Two Wheeler

BS-6 washcoat Technology
&
Durability Simulation and OBD-II approach

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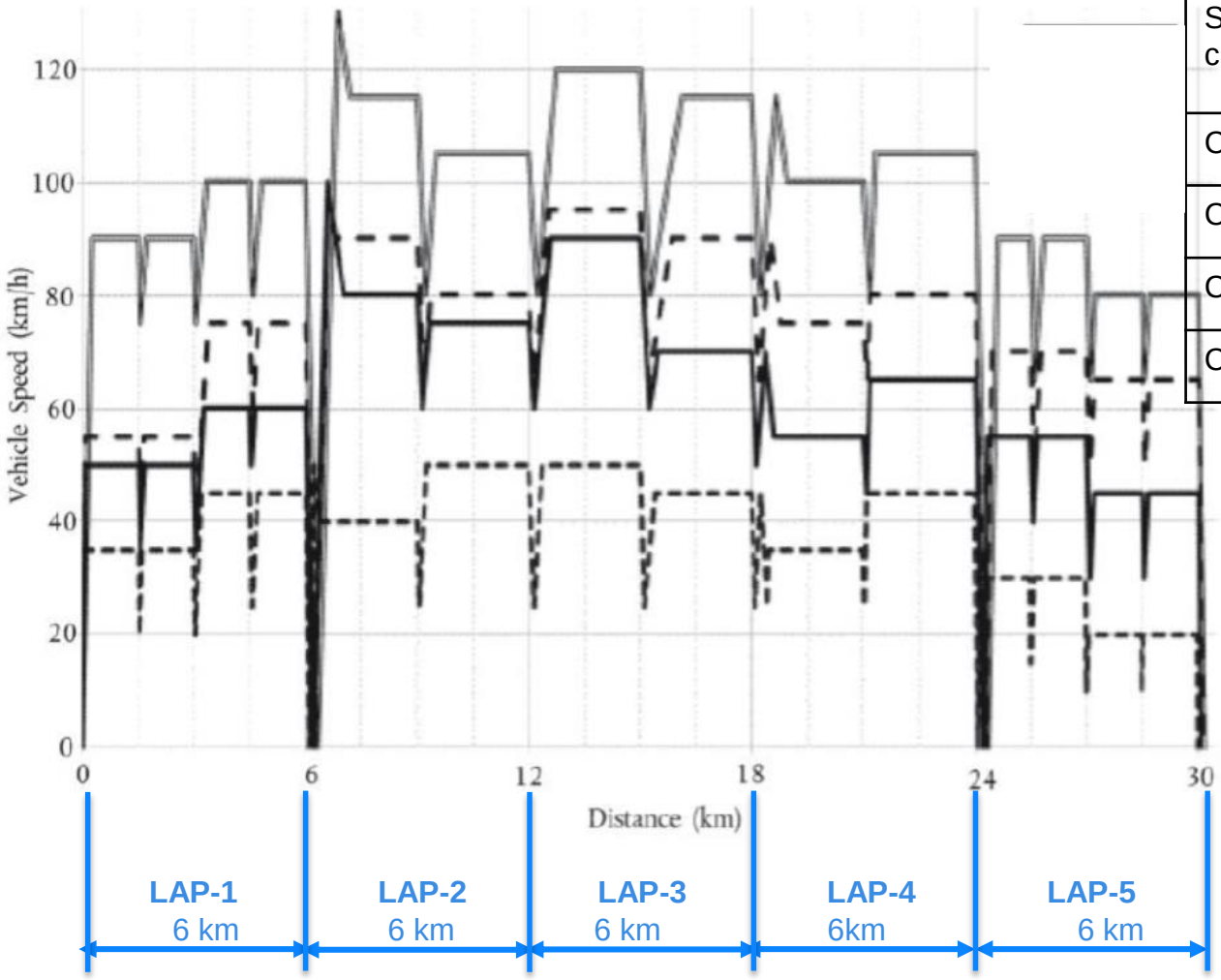
Catalyst Durability

- The Durability of exhaust after treatment for Two wheeler is defined as 20K and 35 K for vehicle Class 1-2 and class 3 respectively
- OBD-II for Two wheeler shall be implemented from April 2023
- In AIS-137, on road /CD durability is defined in SRC and it's simulation on ED as SBC
- Automotive catalyst are subjected to physical, chemical and thermal aging mechanism with different intensity
- This presentation covers, BS-6 washcoat Technology, aging test set-up and results as per SBC for catalyst durability for two wheelers

Pros & Cons of Catalyst aging on vehicle and accelerated aging on engine test bed

Mileage Accumulation on Vehicle (SRC)	Accelerated Engine-bench Aging (SBC)
Real world aging of after treatment system	It is different in terms of chemical interaction and physical phenomenon
Catalyst deterioration due to thermal aging, poisoning due to fuel and oil are more realistic	Deterioration may not be adequately accounted
Components responsible for after treatment systems are tested simultaneously	Generally it is for catalytic converter
Higher cost and time	Lower cost and time
If vehicle driven on road/test track, difficult to control variability	Well controlled engine operation and good repeatability
If tested on Chassis Dynamometer, long term engagement of test setup	Shorter duration, multiple catalyst can be aged simultaneously

SRC-LeCV Distance accumulation Characteristics



SRC cycle classification	WMTC classification
Cycle-1	Class 1
Cycle-2 ———	Class 2-1 / 2-2
Cycle-3 – – –	Class 3-1
Cycle-4 ═══	Class 3-2

Durability

Class 1, 2.1-2.2
20000 km

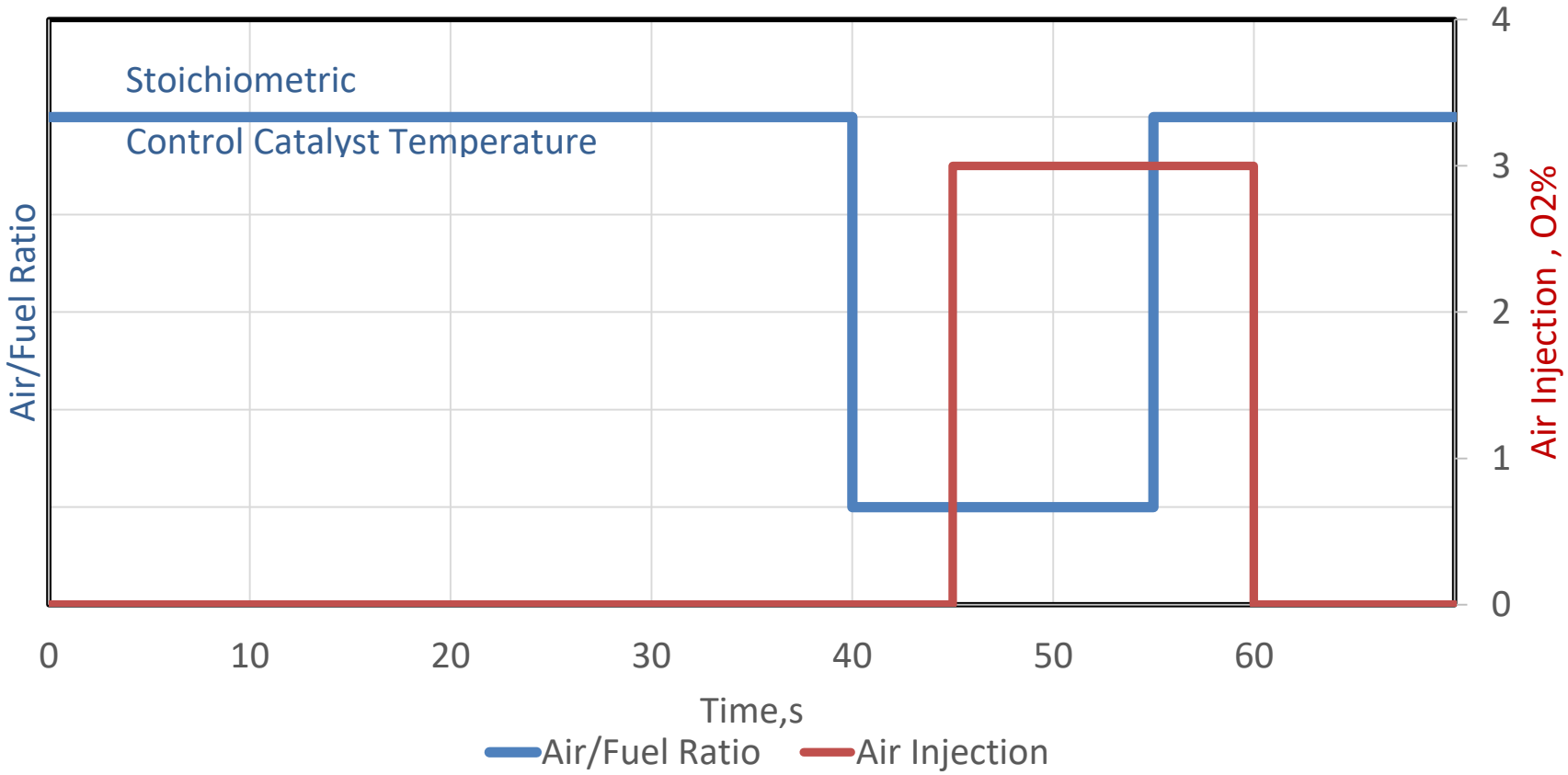
Class 3.1 & 3.2
35000 km

REF: AIS-137

Standard Bench Cycle (SBC)

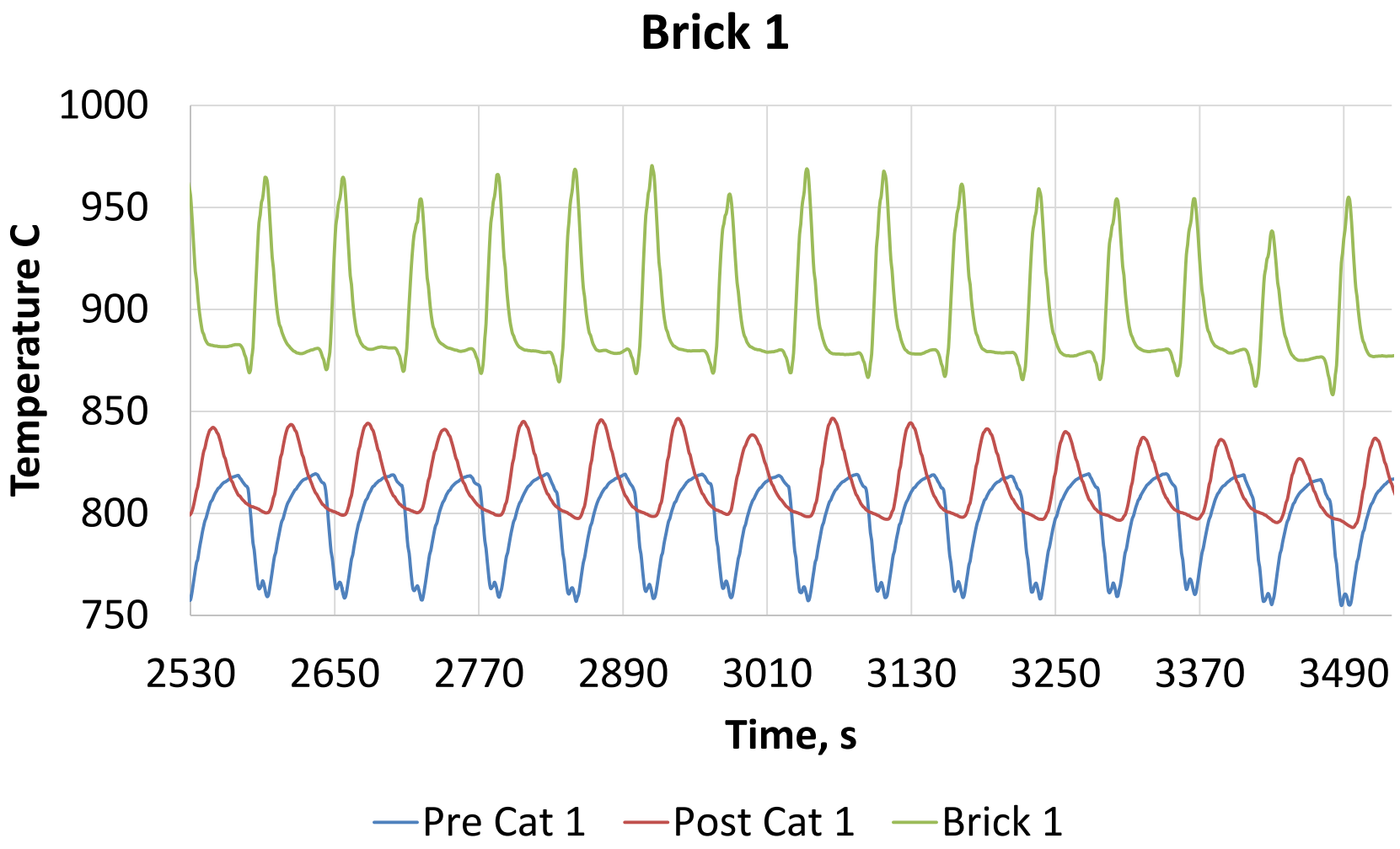
Time, s	Engine Air/Fuel Ratio	Secondary Air
01-40 s	Stoichiometric, A/F Engine Condition to achieve a minimum catalyst temperature of 800 °C	None
41-45 s	"Rich" A/F ratio to achieve a maximum catalyst temperature 890 °C or 90 ° C higher to minimum controlled temp	None
46-55 s		3 % O2
56-60 s	Stoichiometric, A/F Engine Condition to achieve a minimum catalyst temperature of 800 °C	3 % O2

Standard Bench Cycle (SBC)



Time duration on SBC is calculated by Bench Aging Time (BAT) Eq. to equate Desired kms. Run on SRC

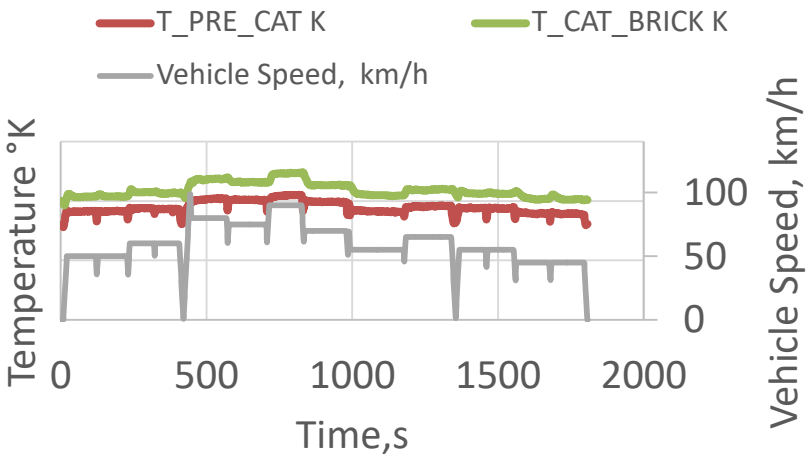
Temperature Traces :

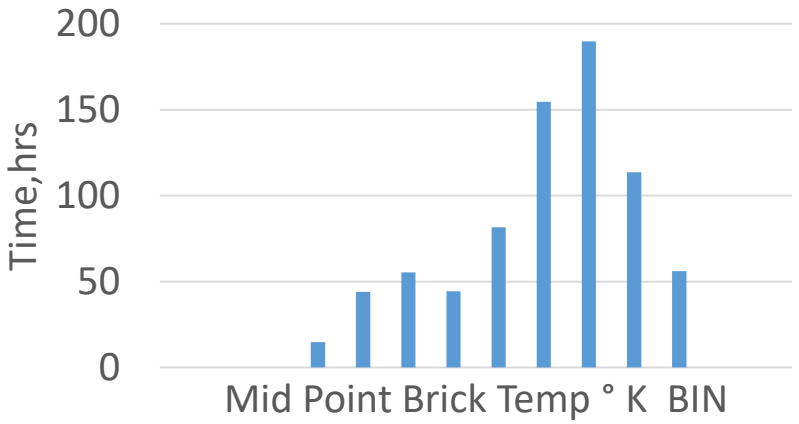


Bench Aging Time (BAT) Eq.

- **BAT Eq. calculates the aging time duration on engine dynamometer for SBC to simulate equivalence to SRC aging on CD**

- ***BAT Eq. Requires*** **-**
  - **Time vs Temperature data measured at 1Hz at the hottest point in the catalyst over SRC**
  - **The measured temperature data shall be tabulated into a histogram with temperature bins**
  - **For each temperature-bin the equivalent ageing time (in hours) is calculated as follows:**





Bench Aging Time (BAT) Equation

$$t_e = t_h exp[R\left(\frac{1}{Tr} - \frac{1}{Tv}\right)]$$

$$BAT = A * \sum t_e$$

t_e : *Equivalent aging time for each temp bin*

t_h : *Measured time in hrs with in temperature bin adjusted for full life*

Tr : *Effective Reference temp. (°K) for Catalyst design and on engine bench*

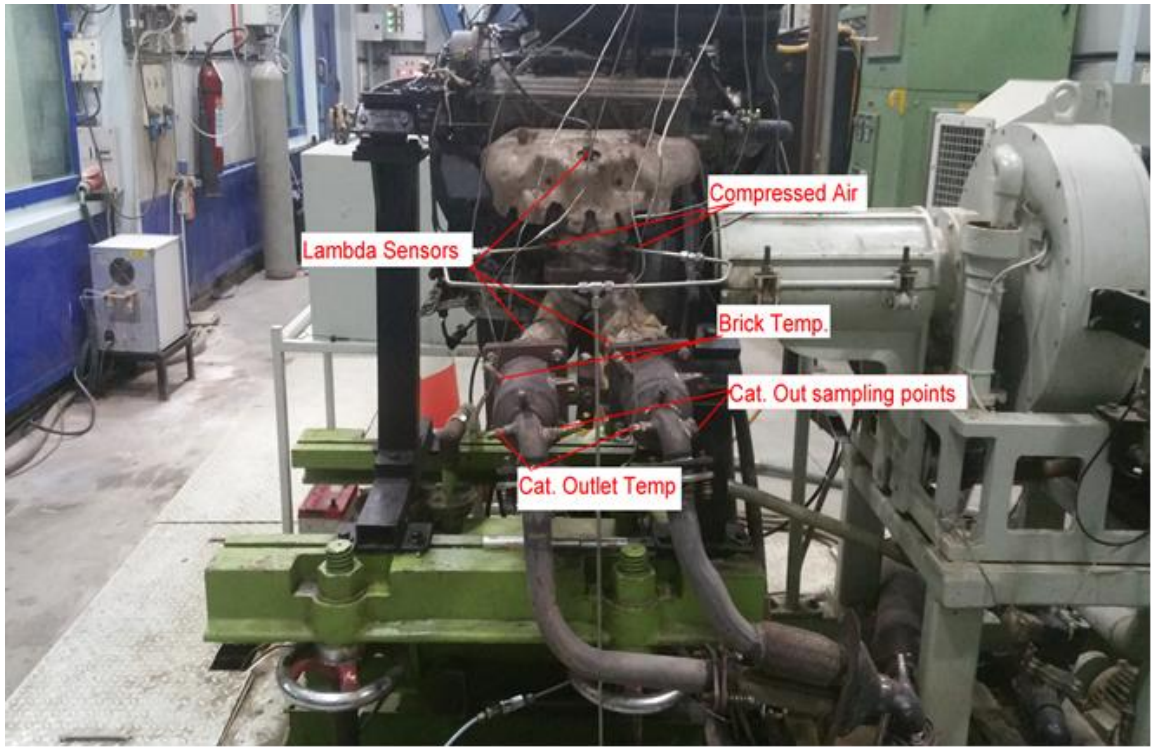
Tv : *Mid point Temperature (°K) of each temperature bin*

A : *1.1 to factor other deterioration e.g. thermal, chemical poisoning etc*

BAT : *Bench Aging Time in hrs*

R : *17500 Catalyst Thermal reactivity*

Engine Aging Set-up @ SCIL Vadodara



- **Engine Specification;**

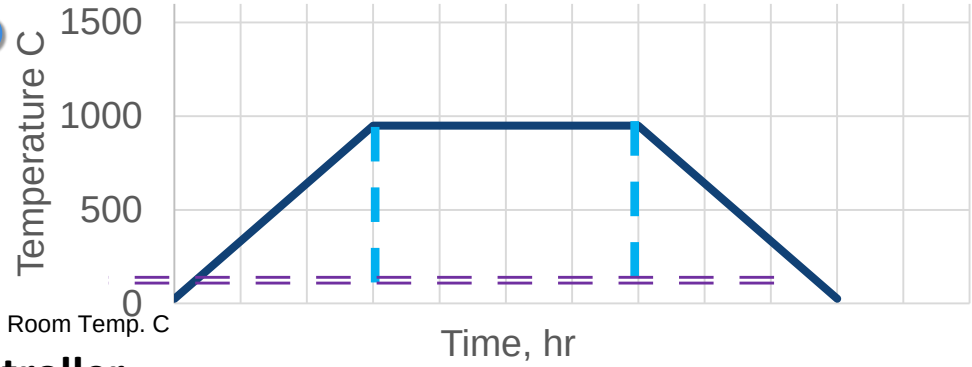
- EngineCapacity : 1298 cc
- No of cylinder : 4 inline
- Bore & Stroke : 74 & 75.5 mm
- Compression Ratio : 9: 1
- Max Power : 87 bhp @ 6000rpm
- Max Torque : 113Nm @4500rpm
- Fuel Distribution : MPFI
- ECU : DENSOO 32 Bit

Modification in Aging setup for Two Wheeler Catalyst

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

No of Catalyst to be aged simultaneously : 8 nos.

Hydrothermal Aging Set up



Maximum Oven Temp. : 1300 C

OBD-II Strategy

Emission Norms and OBD-II Emission thresholds for BS-VI

mg/km

Pollutant	BS-6 Norms (DF)	V1 Limit	Typical % Conversion Efficiency Requirement			OBD –II Limit
			WMTC 2.1	WMTC 2.2	WMTC 3.2	
CO	1000 (1.3)	538	80	77	82	1900
NMHC	68 (1.3)	37	96	94	95	250
NOx	60 (1.3)	32	92	96	97	300
Durability km			20000		30000	

BS-4 THC+NOx : 790 mg/km NOx : 390 mg/km

Most Stringent Target : NMHC

OBD

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 1st April 2023
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)	√	√
Catalytic Converter Monitoring	X	√
EGR system Monitoring	√	√
Misfire Detection	X	√
Oxygen Sensor Deterioration	X	√

OBD Simulation on Synthetic Gas Reactor of by measuring OSC

OSC Measurement and simulation on Synthetic Gas Reactor

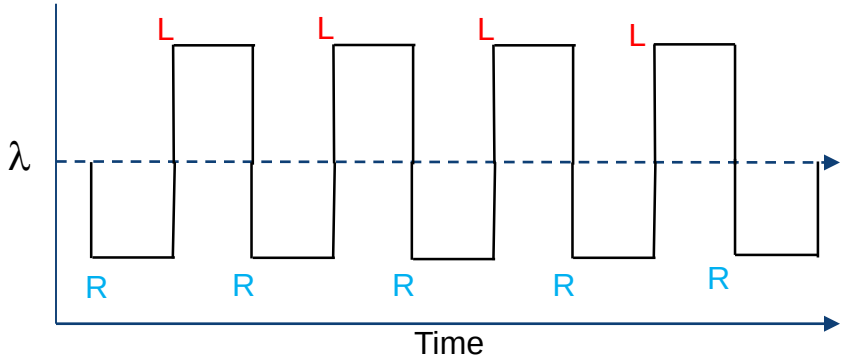
- For OSC assessment on vehicle, procedure followed by some EMS supplier is
  - Deplete stored oxygen in catalyst at Rich A/F
  - Leaning A/F
  - Time delay in pre and post lambda sensor or amplitude corresponding to threshold ME limit

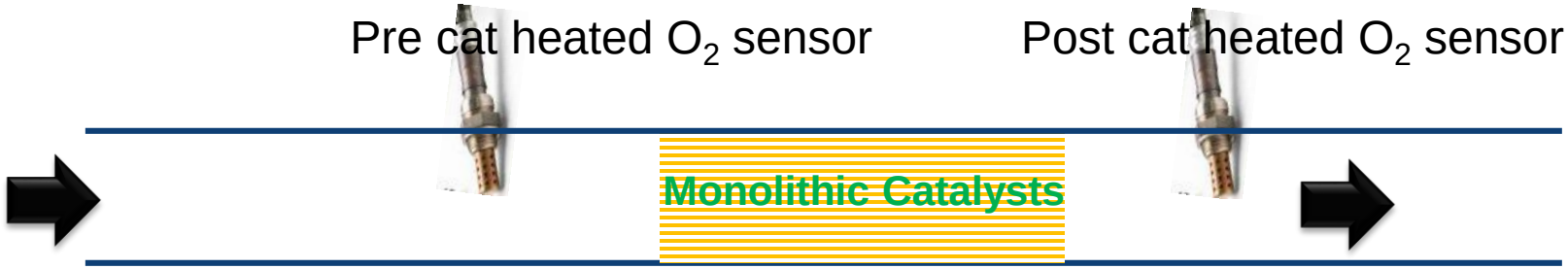
- Same procedure is simulated on Synthetic gas for OBD calibration
- Procedure has been established to quantify OSC by using Broad Band Lambda sensors

OSC measurement on synthetic Gas Rig

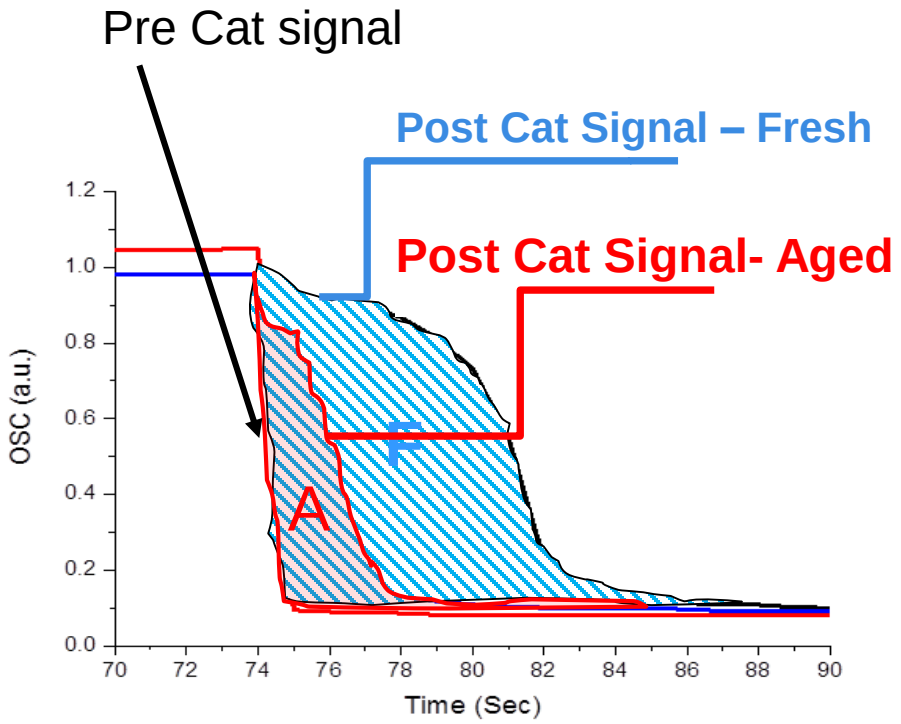
Space Velocity (hr^{-1}) per catalyst: 60k

- Temperature Setting
  - 550 °C
- Cycle Timing 120 sec/120 sec
  - R/L/R/L/R/L/R/L/R/…..
  - Duration: 4.5 cycles; 120sec settling time





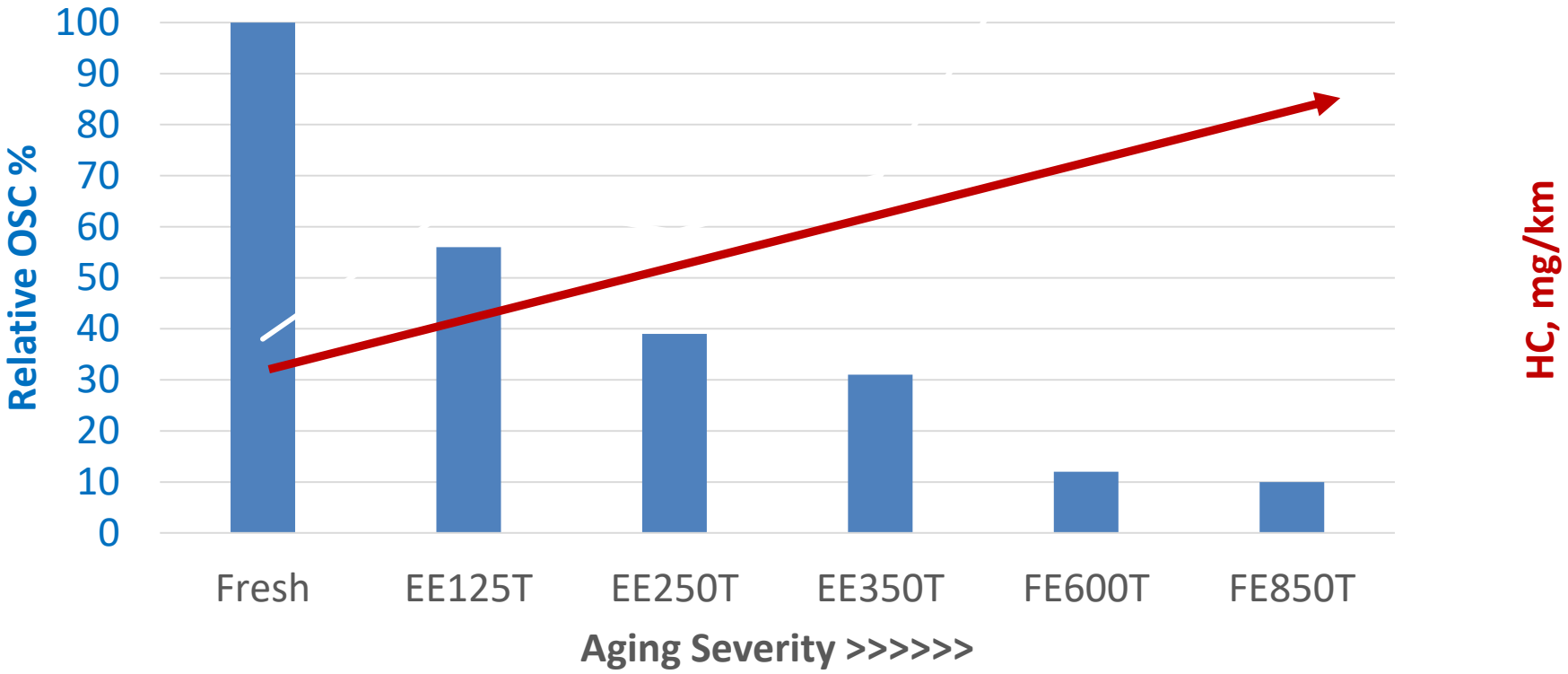
Methodology for OSC Estimation



% age OSC of aged Catalyst w.r.t Fresh

$$\text{OSC } \% = \frac{\textit{Area of Aged Catalyst } (A)}{\textit{Area of Fresh Catalyst } (F)} * 100$$

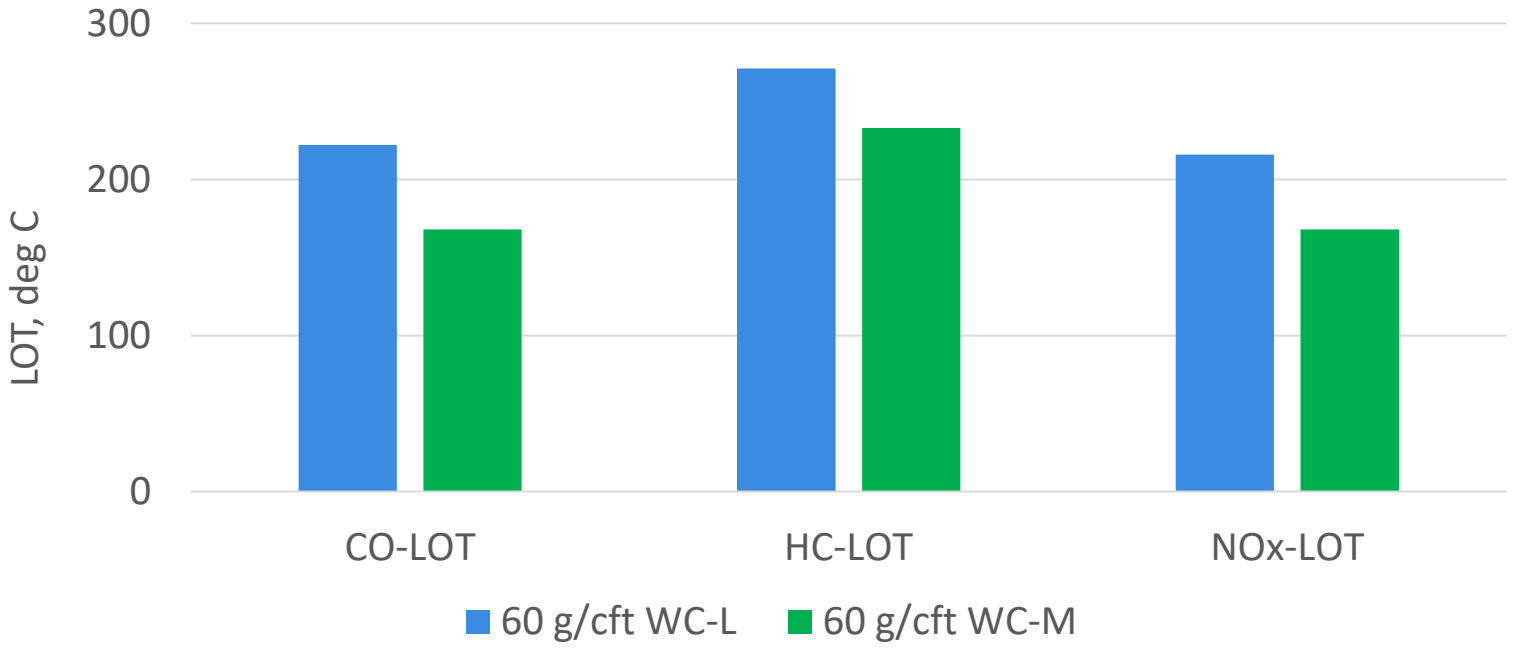
Relationship between HC and OSC – Two wheeler



With increase in Aging severity, OSC drops, resulting in increase in HC emission

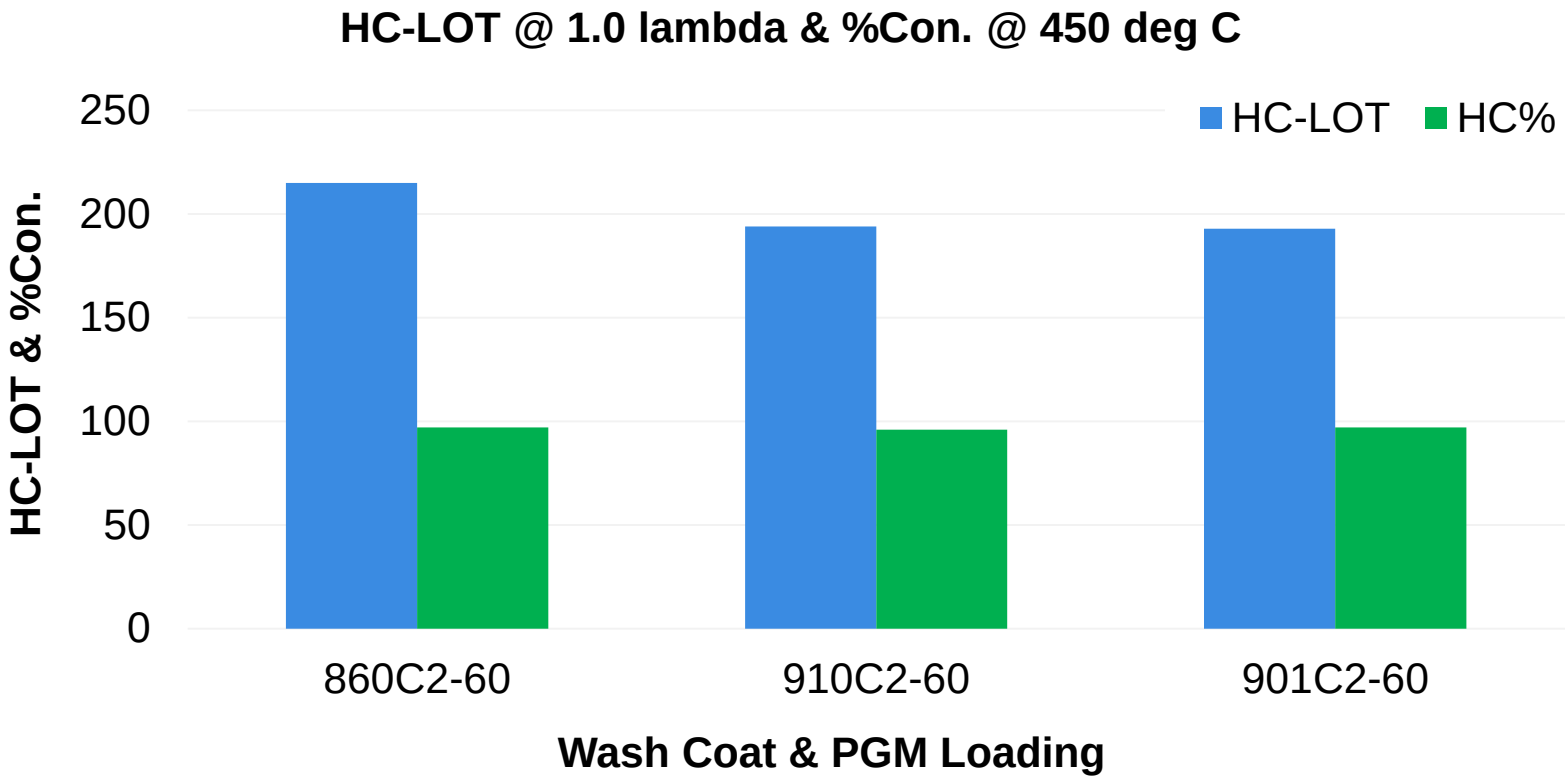
Test Results on BS-VI washcoat Technology

Effect of WC on Light-off @ 0.97 lambda



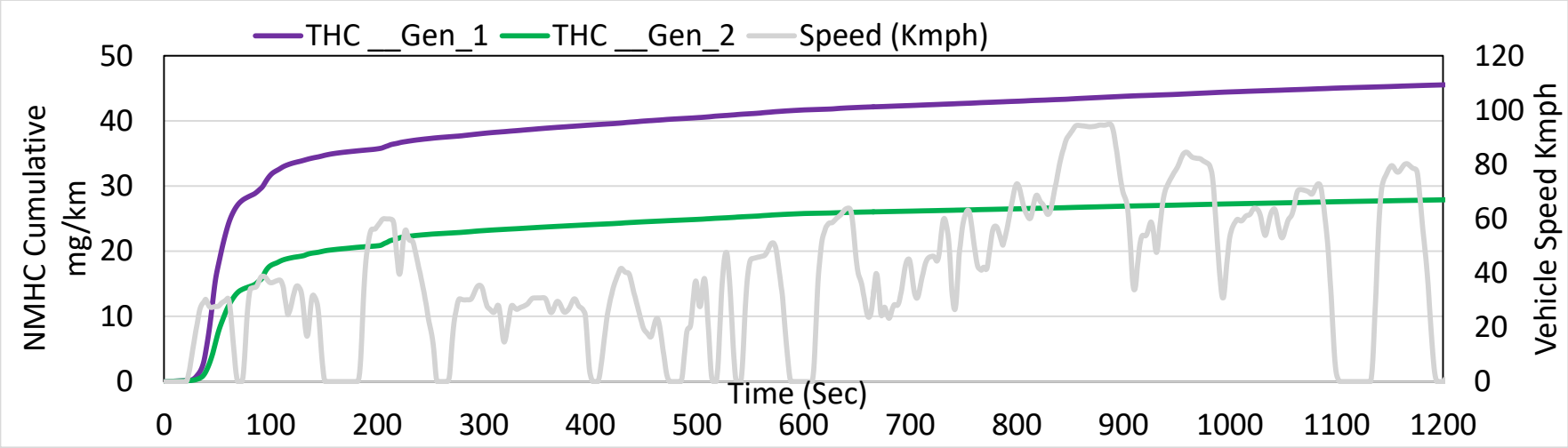
- All catalysts prepared with same PGM ratio
- HC-LOT lowered with change of wash coat chemistry

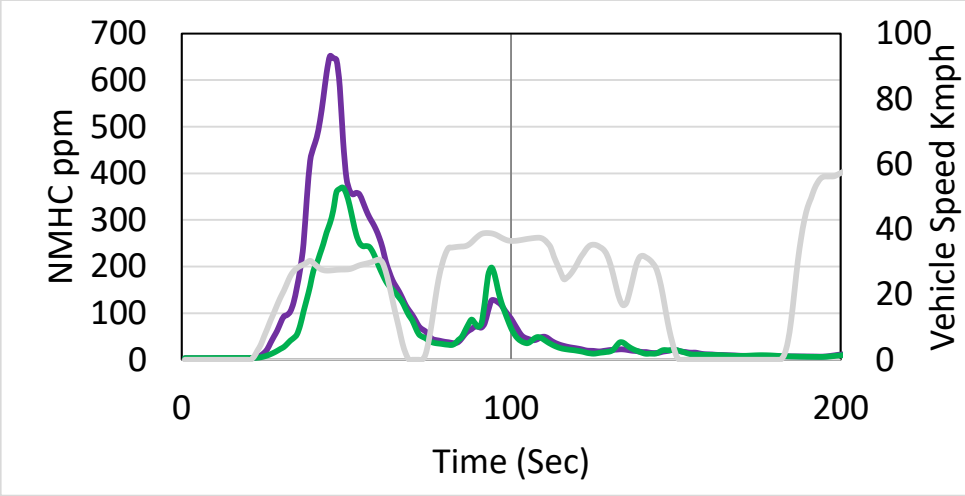
HC-LOT vs WC's @ 1.0 Lambda (GHSV 100,000 1/h)

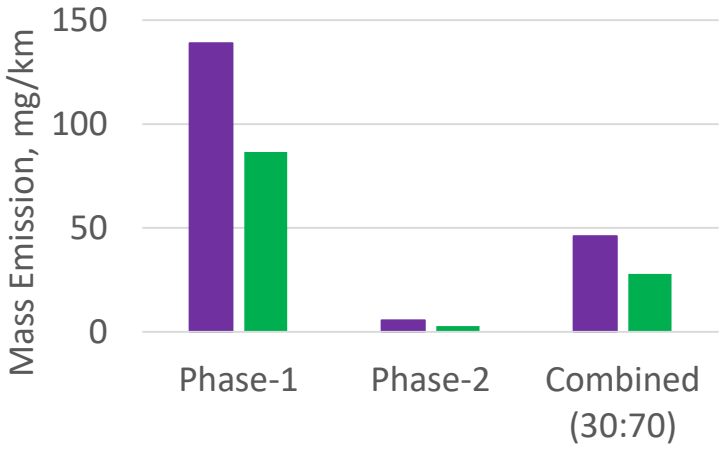


- All pristine samples are loaded with the PGM of 60 g/cft

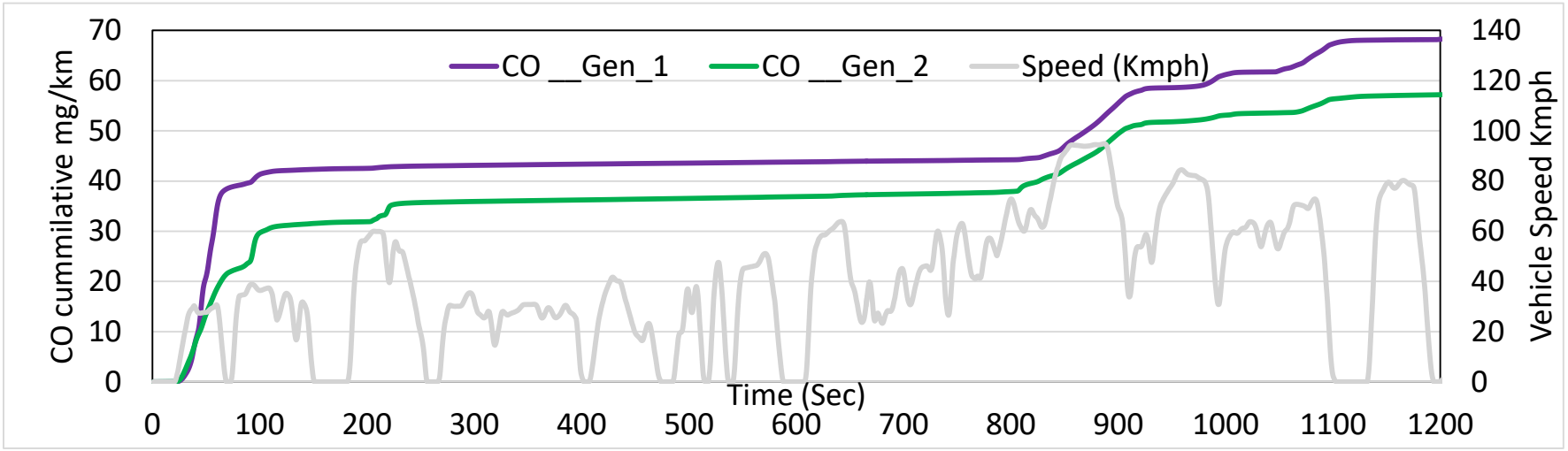
NMHC dilute emission comparison Gen-1 & Gen-2

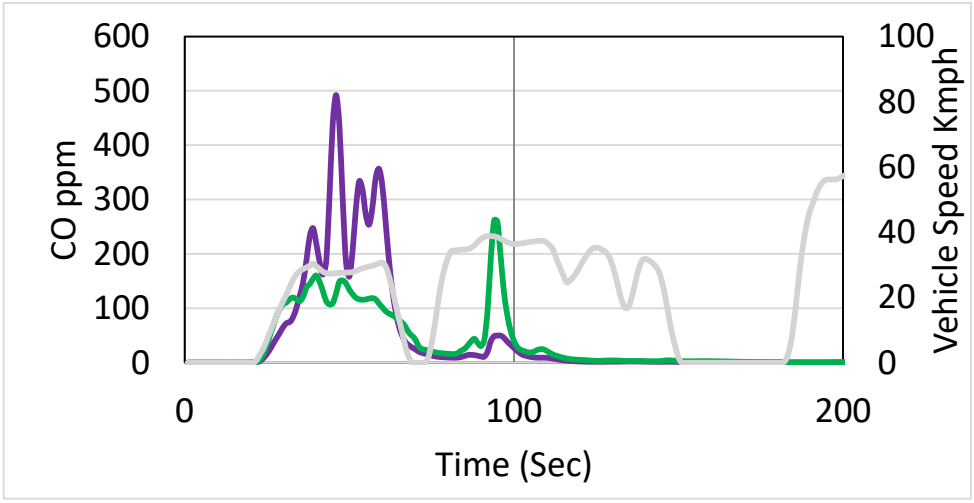


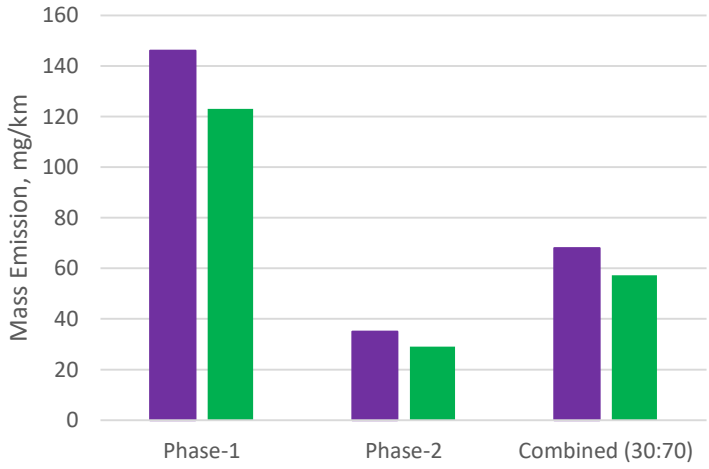




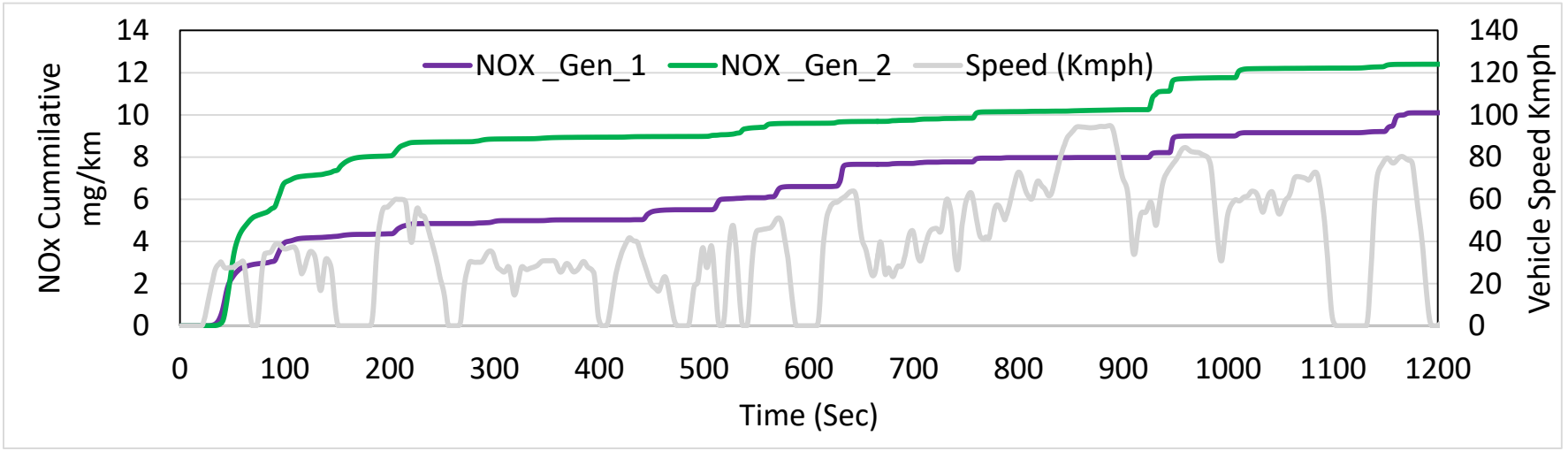
CO dilute emission comparison Gen-1 & Gen-2

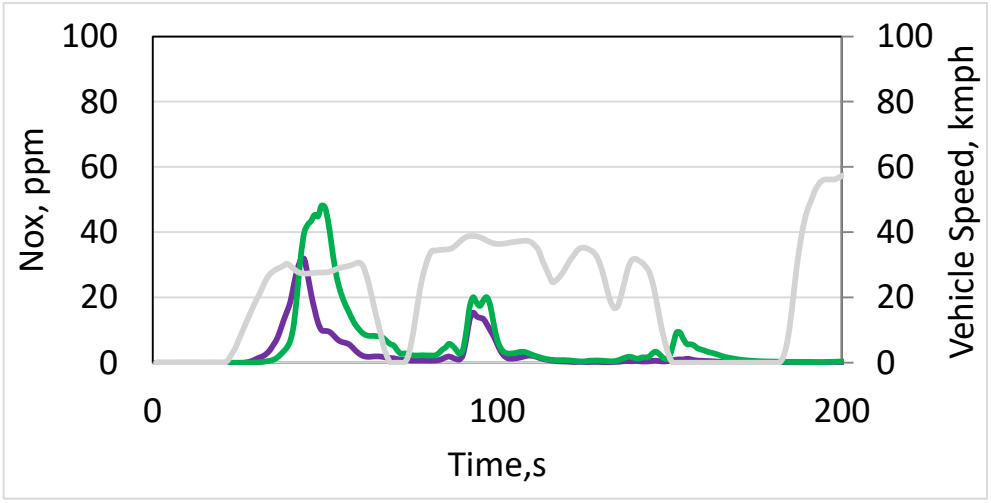


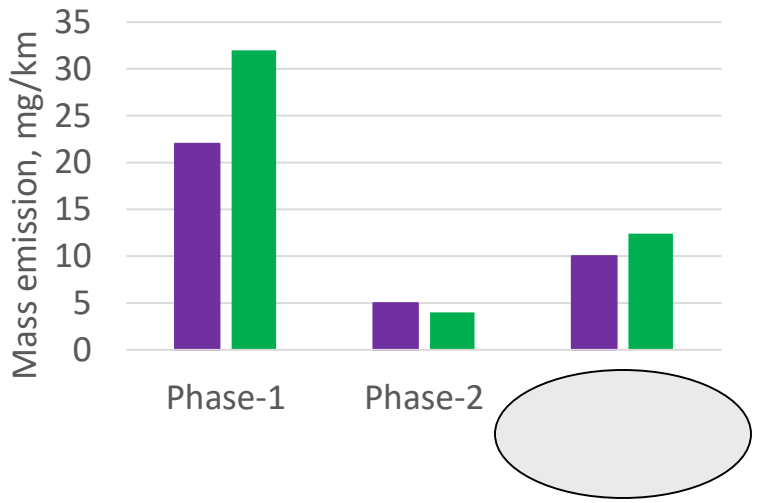




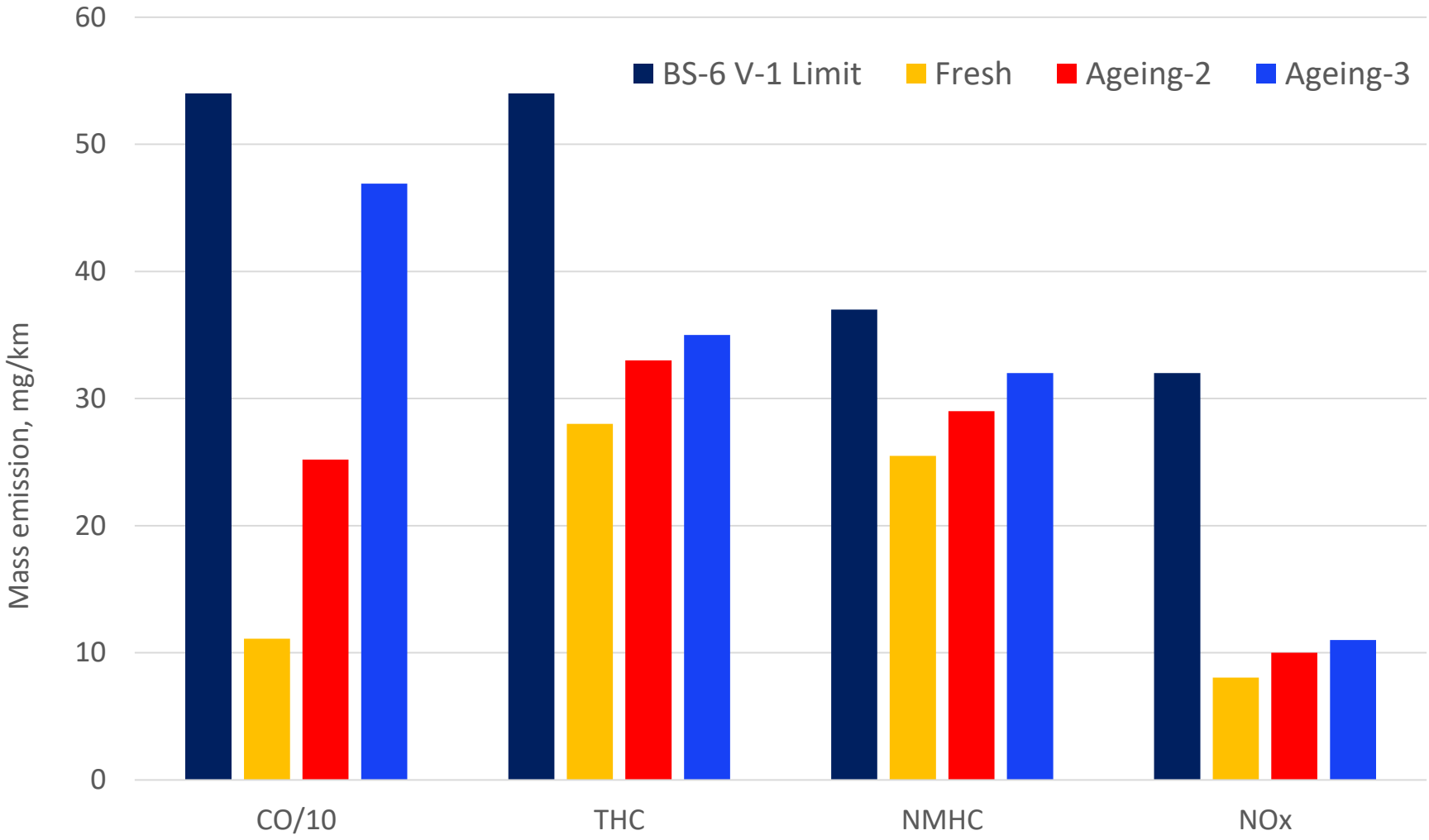
NOx dilute emission comparison Gen-1 & Gen-2







Mass emission performance for Fresh and Aged Catalysts



BS-4 Catalyst aging comparison on Class 2.1 Motorcycle

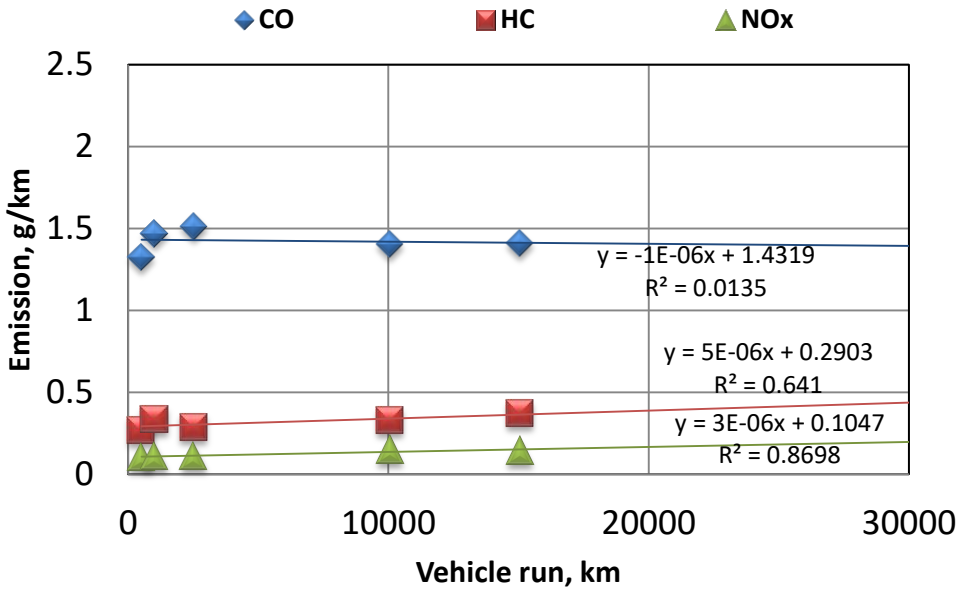
Road Aging

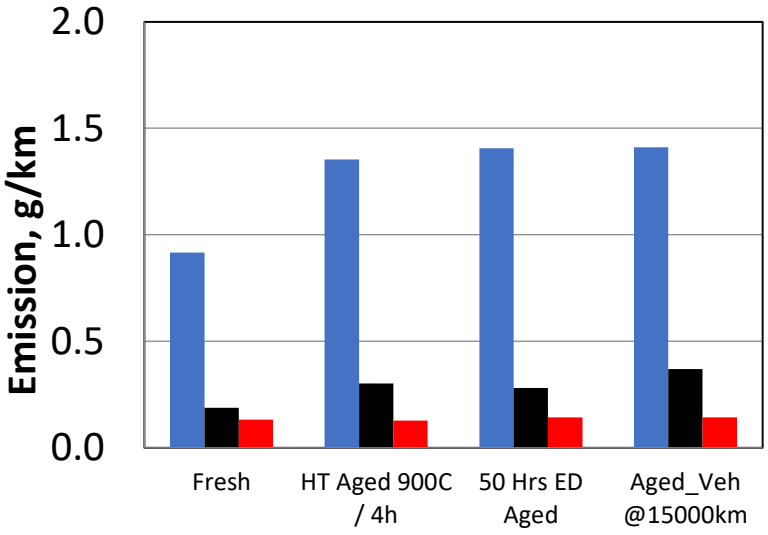
Mass emission tested, kms	Run on Road	Run on Taiwan cycle
510	510	0
1021	1021	0
2513	2513	0
10064	9787	277
15057	13080	1977

HT Aging

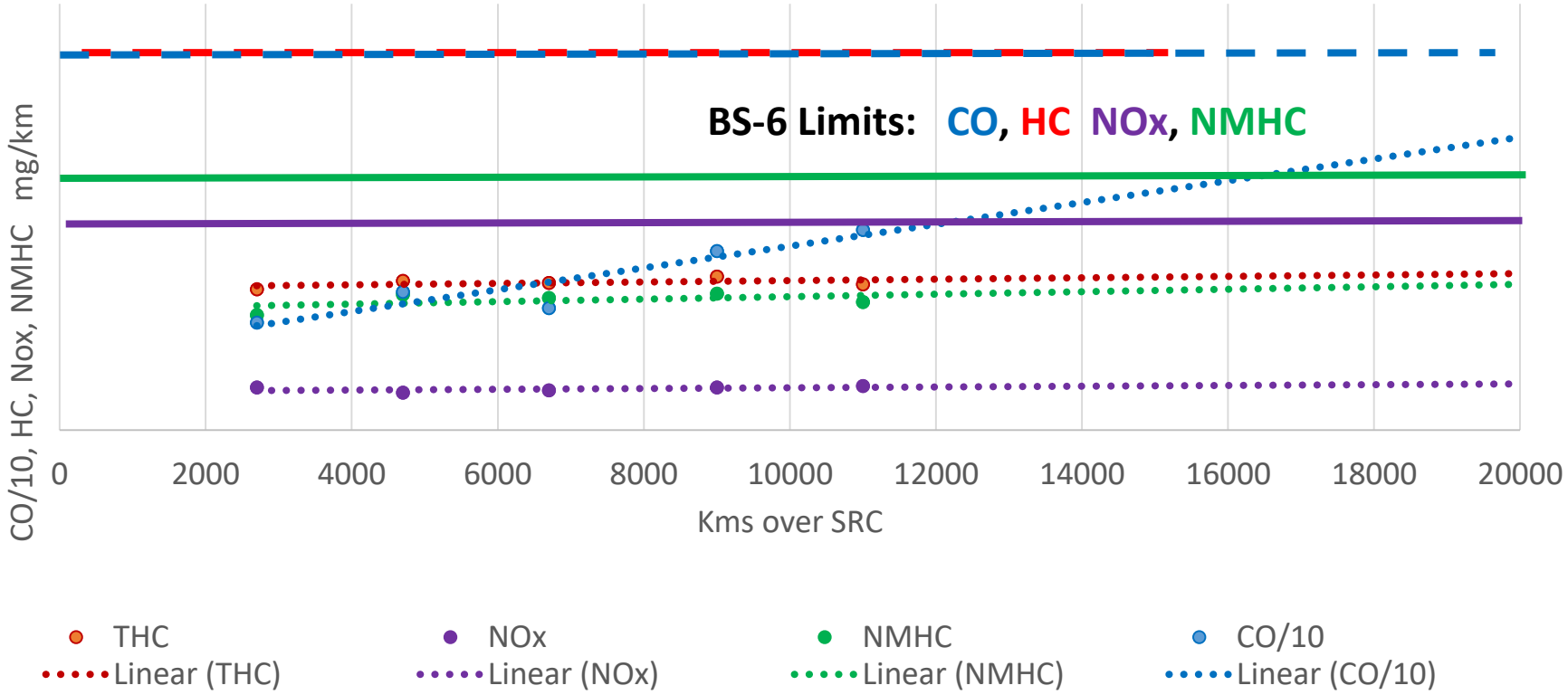
ED Aging Condition

Mode	Condition	Brick Temperature ,Degc	Time, Hr	Avg. Lambda	CO (% Vol)	O2 (% Vol)
1	Stoichiometric	850-870	50	1.014	3.79	1





BS-6 Catalyst Durability of WMTC Class 2.2 Vehicle over SRC



Conclusions

- New Generation low LOT washcoat has met BS-VI engineering Target including durability across various models with different OEM
- SCIL is equipped to perform accelerated catalyst aging on Engine Dynamometer as per the procedure defined in AIS-137 for two wheeler
- Developed methodology to measure OSC of catalyst on Synthetic Gas reactor in a similar manner as followed on vehicle for OBD-II simulation

SCIL is equipped to work closely with OEM's on After treatment system - complying to OBD-II


Thank
you