Catalyst Aging Methods for Creating Two-Wheeler OBD-II limit samples

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OBD- Stages

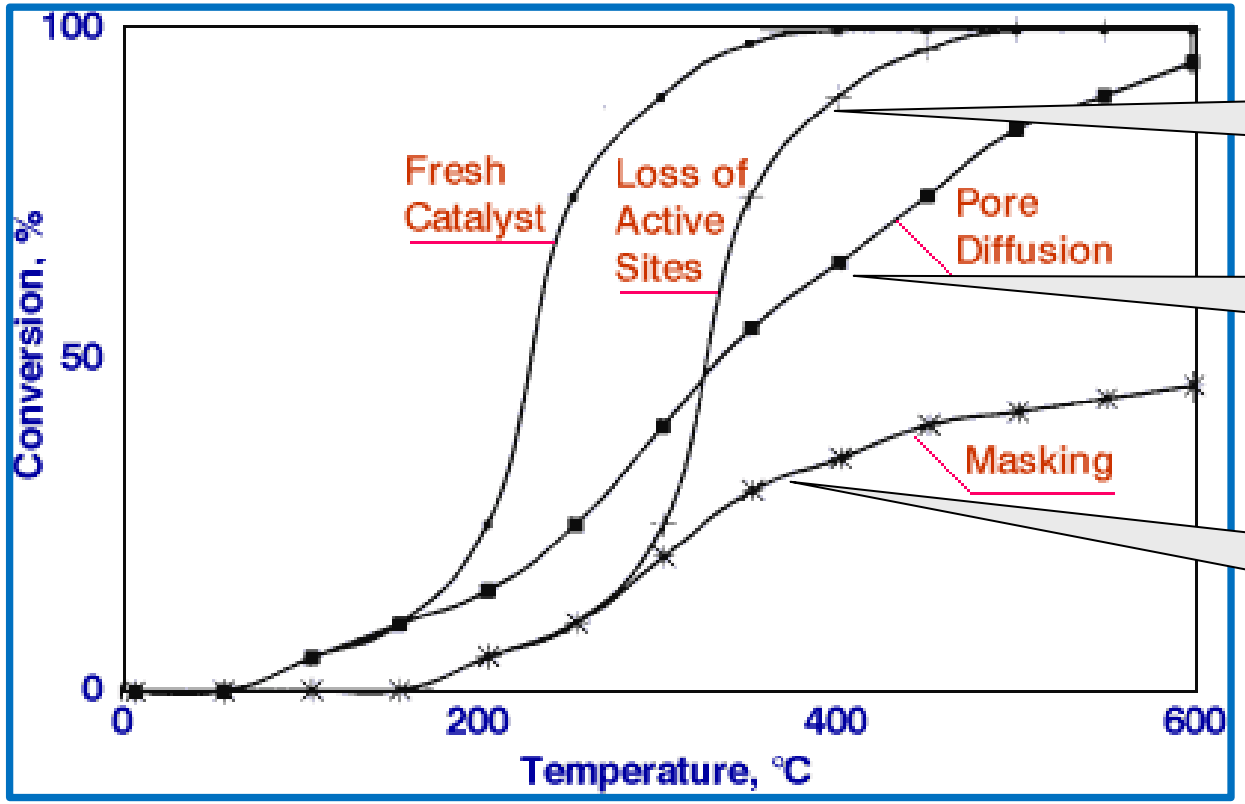
OBD in automotive terms refers to a Vehicle's self Diagnostic and reporting capability. OBD for emission control detects the likely area of malfunction by means of fault codes stored in the computer memory

Monitoring Items	OBD-Stage-I 1st April 2020	OBD-Stage-II A 1st April 2023	OBD-Stage-II B 1st April 2025
Circuit continuity for all emission related powertrain component (if equipped)	√	√	√
Distance Travelled since MIL ON	√	√	√
Electrical disconnection of Electronic Evaporative purge control device (if equipped & if active)	√	√	√
Onboard Diagnostic Emission Threshold limit	X	√	√
Catalytic Converter Monitoring	X	X	√
EGR system Monitoring	X	√	√
Misfire Detection	X	√	√
Oxygen Sensor/ NOx sensor Deterioration	X	√	√

BS-6 Emission Norm and OBD limit for 2W

		CO	HC	NMHC	NOx
BS-6		1000	100	68	60
DF		1.3	1.3	1.3	1.3
Norms with DF		769	77	52	46
V1 Limit	70% of DF limit	538	54	37	32
OBD Stage-IIA (1st April 2023)	Class 1,2-1, 2-2	2170	1400		350
	Class 3-1 & 3-2	2170	630		450
OBD Stage-IIB (1st April 2025)	All	1900		250	300

Catalyst deactivation Mechanism

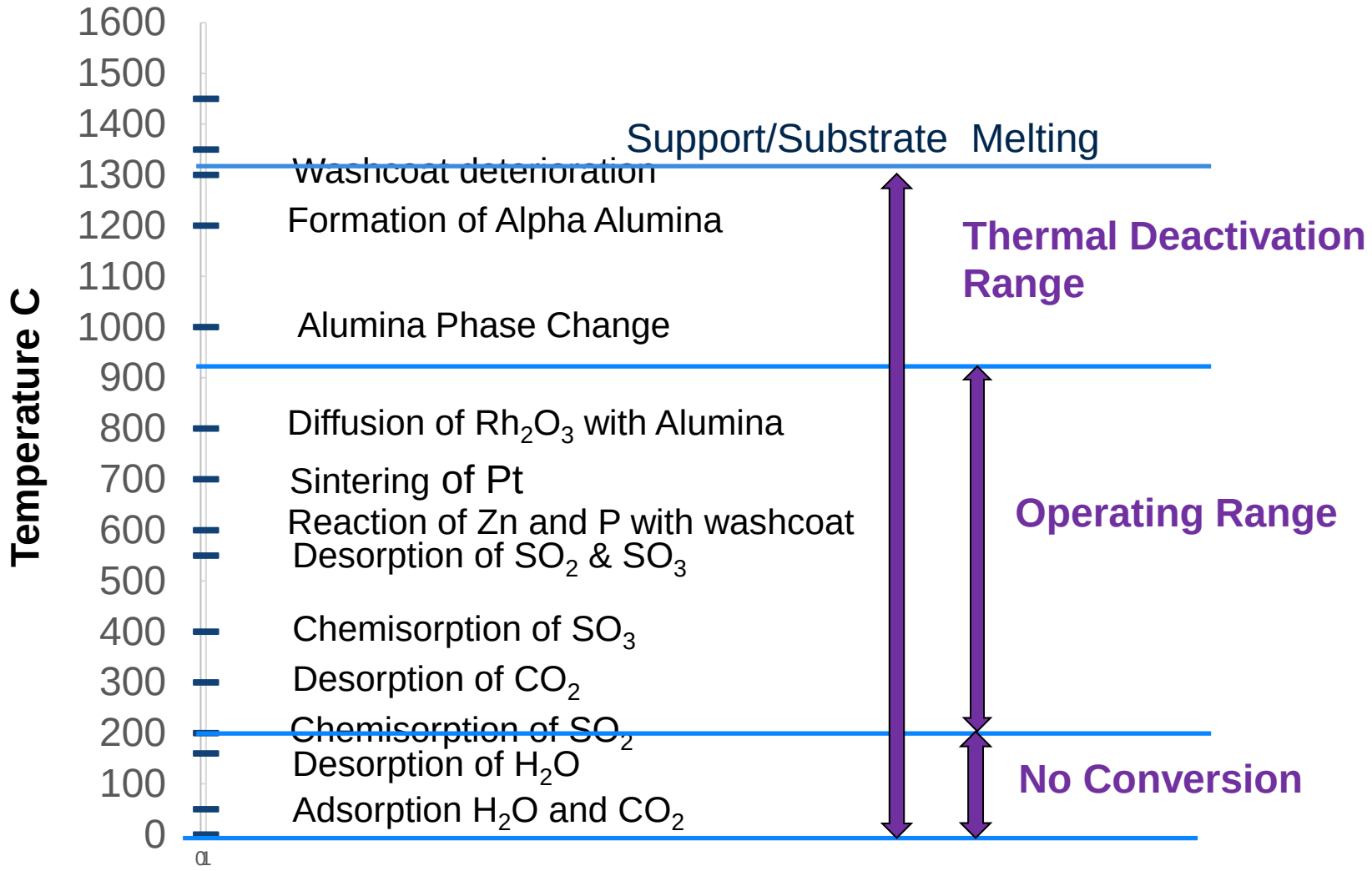


Loss of Active Sites : Due to precious metal agglomeration

Pore Diffusion constraint : Wash-coat agglomeration leading to blockage of pores

Masking of Active Sites: Due to poisoning (fouling) from additives (Zn, P etc.) from lubricating oil

Schematic Overview of Deactivation Phenomena of TWC as a function of Cat Temp



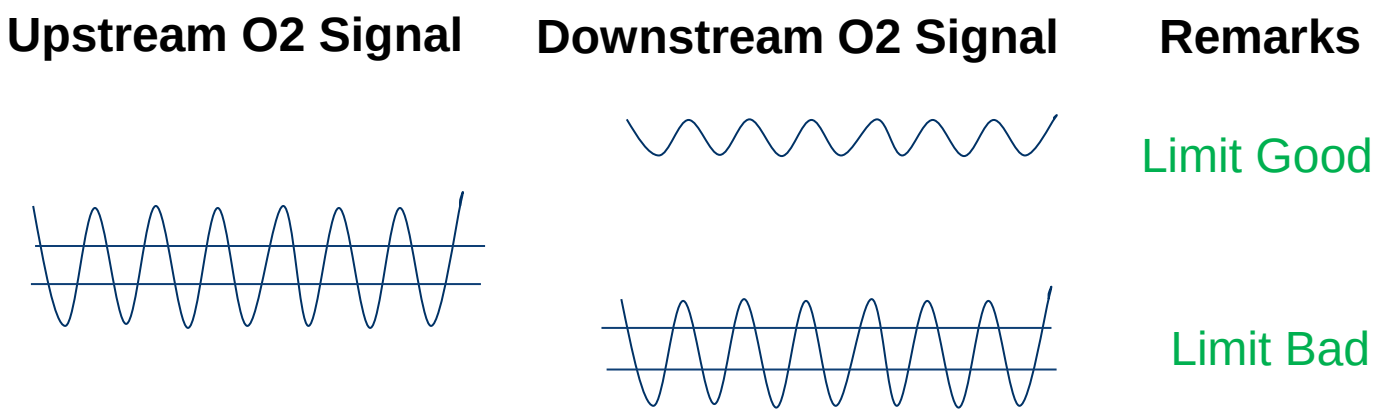
Oxygen Storage (OSC) Mechanism

- **OSC is a key mechanism that enhances catalyst activity, helping oxidation- reduction reactions**
- **Excess Oxygen in combustion will be chemically stored (up to a certain capacity) in the catalyst**
- **Cerium has an ability to exert dual oxidation state of +3 and +4 and while being oxidized from +3 to +4 (Ce_2O_3 to CeO_2) if a deficit of O2 exists, then the catalyst will release oxygen to allow reactions to happen**

$$4\ CeO_2 \rightleftharpoons 2\ Ce_2O_3 + O_2$$

- **During it's life, the TWC loses OSC property, which is considered as an indirect index of the aging process and consequent deterioration of the catalyst**

Schematic of OSC Measurement System in the Vehicle



- Catalyst Monitoring by Downstream O2 sensor – differentiate good and bad catalyst
- With aged (bad) catalyst, downstream O2 signal indicates deterioration of OSC

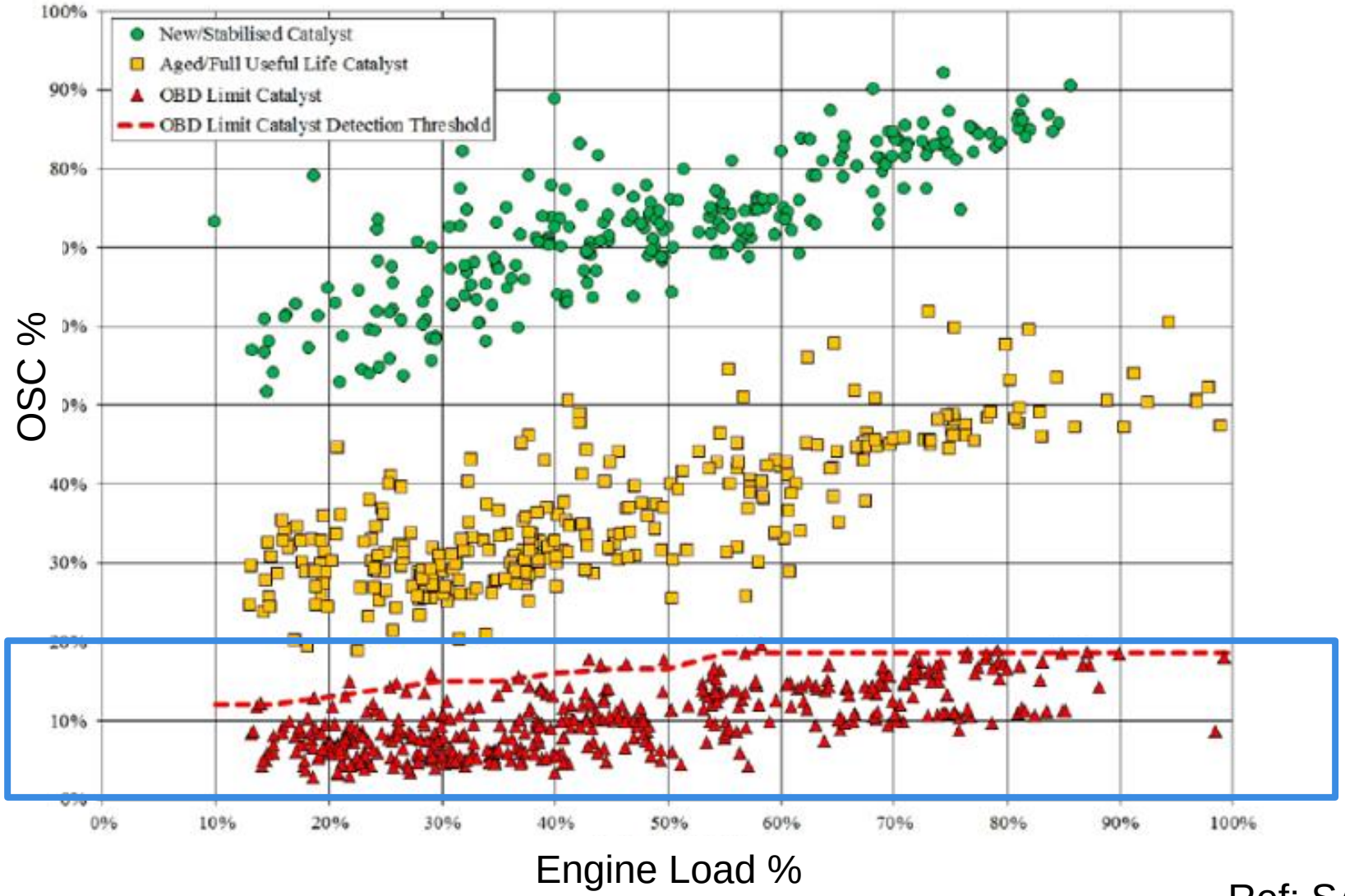
Factors Affecting Catalyst Deterioration for OBD limit Sample Simulation

- Catalyst Volume, Substrate Cell Density
- *Oxygen Storage Components:*
  - Type, Stability, Density, Distribution, PGM Interaction
- *PGM Loading Density and Ratio:*
  - PdO - Very Active OSC
- *Aging Conditions:*
  - Temperature, Duration
  - Atmosphere-Lean/Rich (Oven, Engine)
  - P/Zn/Ca/….. Poisoning (Fouling)
- *Fuel Sulfur Level:*

➢The common concept for preparing an OBD limit catalyst sample is to reduce OSC in an accelerated way to speed up the deterioration.

➢The reduction in OSC should be stable and not regenerate during driving

OSC vs Engine Load : Comparison of OSC between New/ Aged-full life/OBD limit Catalyst



Ref: SAE 2017-26-0147

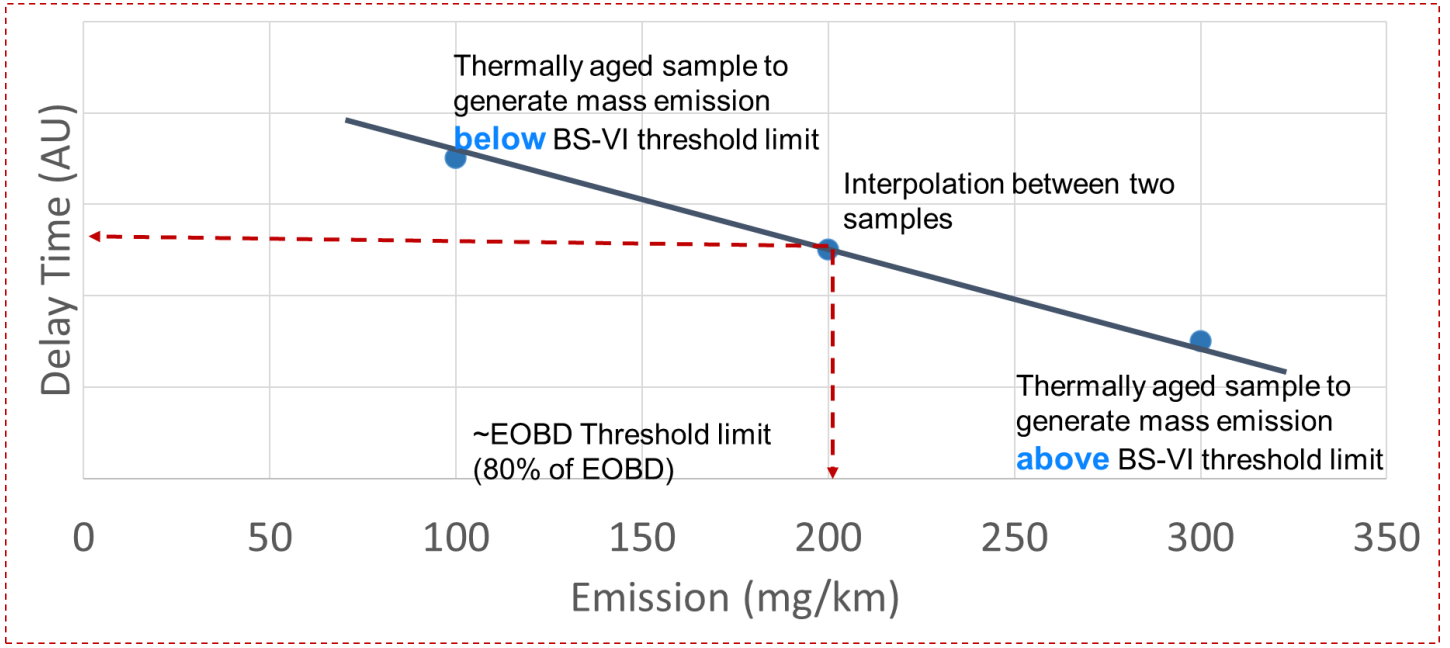
Different Methodologies Used to Accelerate Ageing for Limit Samples

Objective : To age the catalyst in laboratory to match catalyst performance equivalent to road age catalyst for setting OBD-II limit

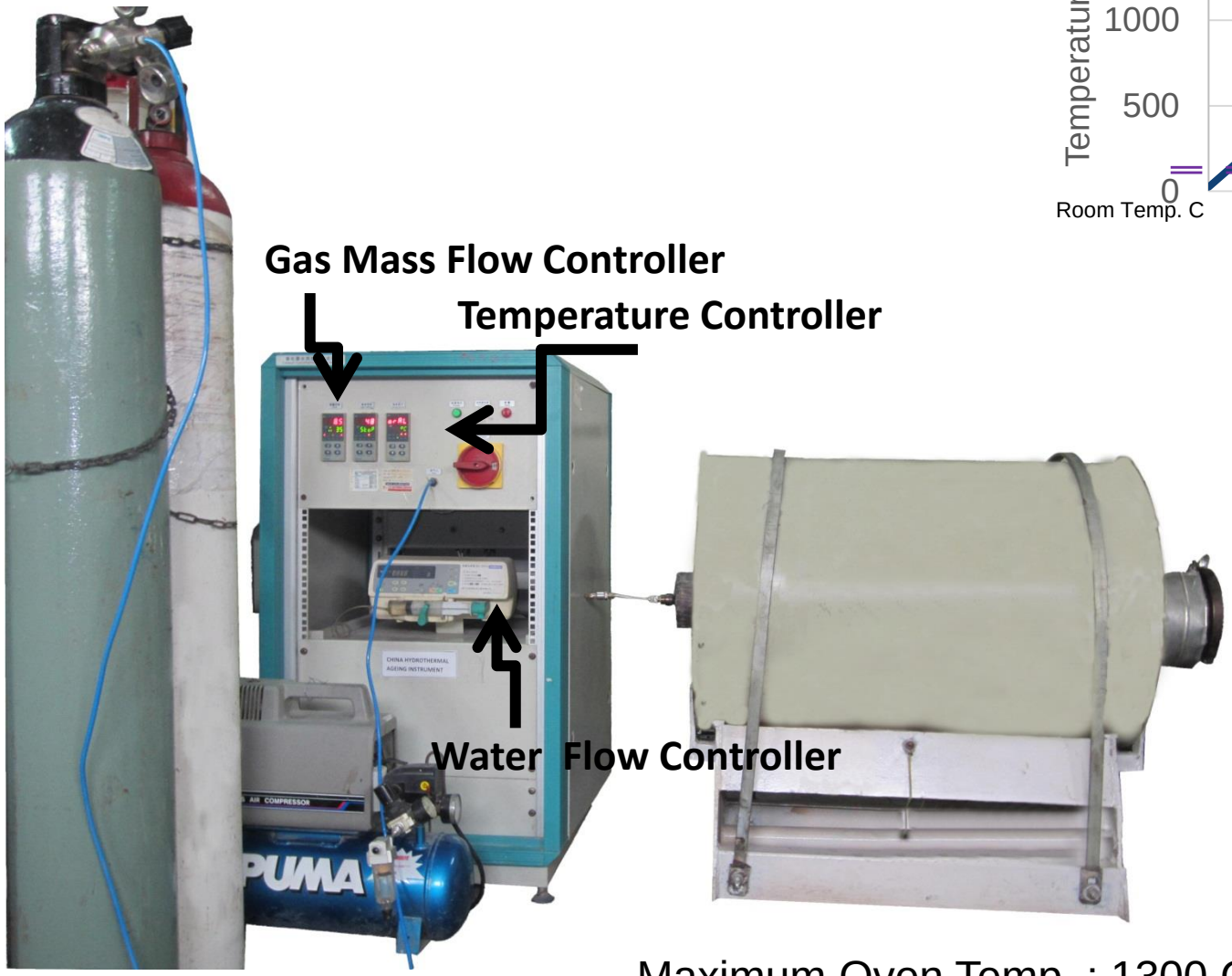
Catalyst Ageing : Mild, Medium & Sever ageing level used for submission of first level of sample

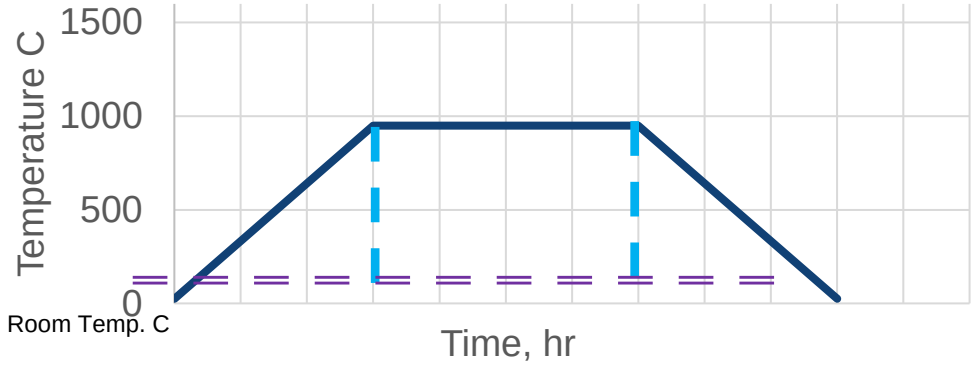
Different catalyst aging methodologies used

- Oven Aging
  - Oven Aging (900 °C – 1200 °C)
  - Oven Aging with poisoning
- Engine Aging
  - Misfire Generation on engine test bench
  - Engine Aging - (RAT -820) (Under Progress)



Hydrothermal Aging Set up @ SCIL





Maximum Oven Temp. : 1300 C

Engine Test Bed Setup for Two Wheeler Catalyst Aging @ SCIL

Catalytic Converter size : Dia 40 * 60 or 74.5 mm L

No. of Catalyst : 8

Brick Temperature °C

- Normal Running 850
- RAT Cycle 950
- Misfiring 1120

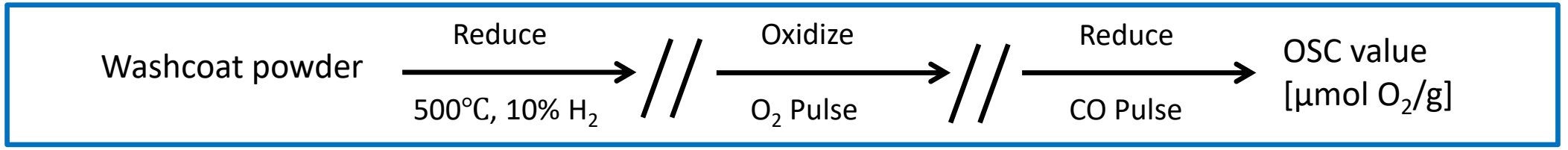
Test Results

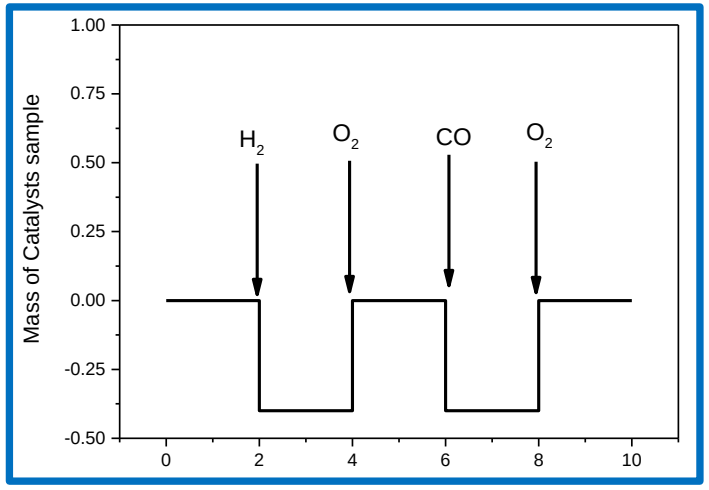
Parameters measured on Aged samples –

- Mass emissions
- BET Surface Area
- Oxygen Storage Capacity - By Pulse Technique

Oxygen Storage Capacity (OSC) measurement by Chemisorption

- OSC of a powder catalyst can be measured by alternating pulses of a reducing gas such as carbon monoxide (CO) and oxygen over the sample. The O_2 storage/release capacity of a three way catalyst (TWC) is a measure of its ability to reduce the negative effects of rich/lean oscillations in the exhaust gas composition. It is measured by CO –Pulse Chemisorption Method.



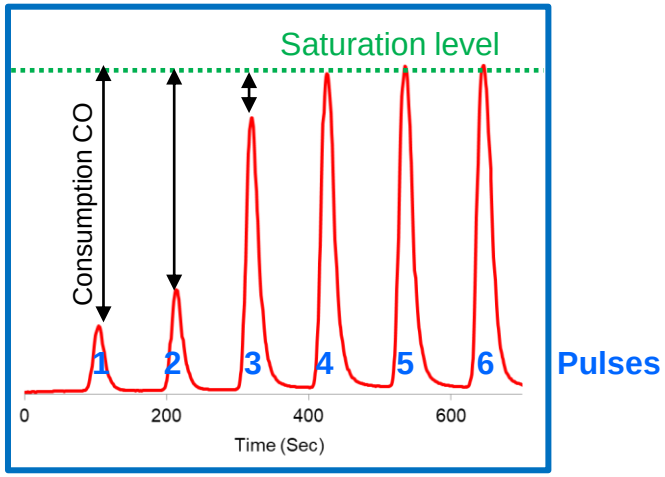


Instrument used: Micromeritics 2920
OSC is measured at 400 deg C

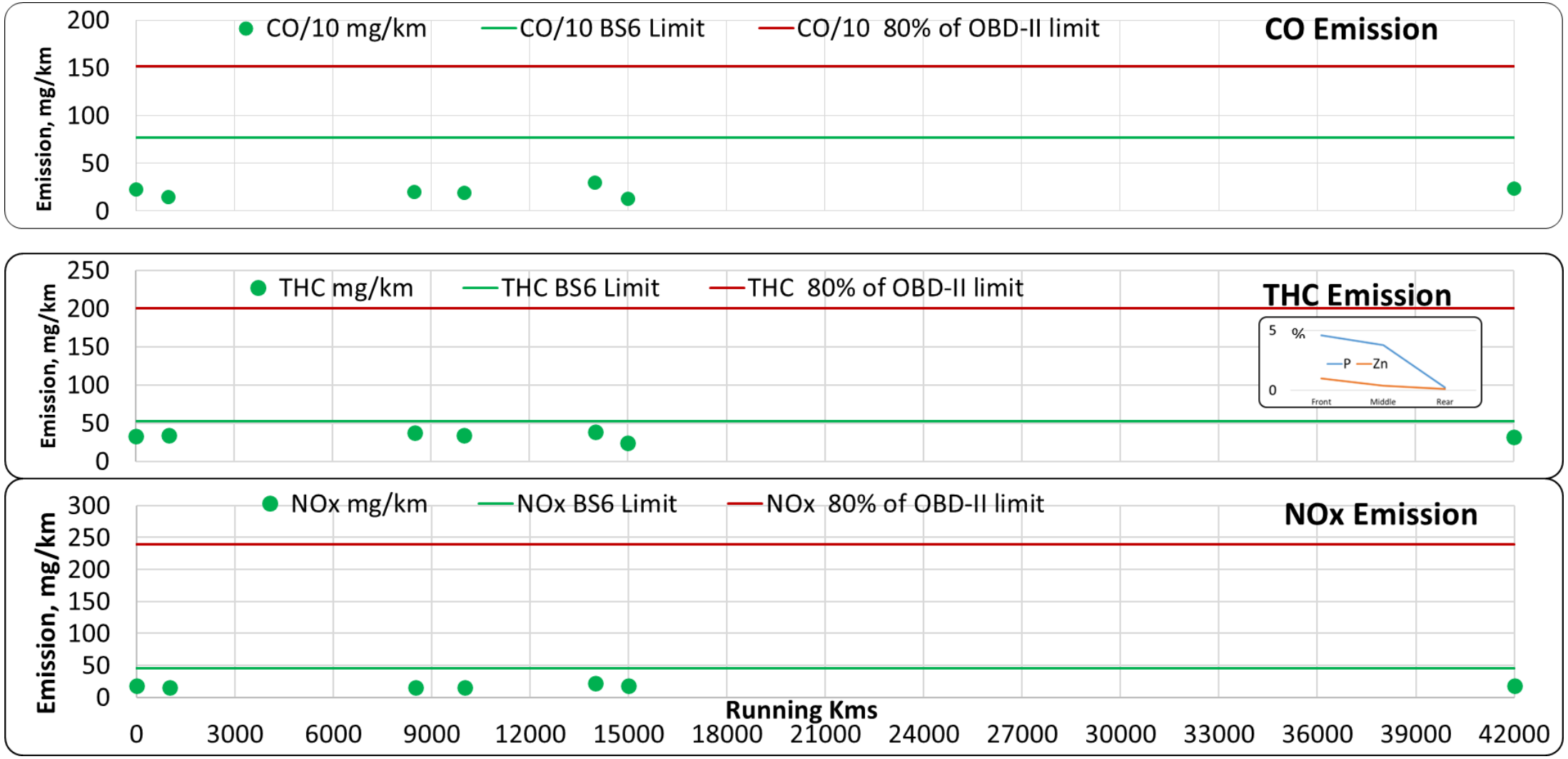
Pulse Parameters influences OSC:

- Temperature
- CO / H_2 concentration
- loop volume

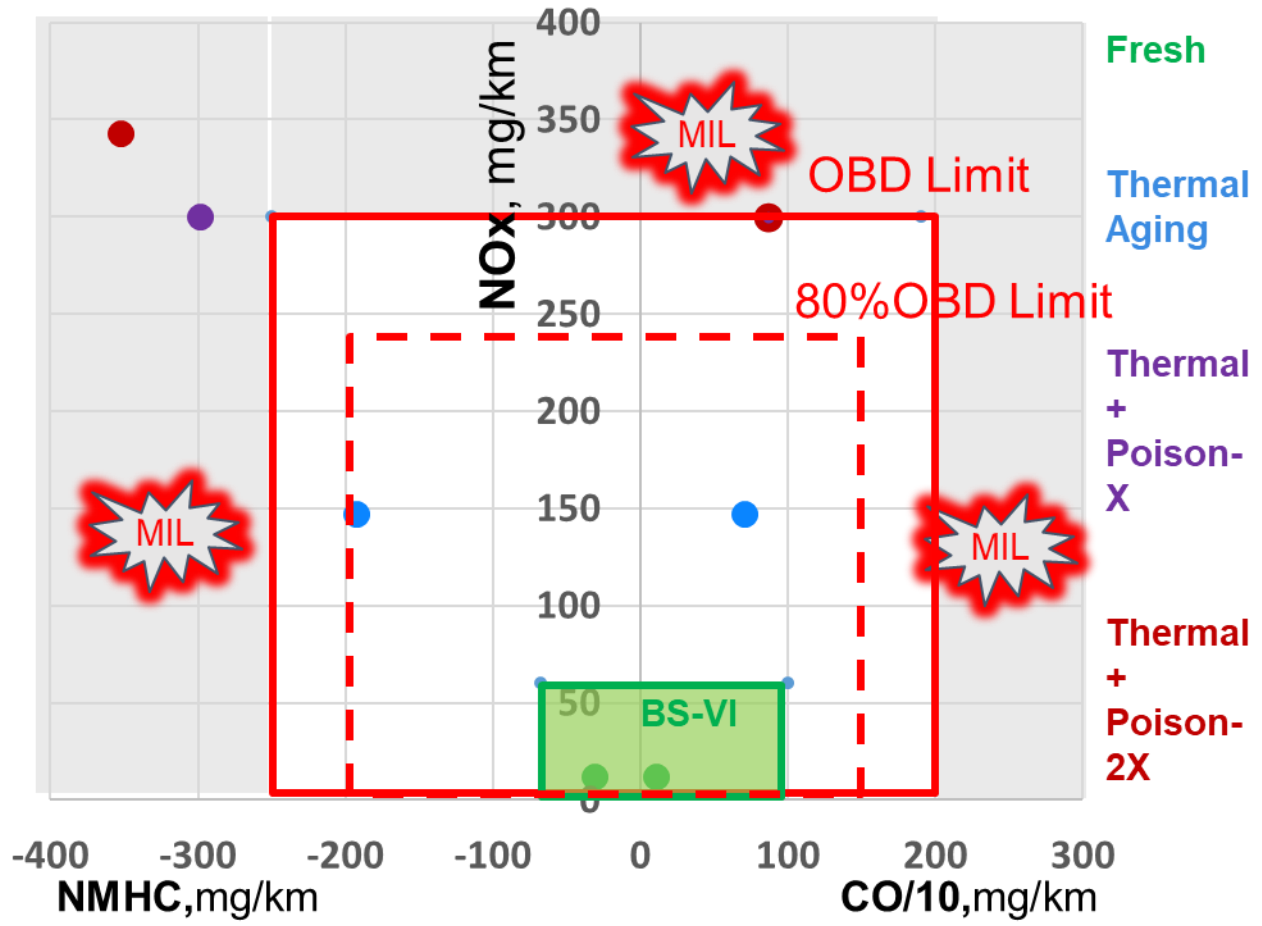
➢ TOSC (Total OSC) is cumulative CO consumption in all pulses.

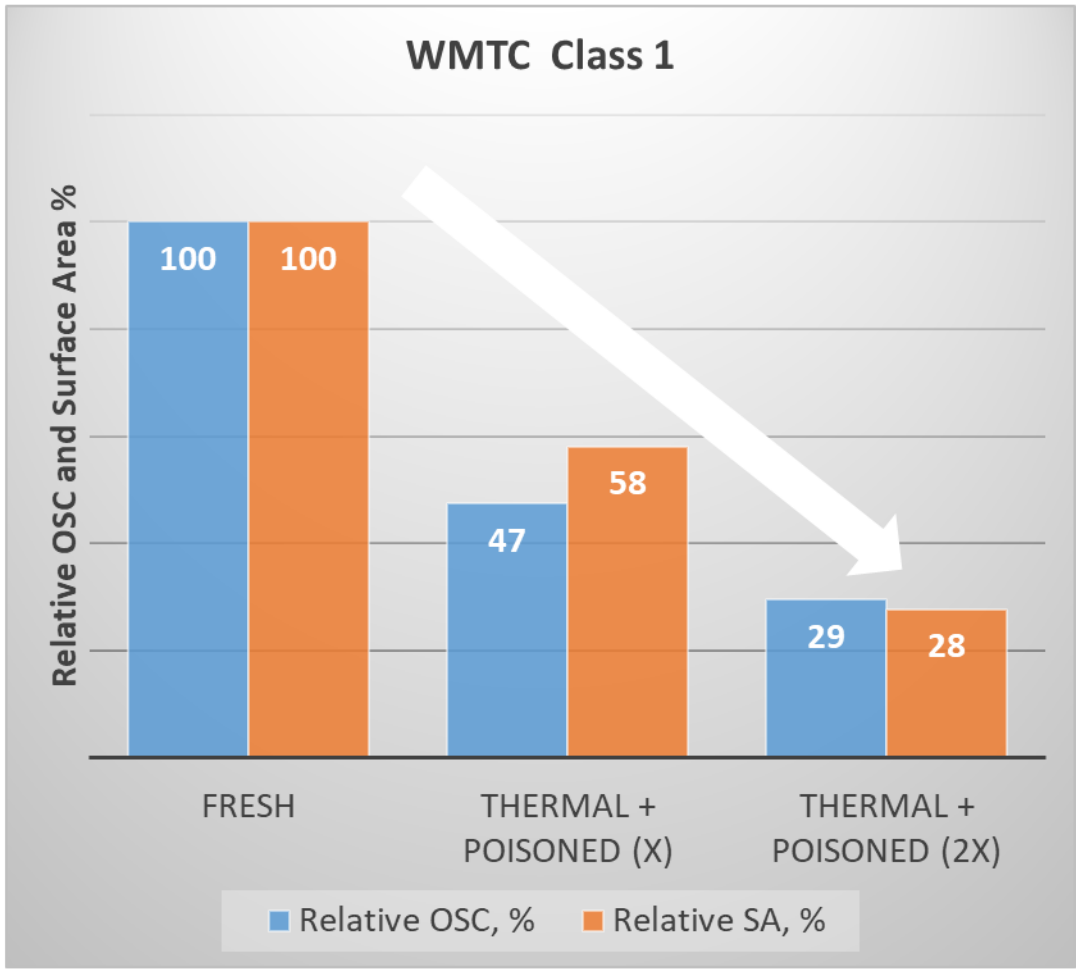


Mass Emission of 100cc M/C Field run Catalysts

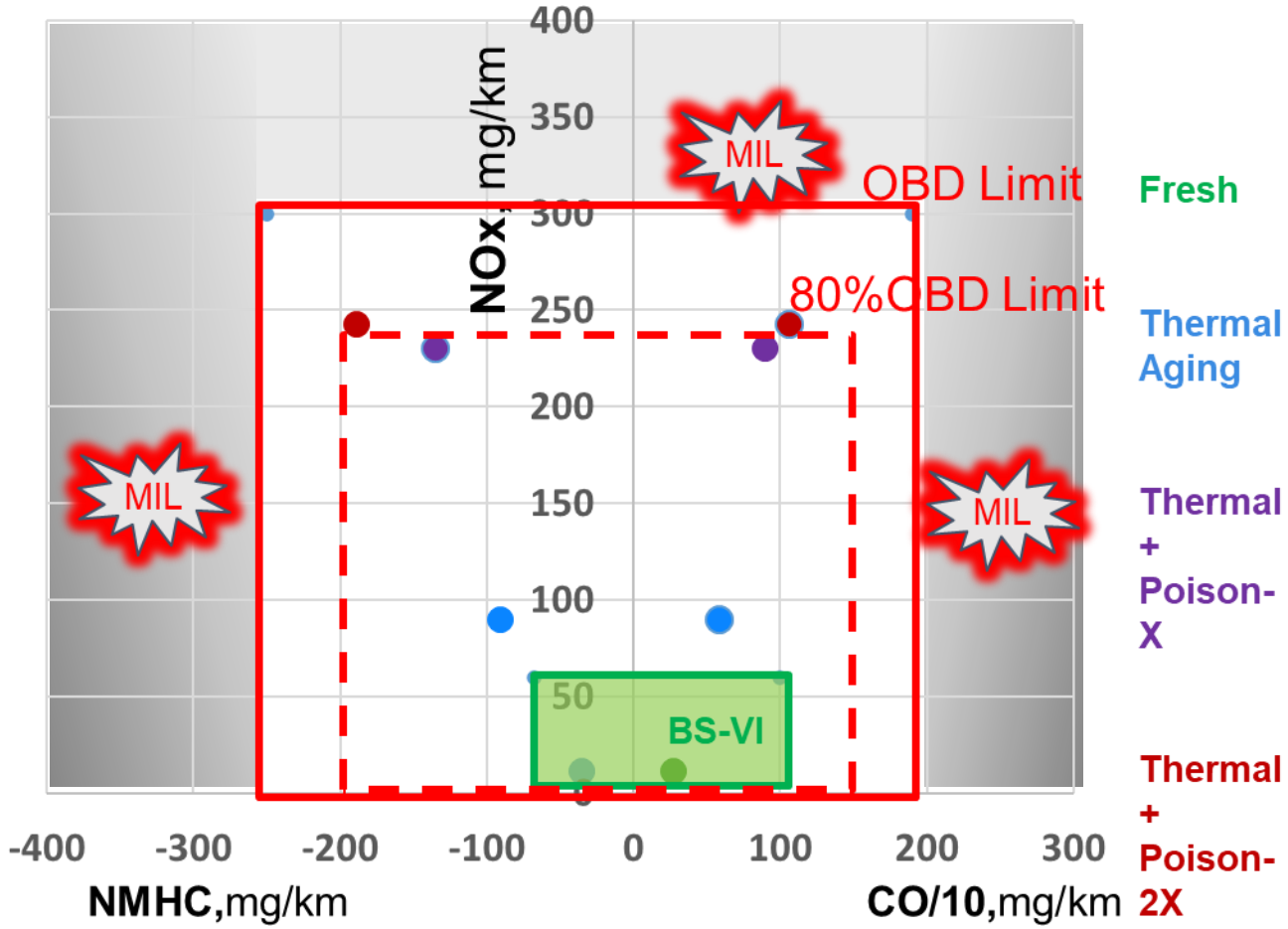


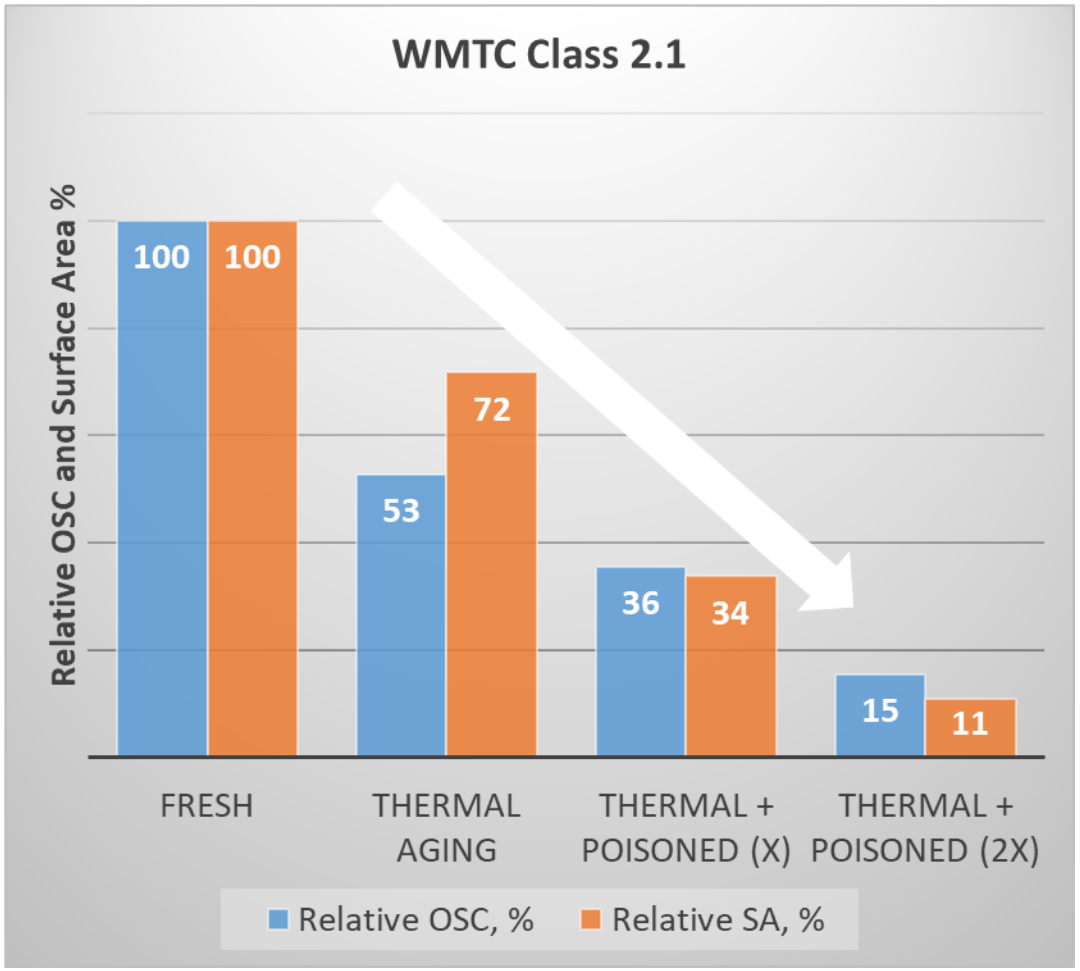
OBD limit sample: for WMTC Class -1 Motorcycle



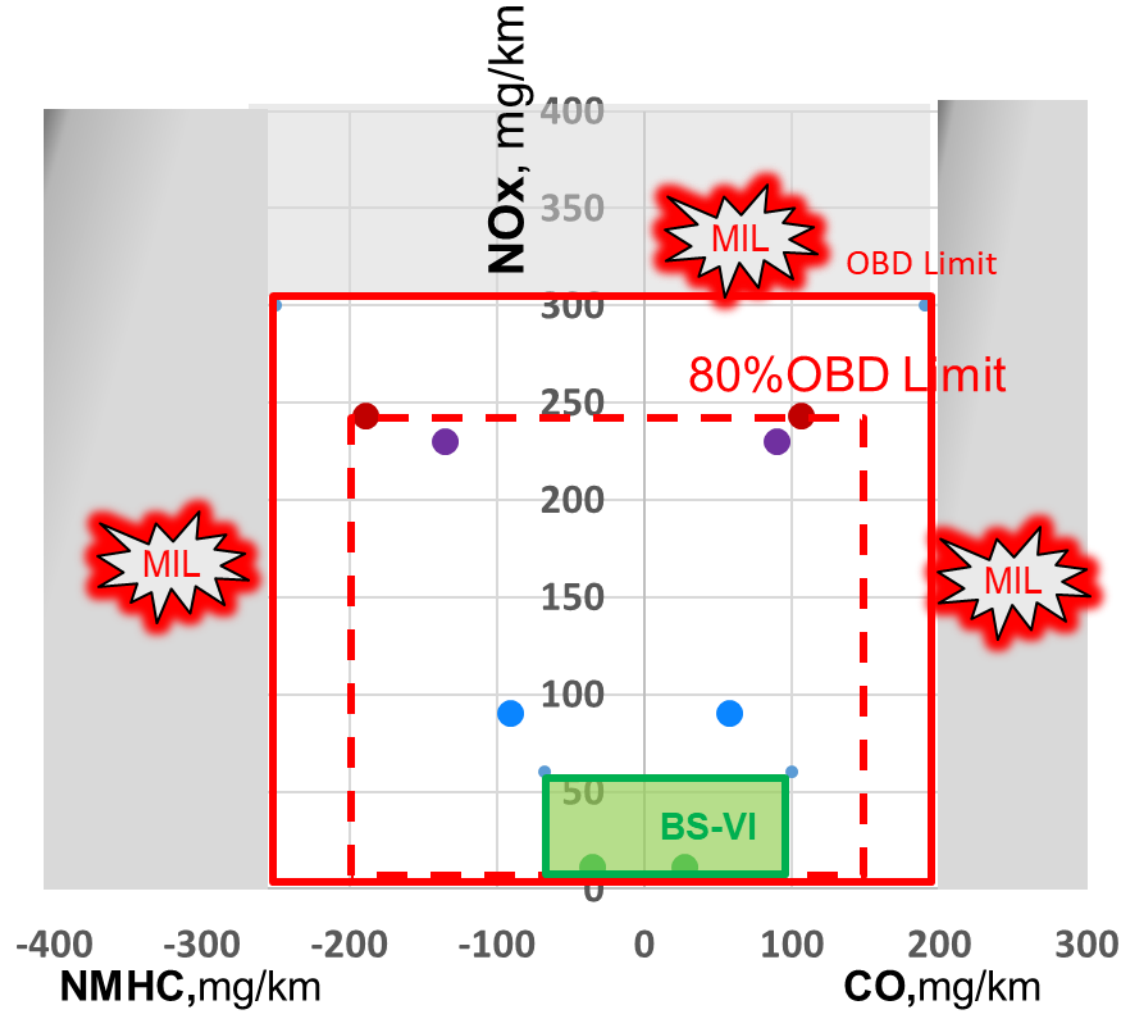


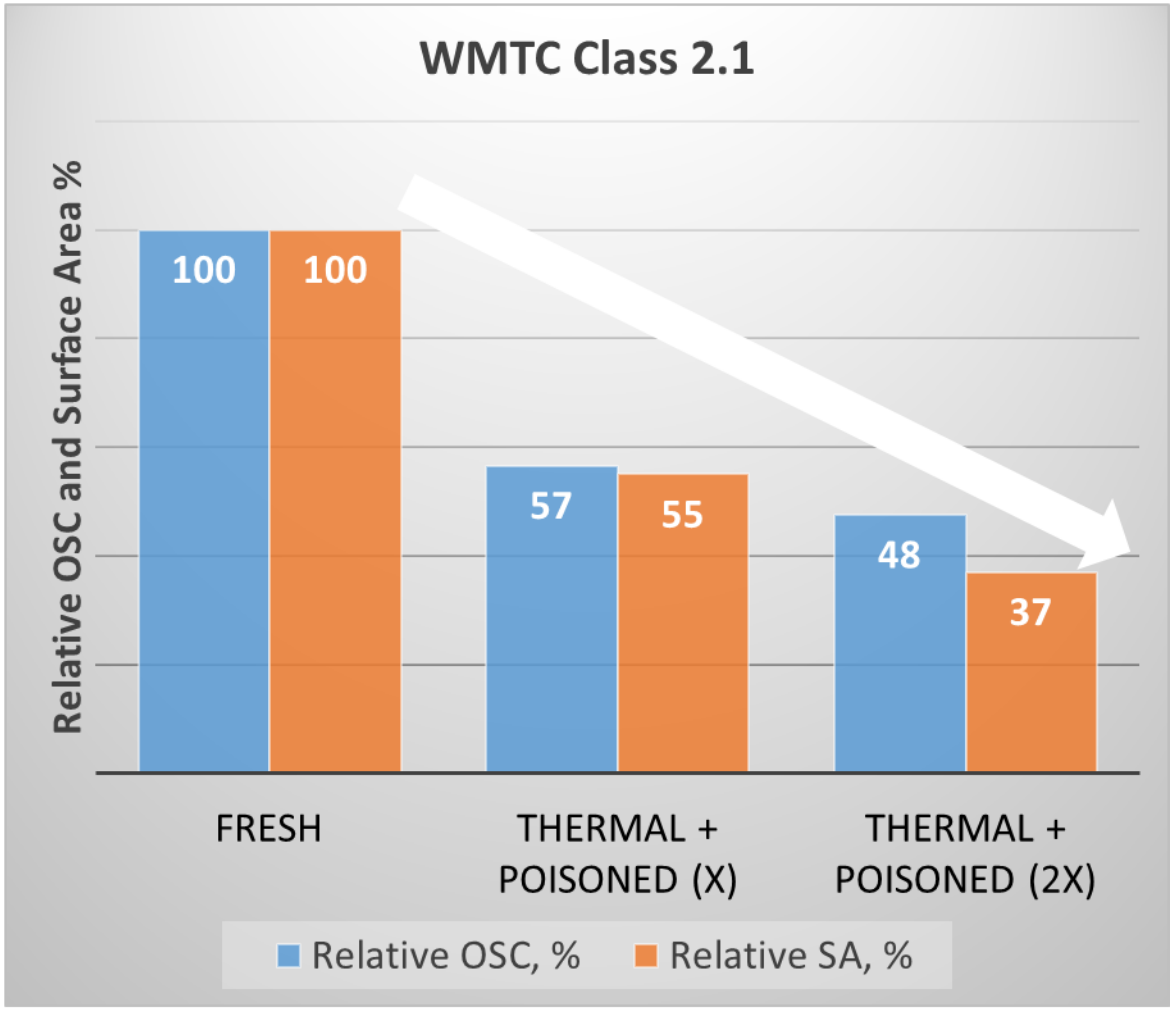
OBD limit sample: for WMTC Class- 2.1 Motorcycle /1



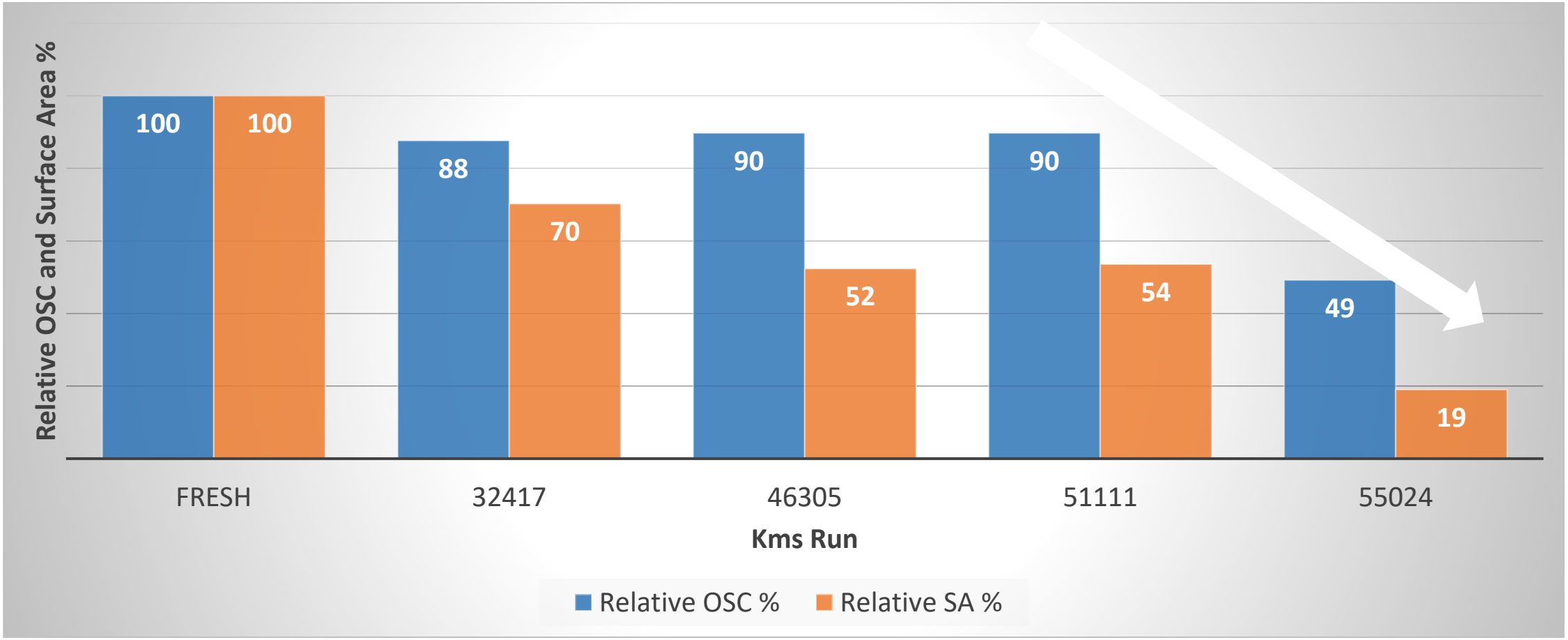


OBD limit sample: for WMTC Class- 2.1 Motorcycle/2





Relationship between Relative OSC and SA of 3W field run Catalyst



%age OSC and SA loss follow the similar trends as of oven aged sample. Oven aging is more severe to Road aging.

Conclusions

- **Only Thermal aging is not sufficient to deteriorate the catalyst to achieve OBD threshold limit mass emission**
- **Threshold limit sample were created by poisoning the catalyst with P & Zn followed by Thermal aging**
- **Catalyst OSC and Surface area both deteriorated in the same manner**
- **In few cases poor mass emission repeatability of poisoned sample has been observed…. Optimization of poison adherence with the wash coat**
- **Catalyst shall be aged on engine test bed using RAT cycle and correlation shall be established with Thermal + Poison sample**


Thank you


Thermo
ICP