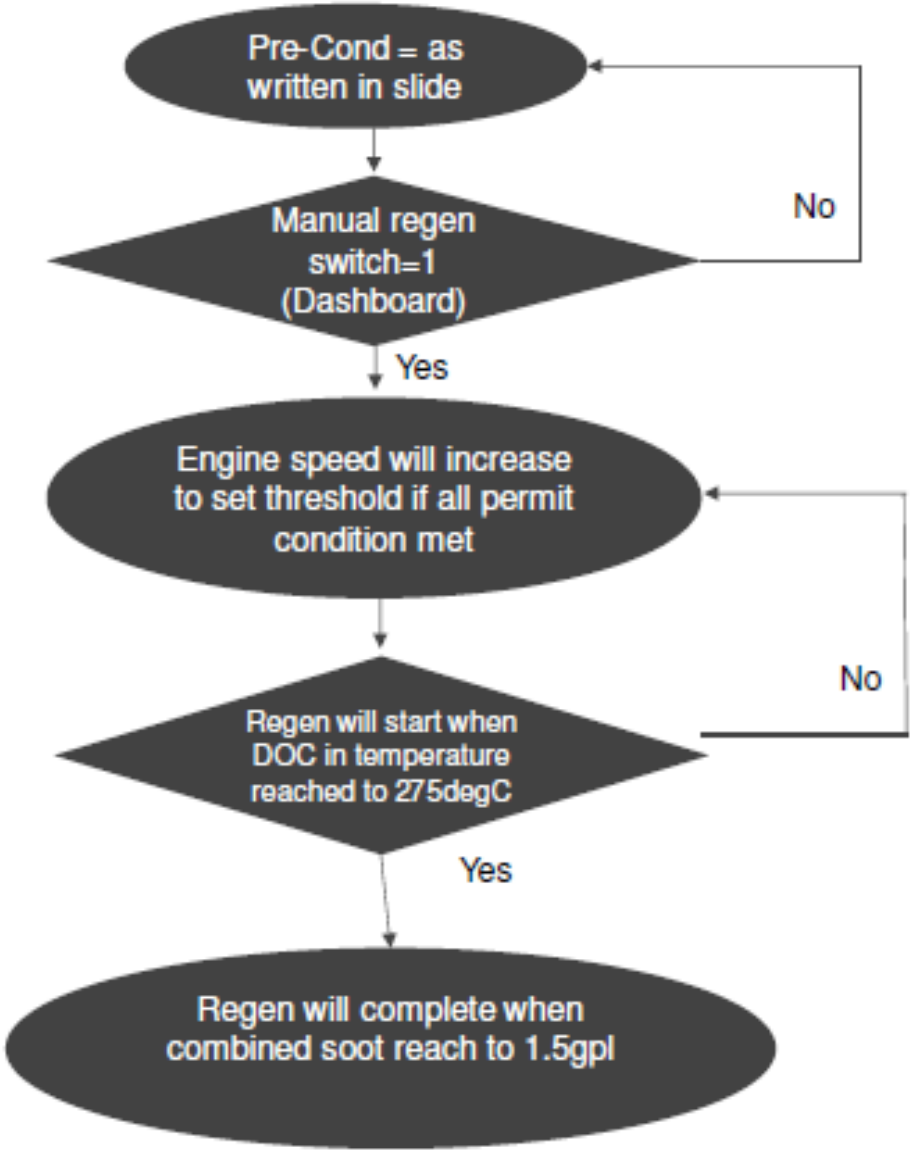
DPF protection strategy



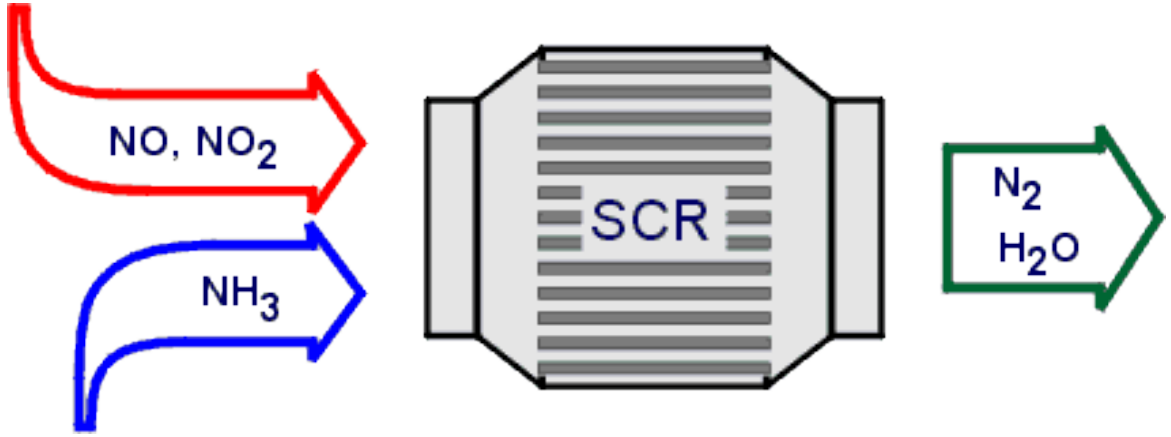
3. Parking regeneration

Necessity:
If Active and Passive regenerations are not effective then Parked regen will trigger to clean aftertreatment system at controlled engine Idle condition.

Enabled condition:
- DPF Regen lamp=ON,
- Park the vehicle at safe place
- Inhibit Switch=OFF
- Parking brake=ON
- Acceleration pedal position=0
- Clutch and Brake Switch= Off
- Vehicle Speed=0
- PTO= Off



Selective catalytic Reduction(SCR)

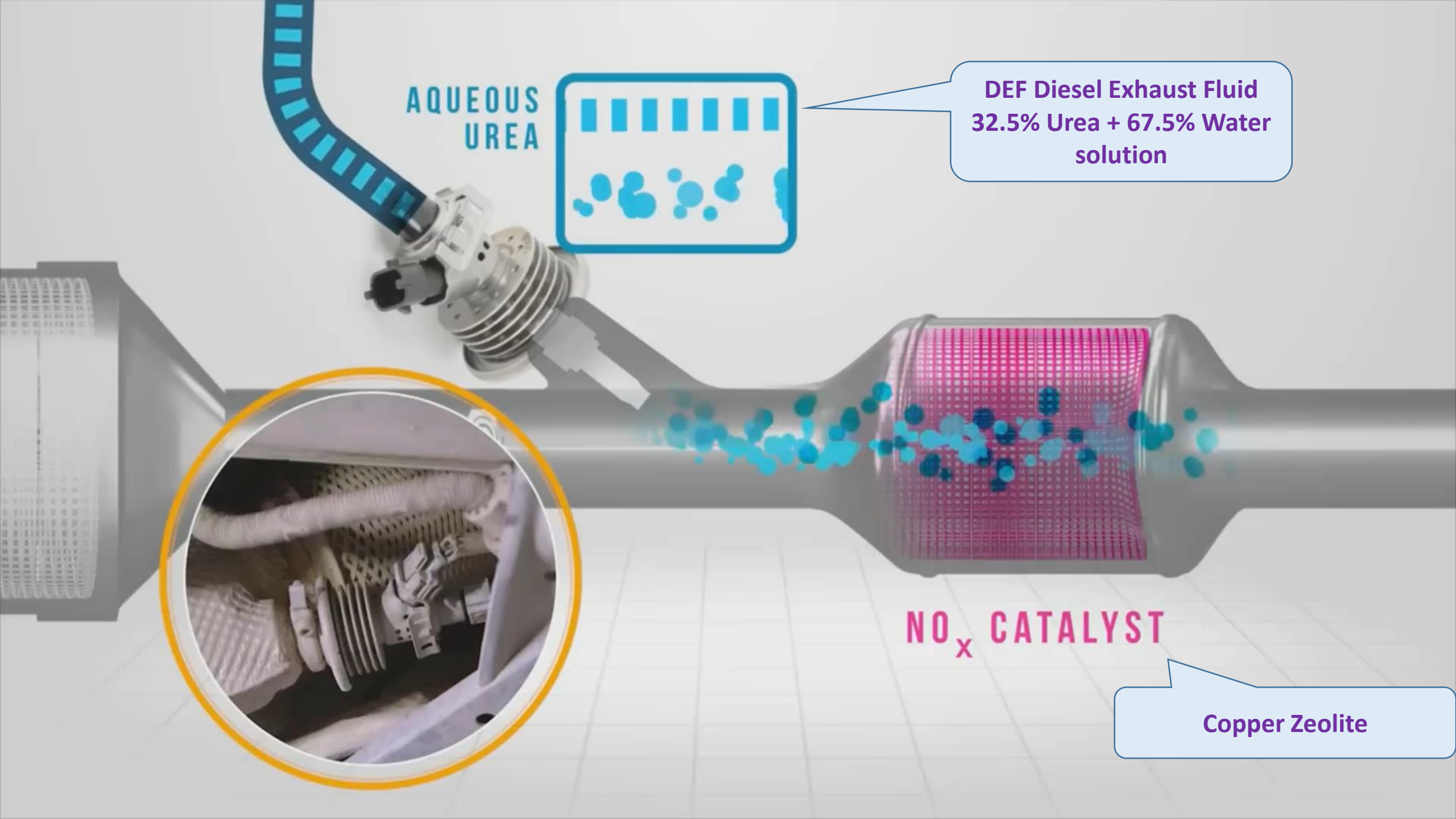


The name Selective Catalytic Reduction (SCR) catalyst is derived from the ability of the catalyst to selectively reduce NOx to N_2 and H_2O in the presence of Reducing agent NH_3(Product of hydrolysis of Ad-blue in DRT)

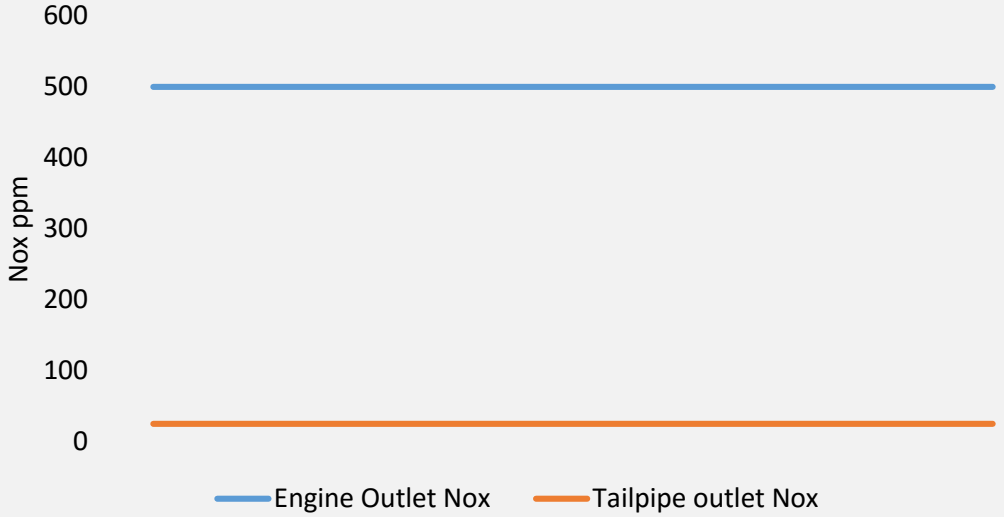
- **Reduction**: The function of the SCR is to reduce Nitrogen oxides (NOx) to Nitrogen (N_2) and Water(H_2O)— Ammonia (NH_3) is used as a reducing agent
- Ammonia (NH_3) is obtained from the hydrolysis of Ad-blue in presence of Carbon-di-oxide (CO2)

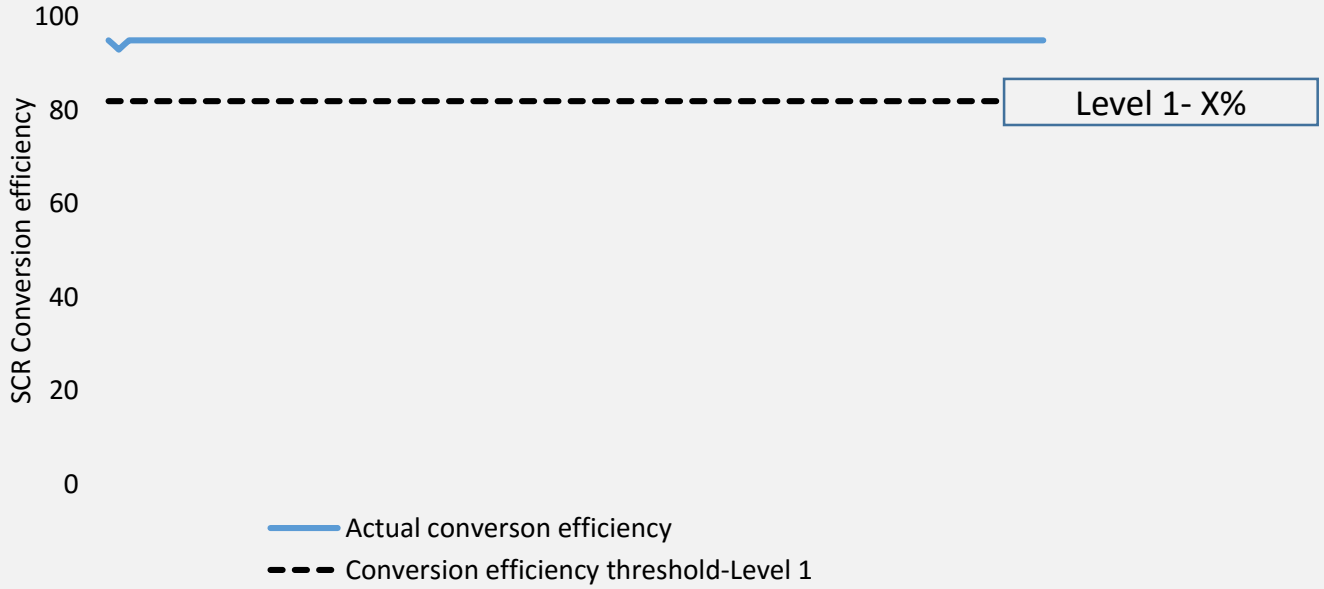
$$4\ NO + 4\ NH_3 + O_2 \text{ -----> } 4N_2 + 6H_2O$$
$$2NO_2 + 4\ NH_3 + O_2 \text{ -----> } 3N_2 + 6H_2O$$

- Catalyst is a combination copper and zeolite oxides


AQUEOUS
UREA
DEF Diesel Exhaust Fluid
32.5% Urea + 67.5% Water
solution
NOx CATALYST
Copper Zeolite

SCR Conversion efficiency diagnostics





4. Reactive regeneration

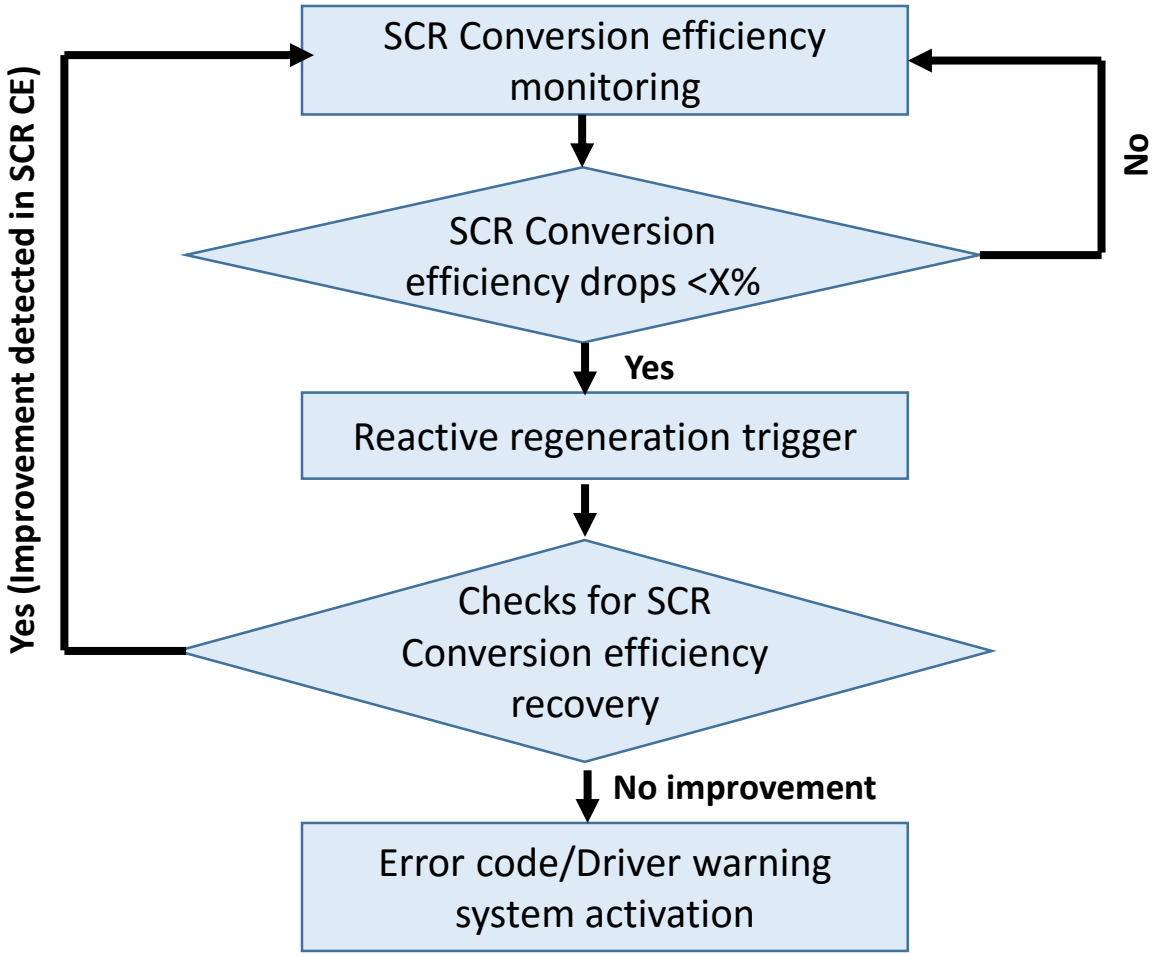
What is Reactive regeneration?

Reactive regeneration is the process of cleaning SCR catalyst through high temperature using HC dosing.

When?

- Sulphur masking due to high Sulphur diesel
- Excessive urea deposits over SCR catalyst
- Any other chemical masking over SCR catalyst
- Deteriorated SCR catalyst

Logic



Thank you