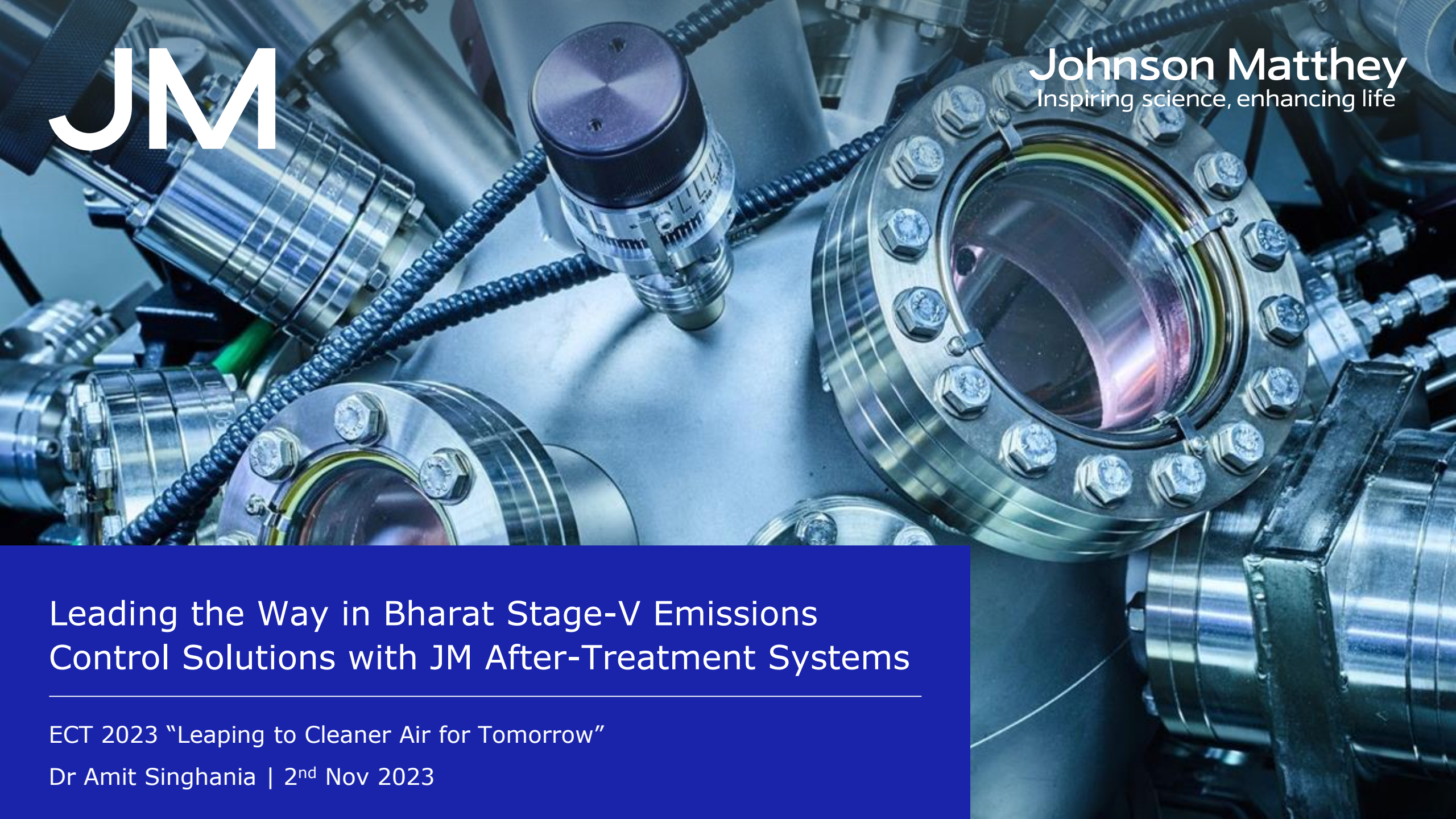

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Inspiring science, enhancing life

Leading the Way in Bharat Stage-V Emissions Control Solutions with JM After-Treatment Systems

ECT 2023 “Leaping to Cleaner Air for Tomorrow”

Dr Amit Singhania | 2nd Nov 2023

Agenda

1 Off-Road Legislation in India

2 Challenges in Bharat Stage V

3 Regeneration Need & Strategies

4 NO Oxidation: Passive DOC

5 JM Capability

6 Summary

https://www.indiatoday.in/auto/latest-auto-news/story

https://timesofindia.indiatimes.com/city/delhi/kids-lives-at-stake-100-mothers-march-to-pms-residence/articleshow/71883129.cms

https://www.goodnewsnetwork.org/diesel-tractors-bulldozers-get-a-clean-up

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Bharat Stage (BS) Norms – Heavy-Duty Off-Road Application

Bharat (CEV/TREM) Stage V - Effective from 1st April 2024

		CO	HC	NOx	PM	PN	Test Cycle
Category, kW	Category, HP		g/kWh			#/kWh	
P < 8	< 10	8.0	7.5 (HC + NOx)		0.4	-	NRSC
8 ≤ P < 19	10 – 25	6.6	7.5 (HC + NOx)		0.4	-	
19 ≤ P < 37	**25 – 50**	**5.0**	**4.7 (HC + NOx)**		**0.015**	**1x10^{12}**	NRSC & NRTC
37 ≤ P < 56	**50 – 75**	**5.0**	**4.7 (HC + NOx)**		**0.015**	**1x10^{12}**	
56 ≤ P < 130	75 – 175	5.0	0.19	0.4	0.015	1x10^{12}	
130 ≤ P < 560	175 – 750	3.5	0.19	0.4	0.015	1x10^{12}	
P > 560	> 750	3.5	0.19	3.5	0.045	-	NRSC

DF - NRSC & NRTC	
CO	1.3
HC	1.3
NOx	1.15
PM	1.05

Durability	
Category, kW	Emission durability period (hours)
≤37 (Constant speed engine)	3000
≤37 (Variable Speed Engine)	5000
>37	8000

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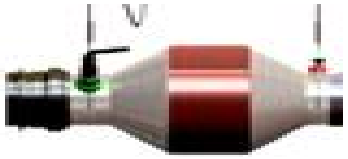
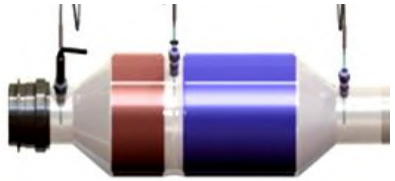
Ministry of Road Transport and Highways, "Notification no. G.S.R. (201) (E) dated 05.03.2018 regarding Emission standards for CEV and Agricultural tractors," May 3, 2018

Emission control solutions

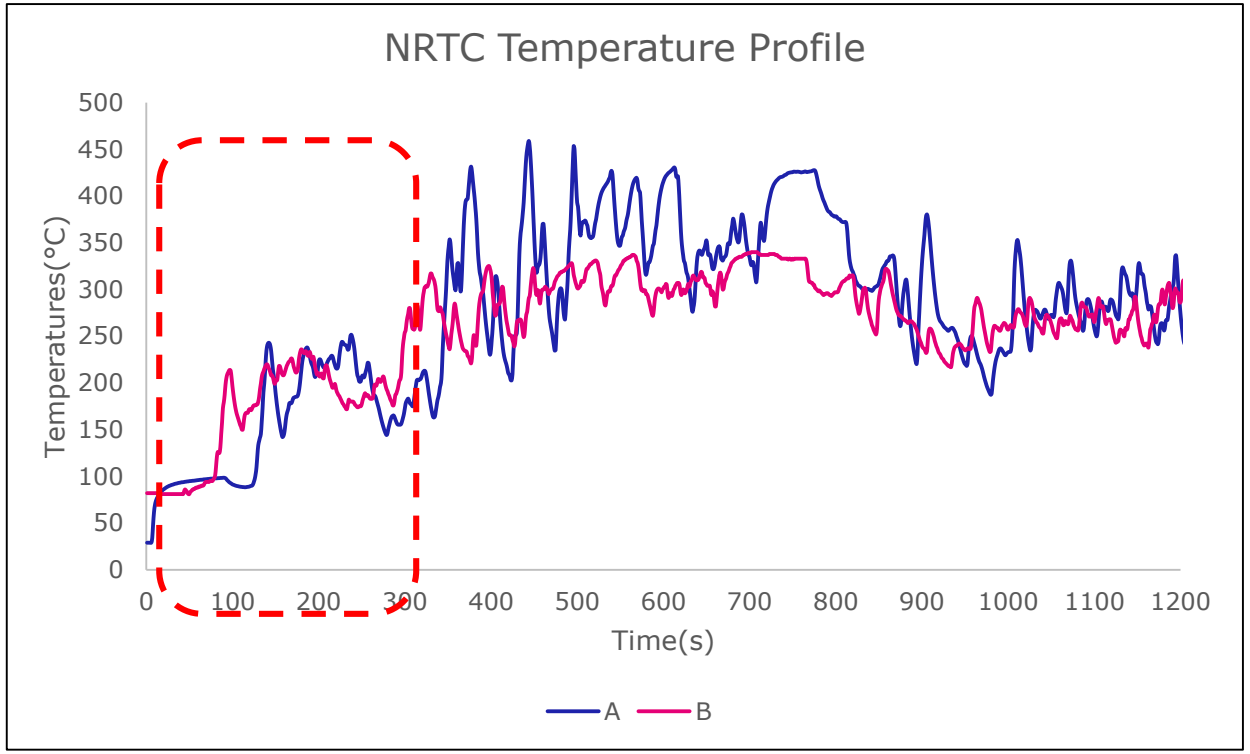
System Architecture – India Off Road Engines

Category kW	Category HP	Bharat Stage V Apr'24
P<19	P<25	DOC 
19≤P<37	25≤P<50	DOC CSF 
37≤P<56	50≤P<75	
56≤P	75≤P	DOC CSF SCR/ASC 

Our Focus in this ECT

Challenges in <56kW

- Tightened limit of PN- Filter required
- Regeneration strategy - complete passive/assisted passive/Active?
- Majority applications, Engine out temperature > 250°C for most of the time. Complete Passive regeneration system is possible?
- CCRT® Design – optimize for volume, PGM loading and distribution to generate sufficient NO_2 & successful passive regeneration.
- Off road market is Cost driven: PGM optimization in terms of end user, Passive Regen systems can provide lower PGM use
- **Durability** of 8000 hours need to be evaluated for passive regen
- Need to understand engines/applications where passive is not possible due to low temperatures, assisted passive or active needed



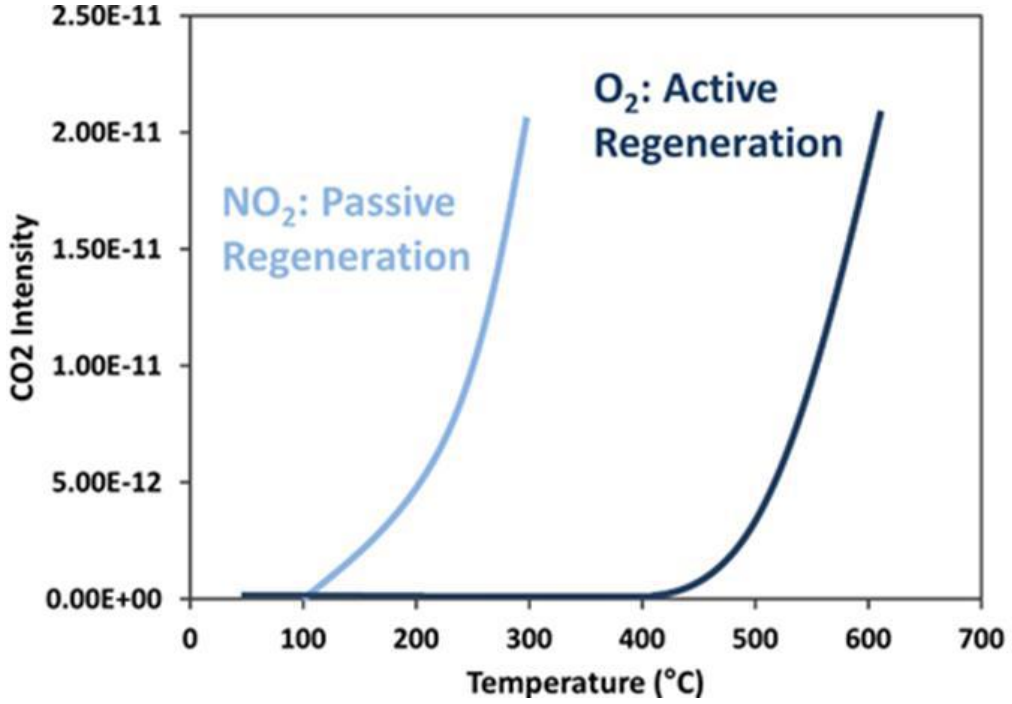
Active Vs Passive Regeneration Strategy

Filter to work effectively:

- Soot that builds up in the filter must be removed since it will cause an unfavourable increase in backpressure.
- This removal must occur during normal vehicle operation.

Methods of soot removal (i.e. Regeneration)

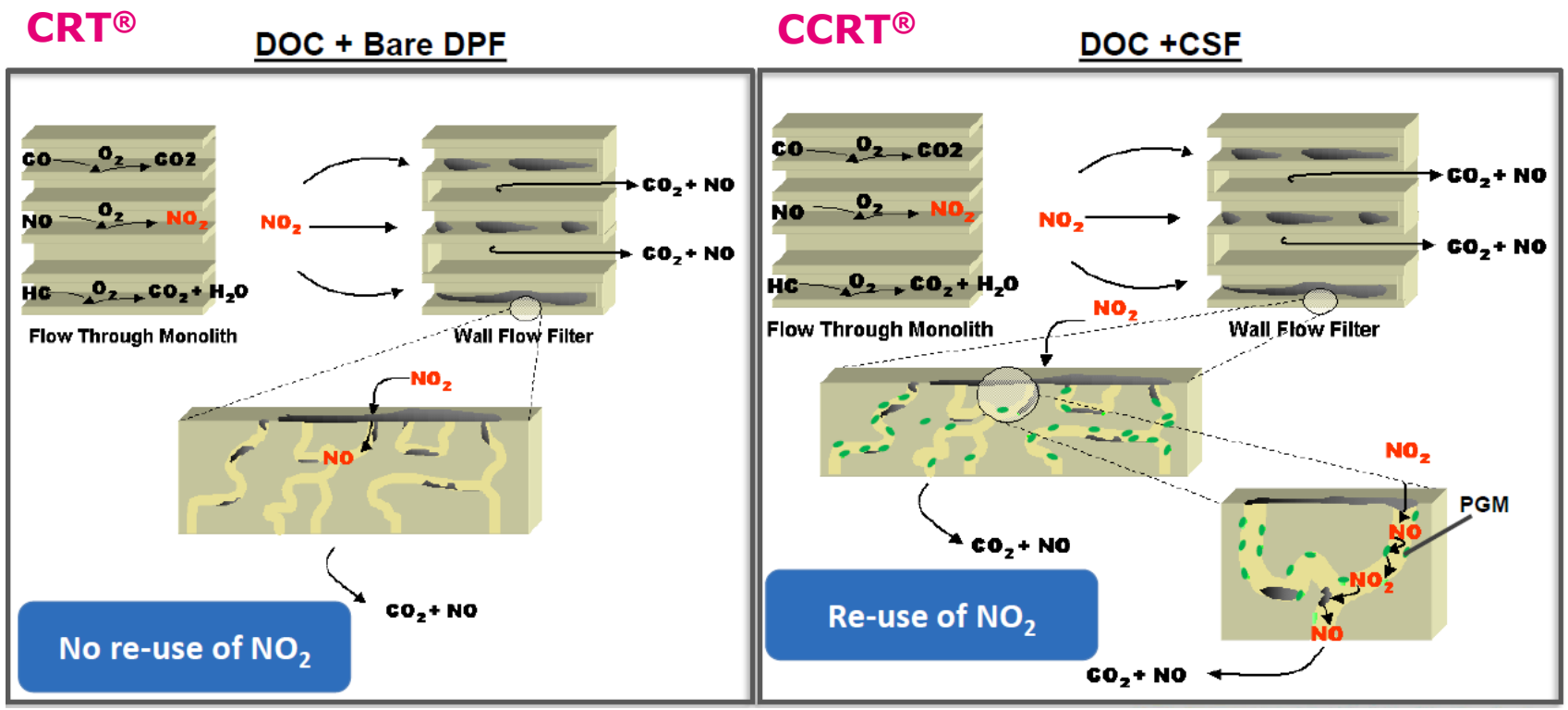
- **<u>Passive regeneration</u>** – This happens without external aid, during normal vehicle operation, NO_2 based soot burn
- **<u>Active regeneration</u>** – Exotherm generated over DOC by burning additional fuel, triggered by system control unit, Oxygen based soot burn



Carbon burn experiment shows greater rate of oxidation to CO_2 using NO_2 rather than O_2, at lower temperatures

CRT® – Continuous Regeneration Trap
CCRT® – Catalyzed Continuous Regeneration Trap

Passive Regeneration: CRT® Vs CCRT®



CCRT® = DOC + Catalyzed Filter

Advantages of CCRT®:

- ✓ Higher soot burn rate than CRT®
- ✓ Low temperature applications (200°C – 250°C)
- ✓ Low NOx/PM applications (NOx/PM>15)

- Within the CRT® system the reaction sequence is:

$NO + ½\ O_2 \longrightarrow NO_2$ (Pt on catalyst)

$2\ NO_2 + C \longrightarrow 2\ NO + CO_2$ (on filter)

- Applying a catalyst coating to the DPF gives the possibility of re-use of NO:

$NO + ½\ O_2 \longrightarrow NO_2$ (Pt on filter)

$2\ NO_2 + C \longrightarrow 2\ NO + CO_2$ (on filter)

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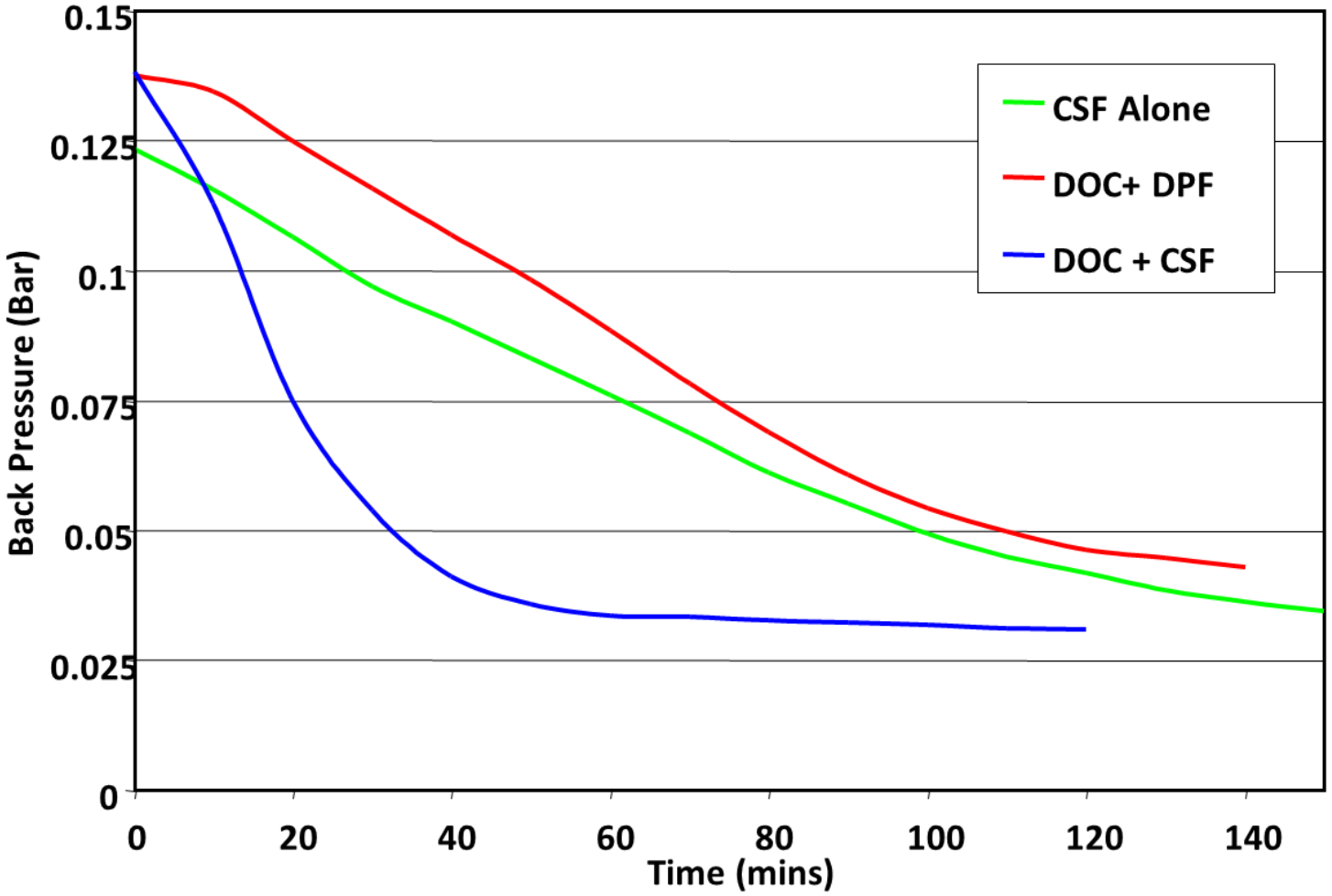
CCRT® system helps in removal of soot in a faster way during elevated temperature exposure

- Soot loaded systems were exposed to 350°C catalyst inlet temperature;
- The change in pressure drop provide an idea about the rate of removal of carbon soot.



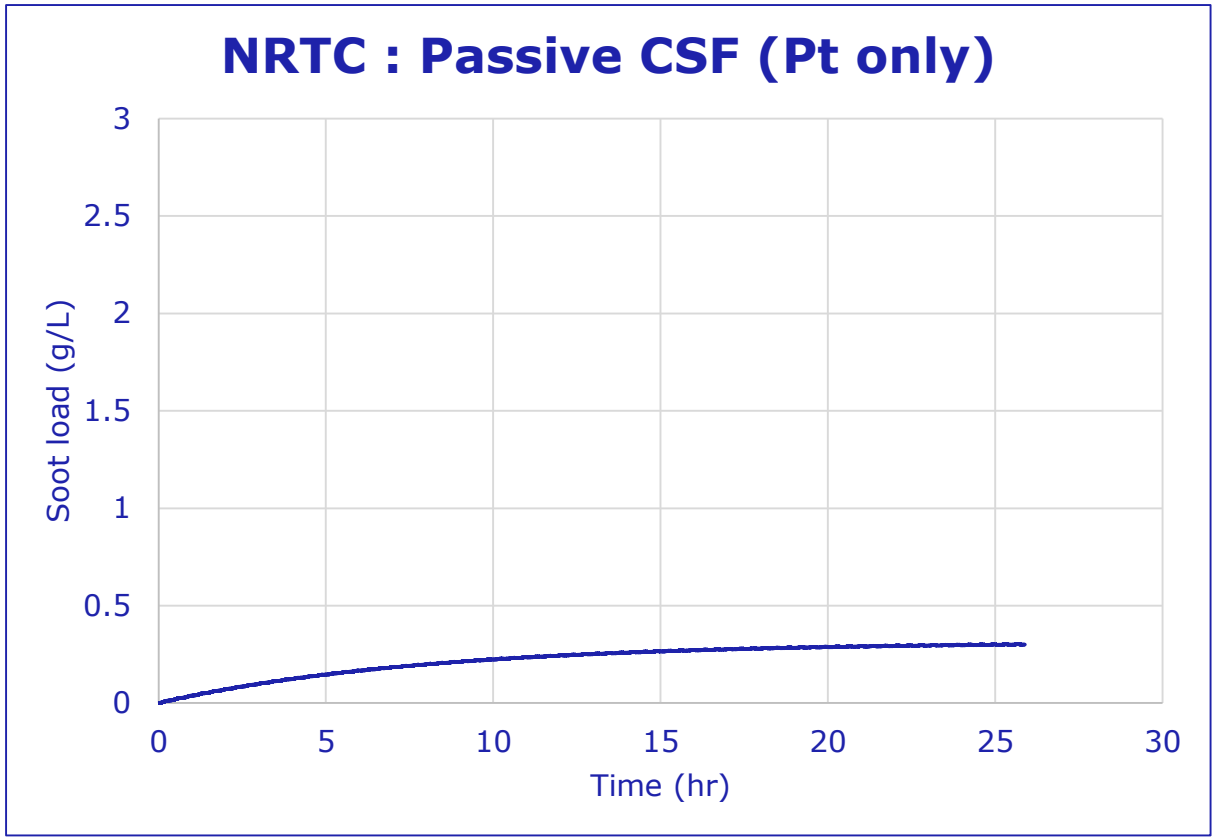
Order of Backpressure:
CCRT® (DOC + CSF) < CRT® (DOC + Bare DOC) < CSF

How Modelling helps!!

- **Balance point soot loading (BPSL):** Rate of soot accumulation is matched by the rate of soot oxidation by NO_2. BPSL is used to measure the effectiveness of passive soot oxidation.

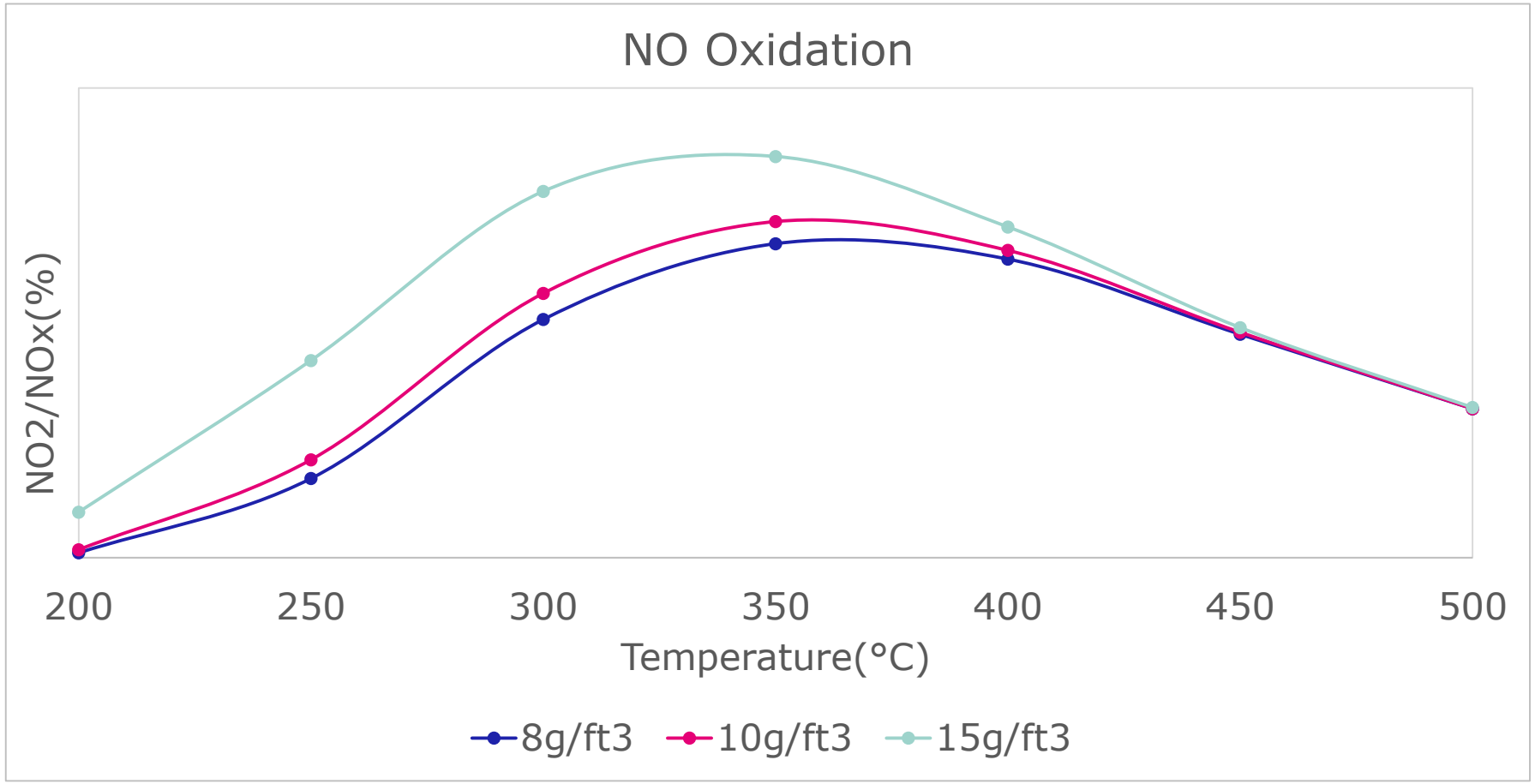
- DPF takes longer time to reach the balance point and evolution of soot loading for DPF subjected to repeated transient drive cycle. Determining BPSL experimentally is extremely time consuming.

- One dimensional mathematical model used to determine BPSL for passive soot oxidation. This results in **significant time, cost and resource saving.**



NO Oxidation: Passive Pt only DOC

Conditioning: 550°C/4hrs-Hydrothermal ageing



JM Capability

- JM has an advantage of better technology of passive and active systems for Bharat Stage V.
- In-house Simulation Capability- Models available for DOC, CSF, SCR & ASC.
- Analytical Testing-Specific Surface Area Analyzer, XRF, ICP, ATR
- SCAT Testing & Oven Ageing Facility
- Less sample turn-around time Coating facility in India – Time Saving and Cost Saving.
- Post-Mortem Analysis locally in short lead time
- Optimized Technical Solutions: **H_2-ICE, H_2-Fuel Cells, Euro7, off-road, Genset**

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Catalysing the transition to net zero with our customers

Summary

- Depending on the circumstances surrounding engine outage and the regeneration strategy/possibilities, both active and passive systems have a potential to achieve Bharat Stage-V emission targets.
- JM is a comprehensive solution provider of for both passive and active systems.
- **JM prefers CCRT® system to meet Bharat TREM-V for < 56kW as compared to CRT®.**
  - CCRT® system allows a more efficient use of the emitted for carbon combustion.
  - Order of Backpressure: CCRT® (DOC + CSF) < CRT® (DOC + Bare DPF) < CSF
  - Superior performance as compared to CRT® and CSF only system even at low CSF metal loadings, especially for
    - Low temperature applications
    - Application with a low NOx/PM ratio
- For low temperature duty cycle assisted passive/ active systems are preferred.
- **All the JM technologies are validated and well proven for Bharat Stage-V.**

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Thank you