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UnICEG

Investigation and Analysis of Ageing Mechanisms for Automotive Catalysts

UnICEG – Emissions, Aftertreatment and RDE

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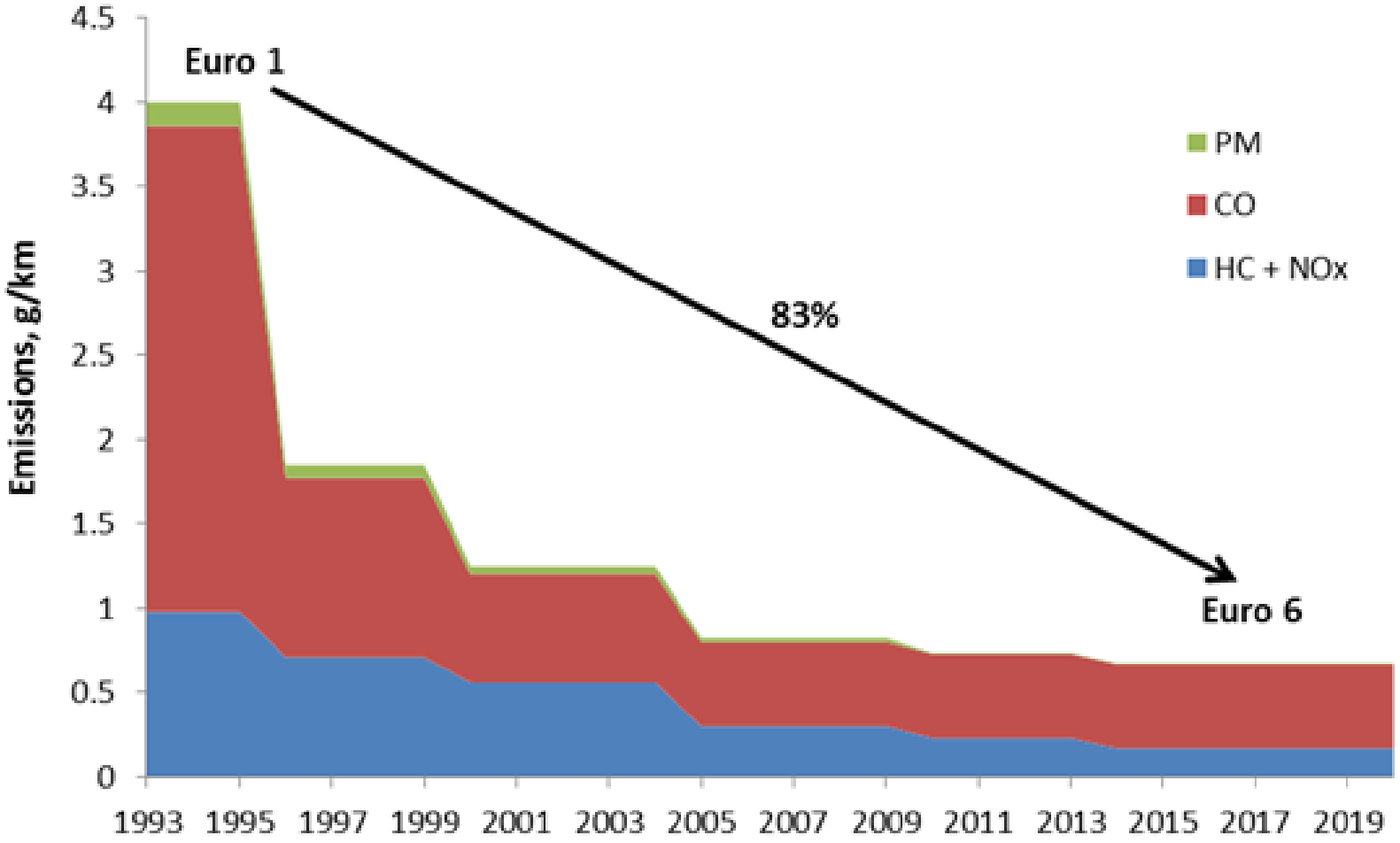
Background/Issues faced



Implats - http://www.implats.co.za/implats/Emission-standards.asp

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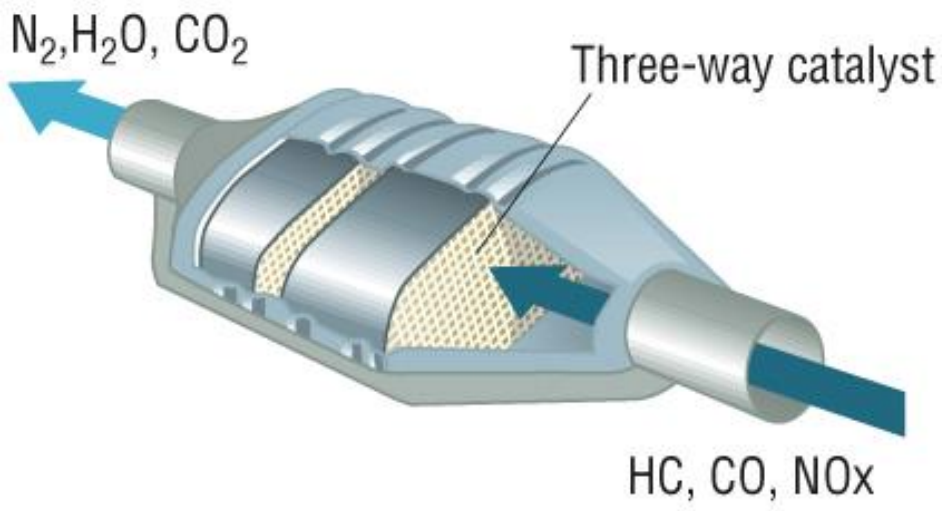
Project Aims & Objectives

- Developing a greater understanding of catalyst deactivation and ageing.
- Compare catalyst performance before and after ageing.
- Concentrating on the effects of oxygen on catalyst ageing.
- Ability to predict a change in dispersion of precious metals applying the kinetic model.
- Algorithms will be further developed to aid prediction of catalyst ageing.



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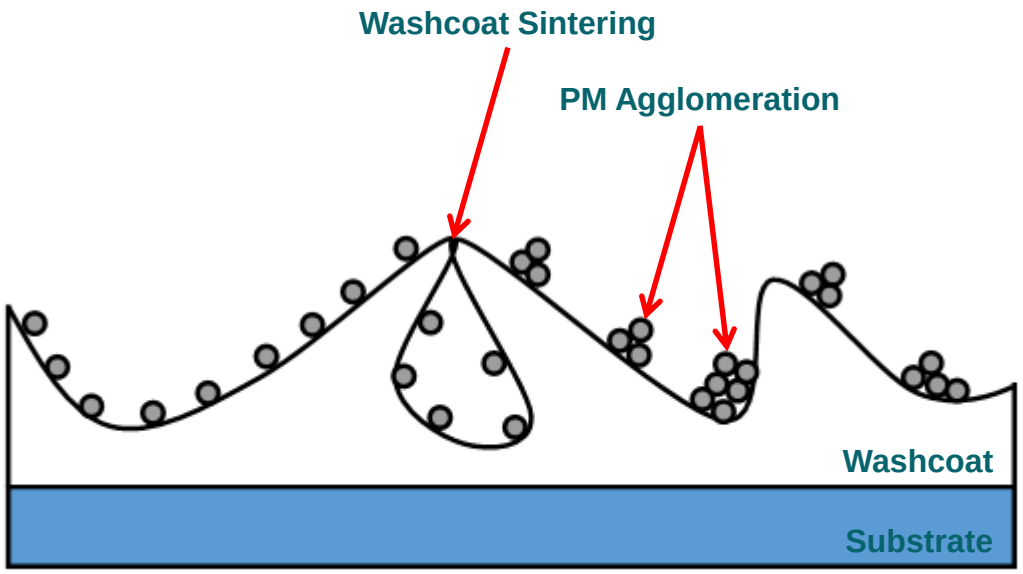
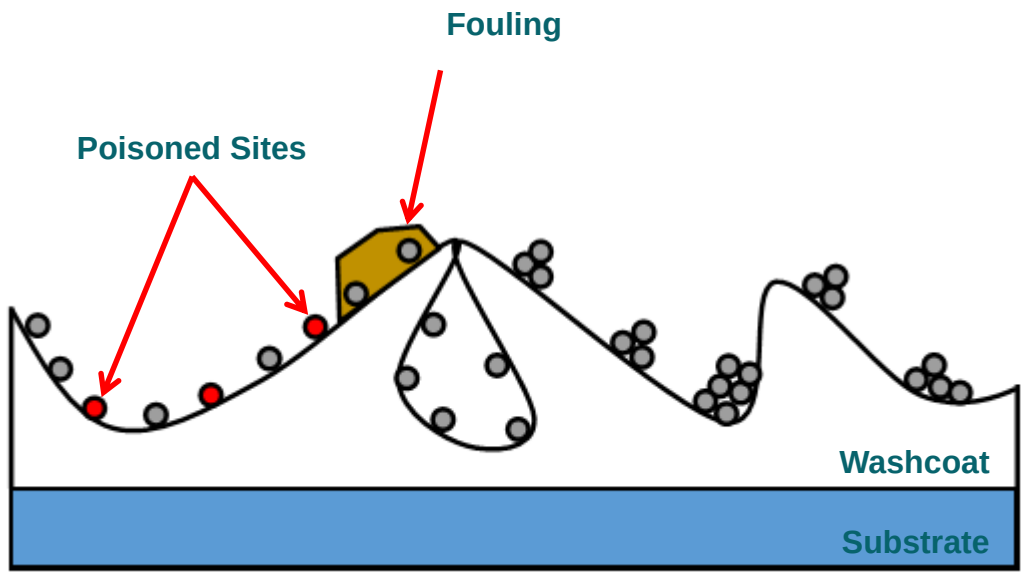
Catalyst Ageing

- **Thermal Deactivation**
  - Washcoat sintering/Phase changes
  - Precious metal agglomeration
- **Poisoning**
  - Selective
  - Fouling
- **Mechanical**





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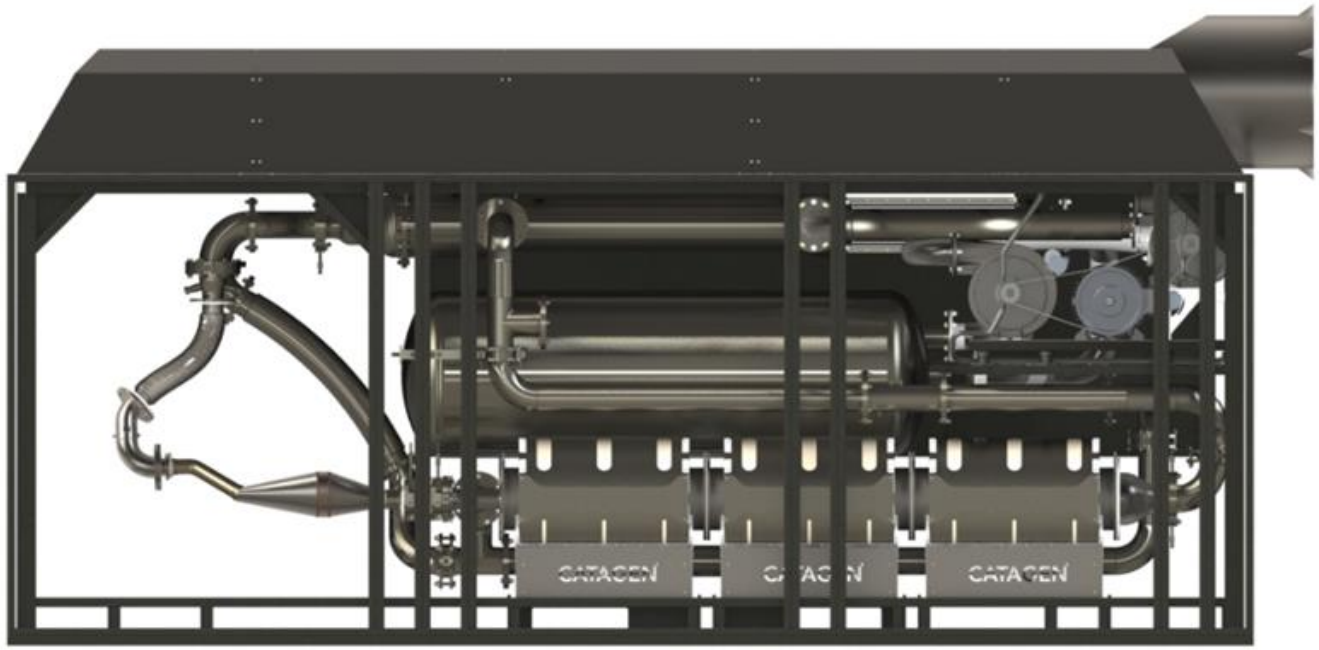
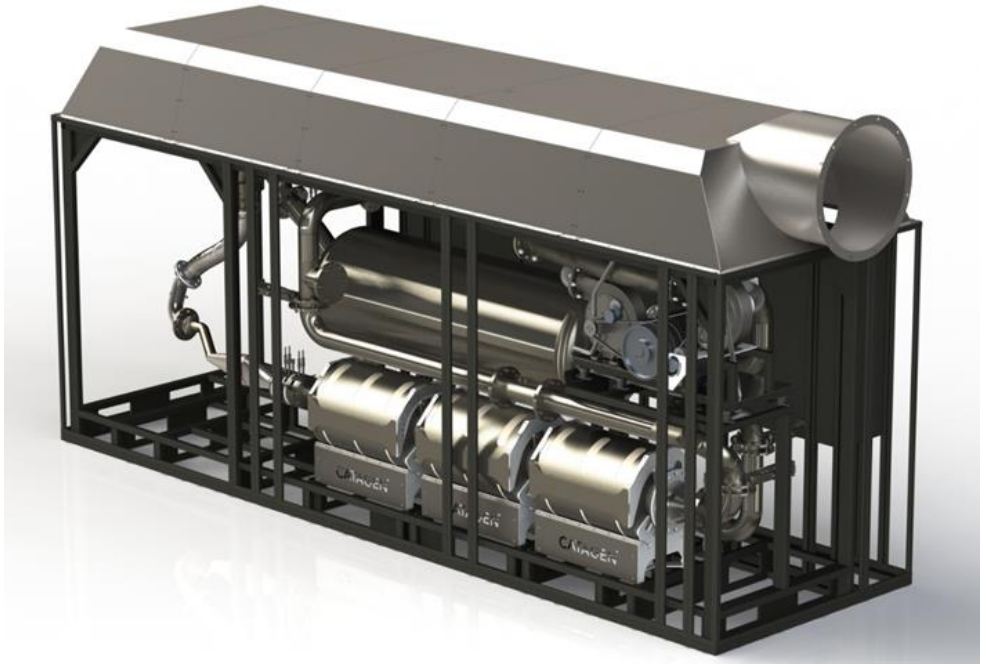
Testing Apparatus





- Temperature control up to 1100°C
- Flow rates up to 100 g/s
- Industry standard emissions measurement
- Transient flow conditions (0 - 50 g/s in 6 seconds)
- Transient temperature conditions (0 - 800°C in 8 seconds)

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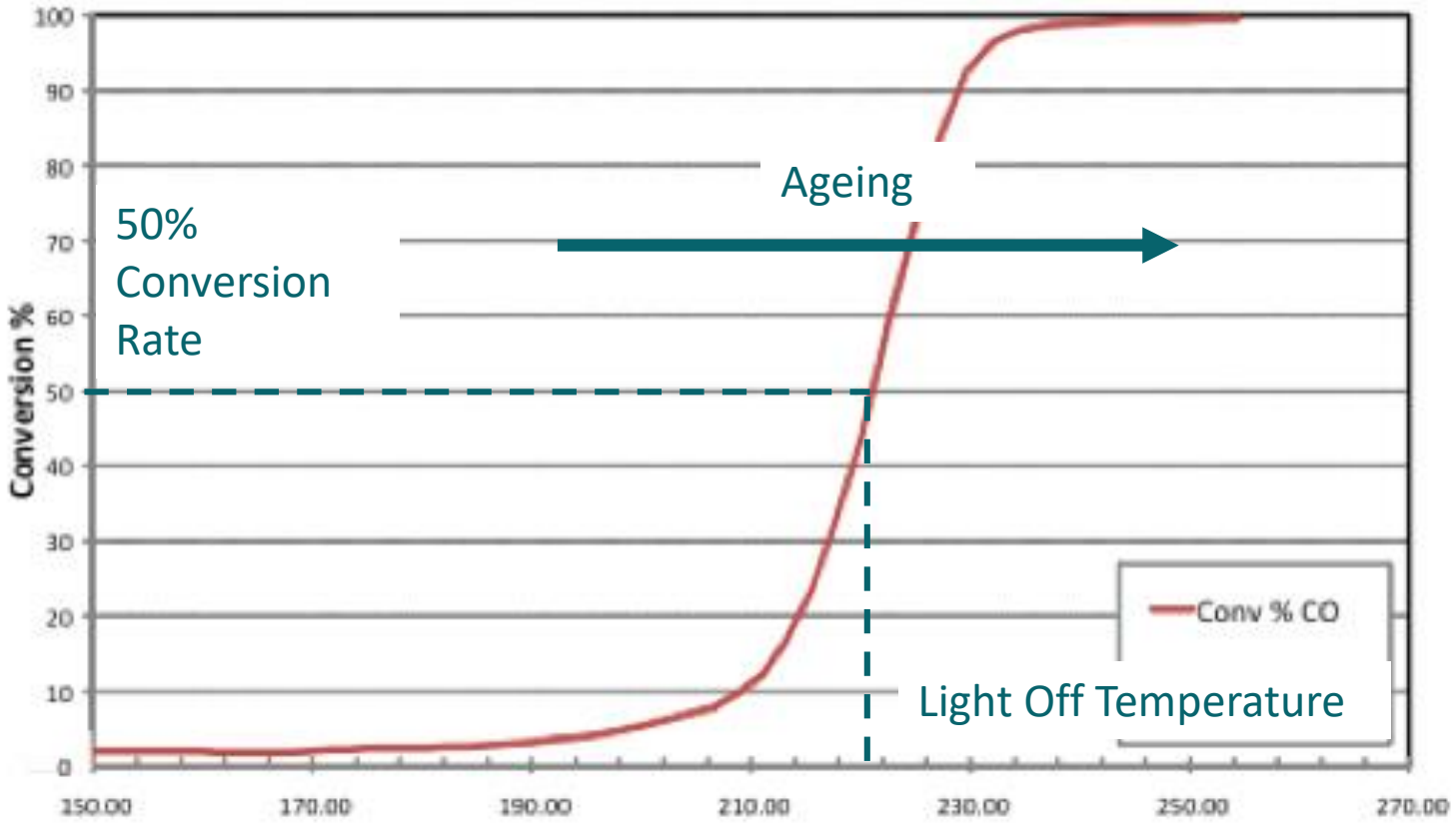
Typical Characterisation Method – Light Off Test



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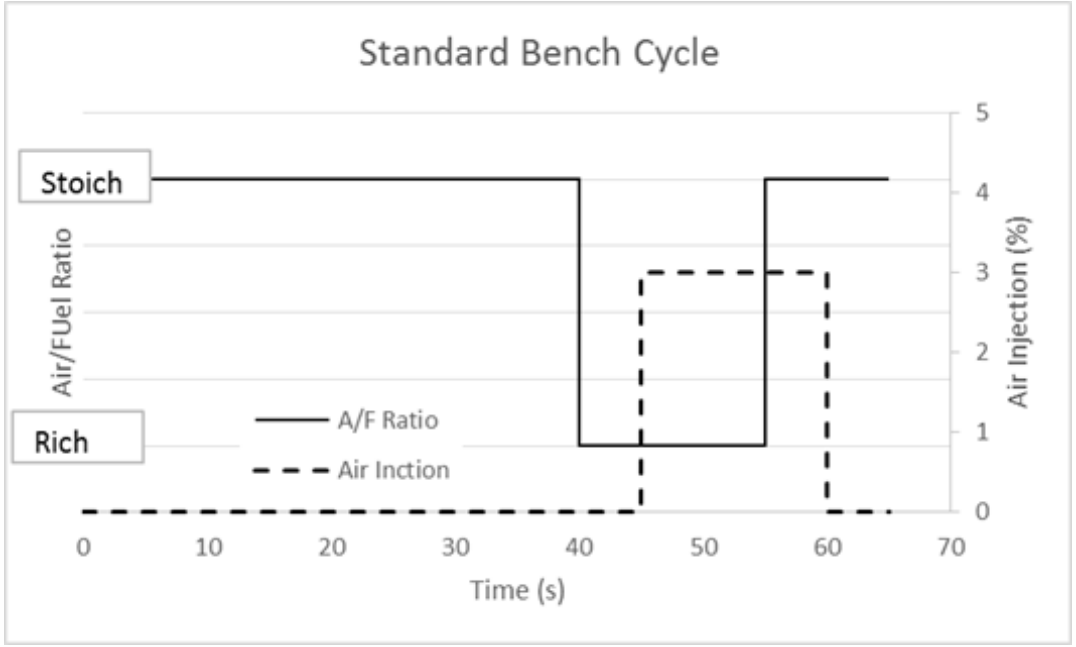
Ageing Environment

- **Standard Bench Cycle (SBC)**
  - Four distinct steps over 60 seconds
    - Stoichiometric – 40s
    - Rich – 5s
    - Rich with air injection – 10 s
    - Stoichiometric with air injection – 10s



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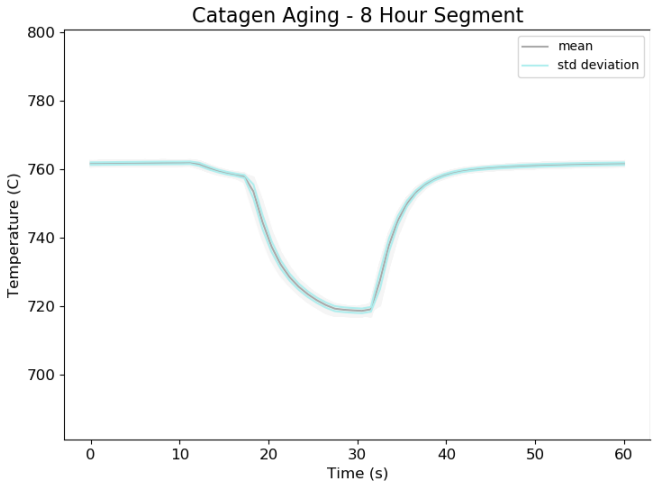
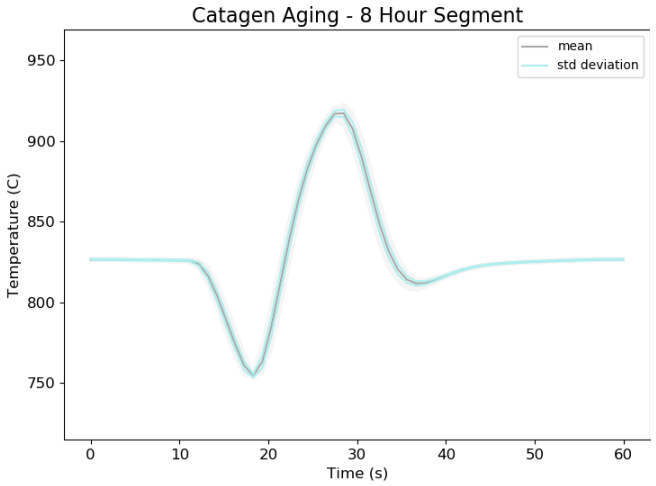
SBC Typical Profiles

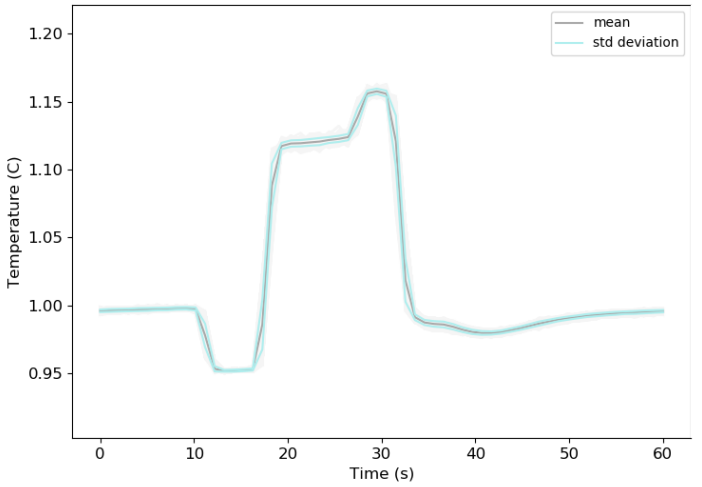
Inlet Temperature Profiles

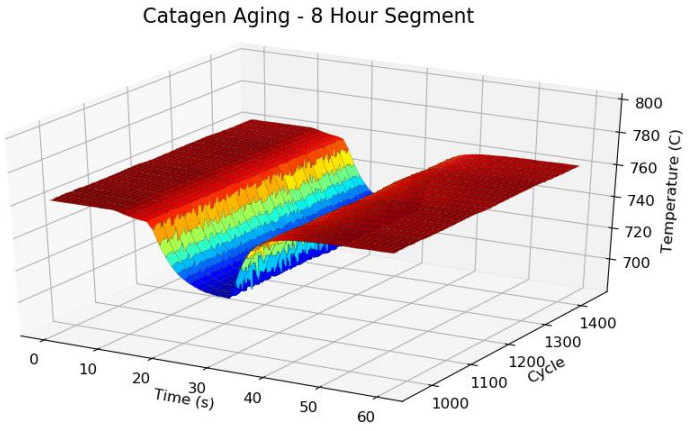


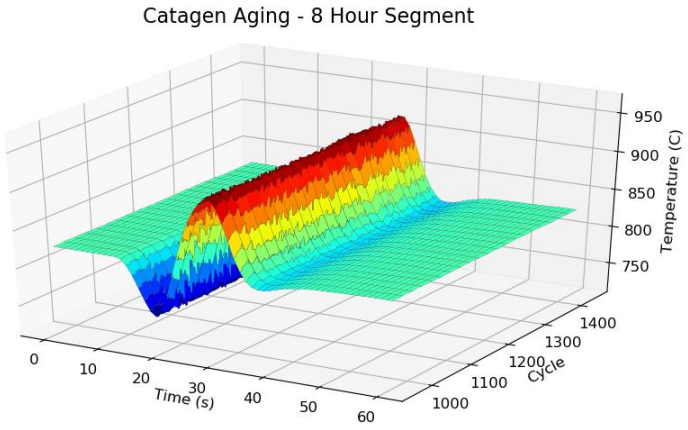
Bed Temperature Profiles

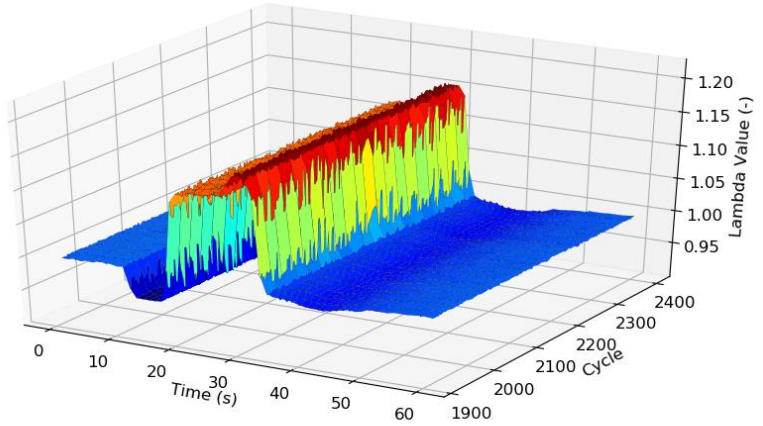


Lambda Temperature Profiles









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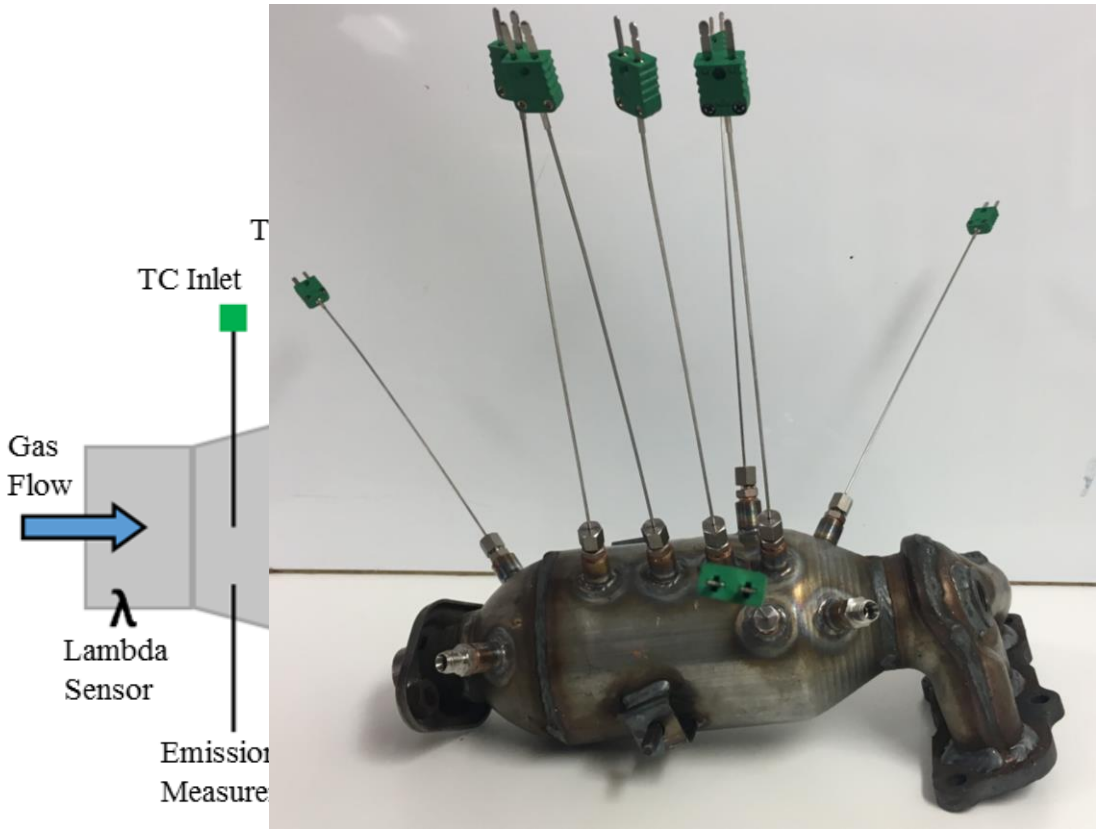
Effect of Oxygen on Catalyst Performance

- **10 catalyst samples**
  - Range of different oxygen concentrations
  - Aged up to the equivalent of 100,000 miles
  - Controlled to 800°C average bed temperature
  - Flow rate of 25 g/s

	Average Oxygen Concentration (%)
Catalyst 0.5%	0.5
Catalyst 0%	0
Catalyst 0.75%	0.75
Catalyst 1%	1
Catalyst 1.5%	1.5
Catalyst 5%	5
Catalyst 0.5% 25K	0.5 (0-25k Miles)
Catalyst Fresh	Fresh



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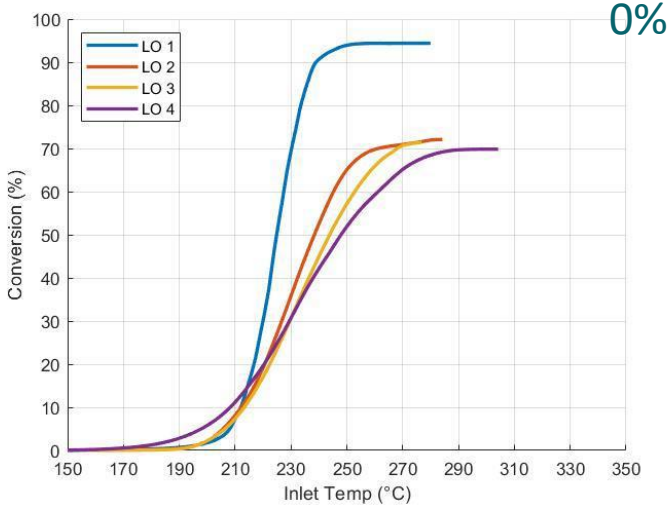
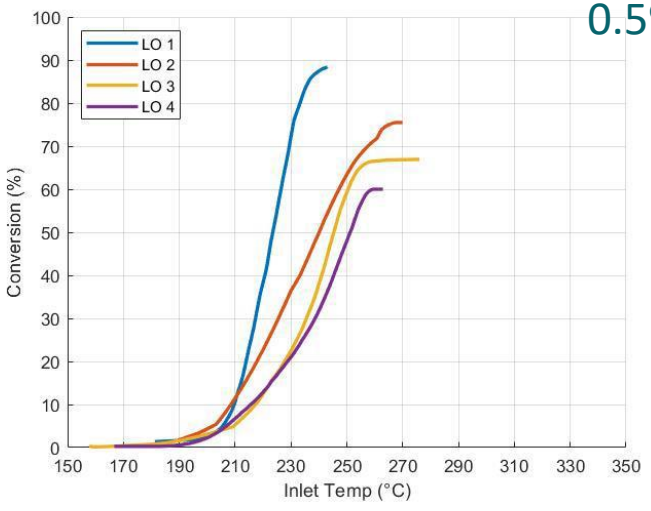
Results - Light-Off Curves

Full-scale light-off tests and results completed on the OMEGA reactor.

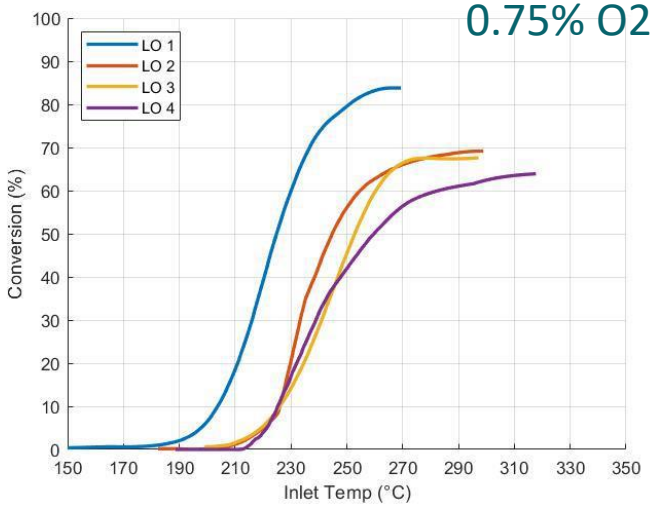
0% O2



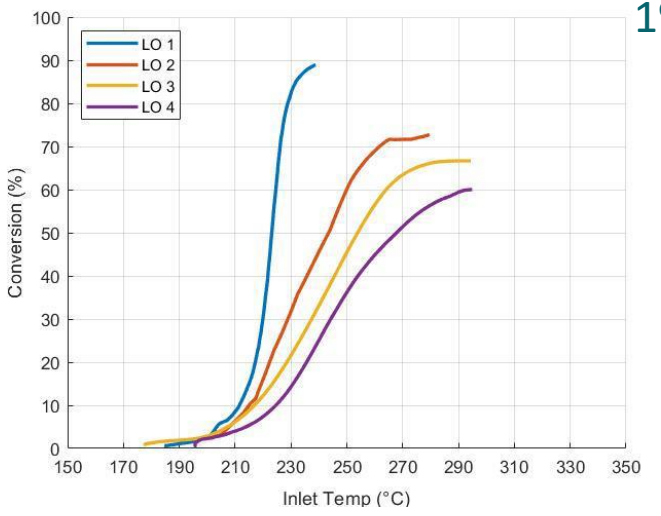
0.5% O2



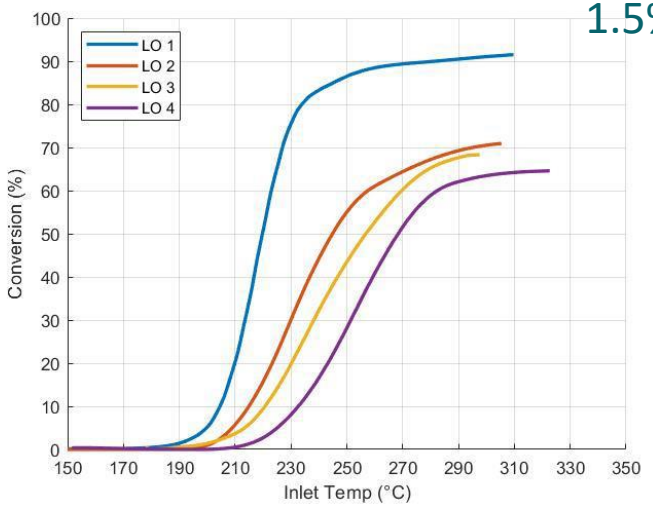
0.75% O2



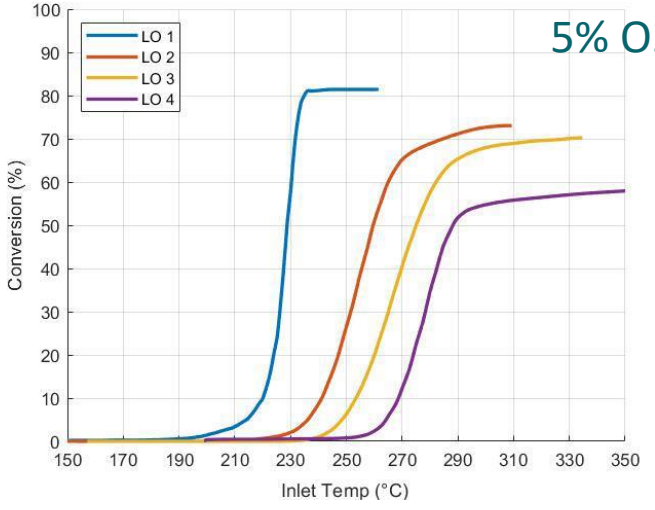
1% O2



1.5% O2



5% O2



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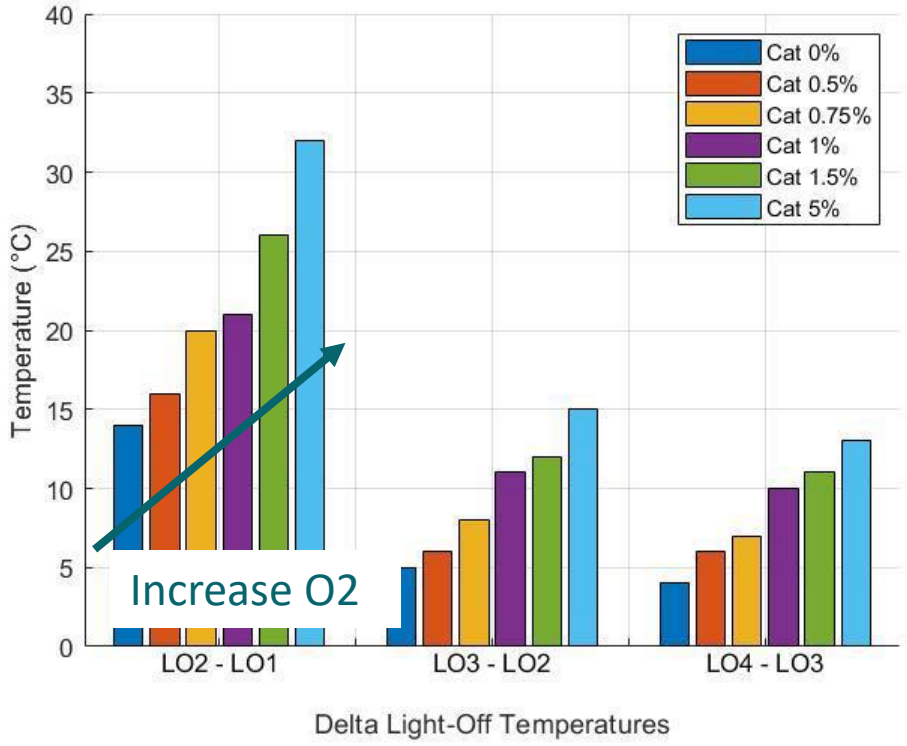
Results - Light-Off Temperatures

Full-scale light-off differences throughout the ageing.

	Ageing Distance (Equivalent Miles)			
Catalyst Sample	0	25,000	50,000	100,000
Catalyst 0% LO Temperature (°C)	225	239	244	248
Catalyst 0.5% LO Temperature (°C)	224	240	246	252
Catalyst 0.75% LO Temperature (°C)	225	245	253	260
Catalyst 1% LO Temperature (°C)	223	244	255	265
Catalyst 1.5% LO Temperature (°C)	219	245	257	268
Catalyst 5% LO Temperature (°C)	228	260	275	288



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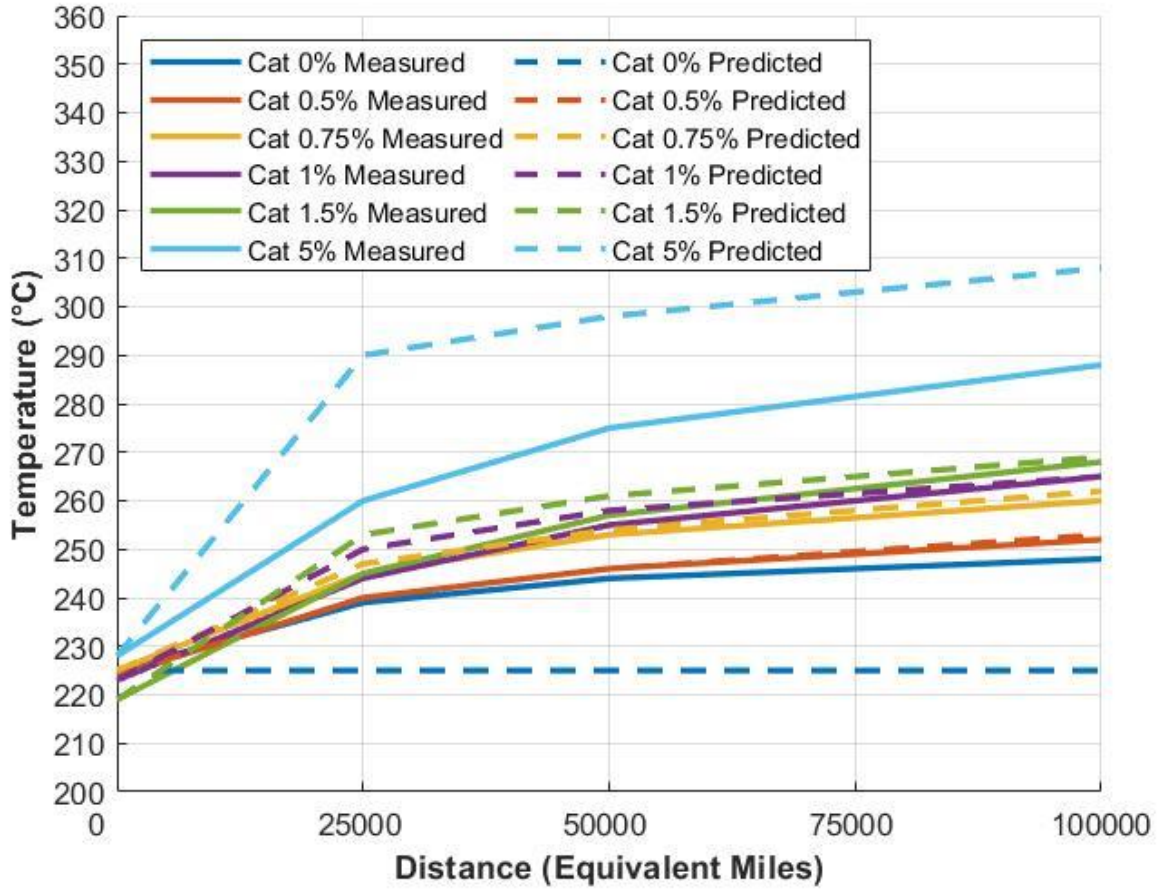
Analysis - Light-Off Temperatures

Measured LO Temps (°C)

	Ageing Distance (Equivalent Miles)			
Catalyst Sample	0	25,000	50,000	100,000
Catalyst 0% LO Temperature (°C)	225	239	244	248
Catalyst 0.5% LO Temperature (°C)	224	240	246	252
Catalyst 0.75% LO Temperature (°C)	225	245	253	260
Catalyst 1% LO Temperature (°C)	223	244	255	265
Catalyst 1.5% LO Temperature (°C)	219	245	257	268
Catalyst 5% LO Temperature (°C)	228	260	275	288

Predicted LO Temps (°C)

	Ageing Distance (Equivalent Miles)			
Catalyst Sample	0	25,000	50,000	100,000
Catalyst 0% LO Temperature (°C)	225	225	225	225
Catalyst 0.5% LO Temperature (°C)	224	240	246	253
Catalyst 0.75% LO Temperature (°C)	225	247	254	262
Catalyst 1% LO Temperature (°C)	223	250	258	265
Catalyst 1.5% LO Temperature (°C)	219	253	261	269
Catalyst 5% LO Temperature (°C)	228	290	298	308



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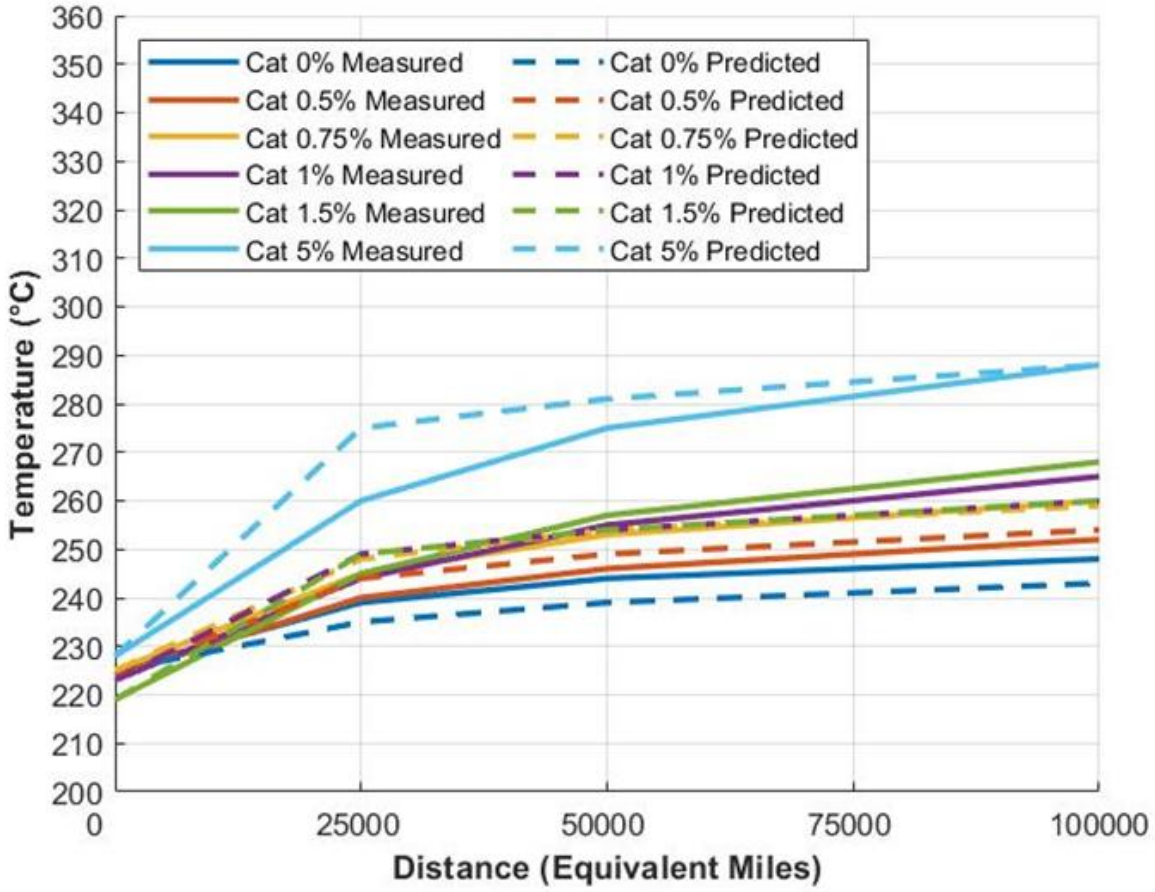
Analysis - Light-Off Temperatures

Measured LO Temps (°C)

	Ageing Distance (Equivalent Miles)			
Catalyst Sample	0	25,000	50,000	100,000
Catalyst 0% LO Temperature (°C)	225	239	244	248
Catalyst 0.5% LO Temperature (°C)	224	240	246	252
Catalyst 0.75% LO Temperature (°C)	225	245	253	260
Catalyst 1% LO Temperature (°C)	223	244	255	265
Catalyst 1.5% LO Temperature (°C)	219	245	257	268
Catalyst 5% LO Temperature (°C)	228	260	275	288

Predicted LO Temps (°C)

	Ageing Distance (Equivalent Miles)			
Catalyst Sample	0	25,000	50,000	100,000
Catalyst 0% LO Temperature (°C)	225	235	239	243
Catalyst 0.5% LO Temperature (°C)	224	244	249	254
Catalyst 0.75% LO Temperature (°C)	225	248	254	259
Catalyst 1% LO Temperature (°C)	223	249	254	260
Catalyst 1.5% LO Temperature (°C)	219	249	254	259
Catalyst 5% LO Temperature (°C)	228	275	281	287



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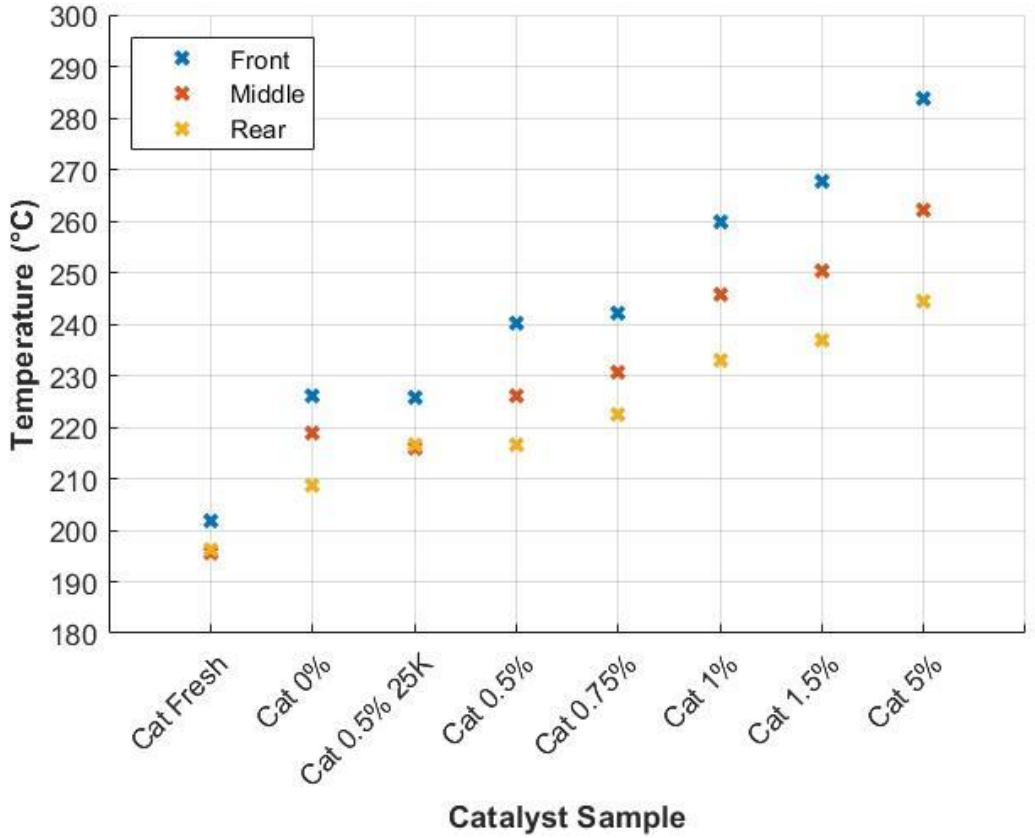
Analysis - Light-Off Temperatures

Cored light-off results, showing ageing throughout the catalyst brick.

Catalyst Sample	Front	Middle	Rear
Catalyst 0% LO Temperature (°C)	226	219	209
Catalyst 0.5% LO Temperature (°C)	240	226	216
Catalyst 0.75% LO Temperature (°C)	242	231	223
Catalyst 1% LO Temperature (°C)	260	246	233
Catalyst 1.5% LO Temperature (°C)	268	250	237
Catalyst 5% LO Temperature (°C)	284	262	245
Catalyst 0.5% 25K LO Temperature (°C)	226	216	216
Catalyst Fresh LO Temperature (°C)	201	196	196



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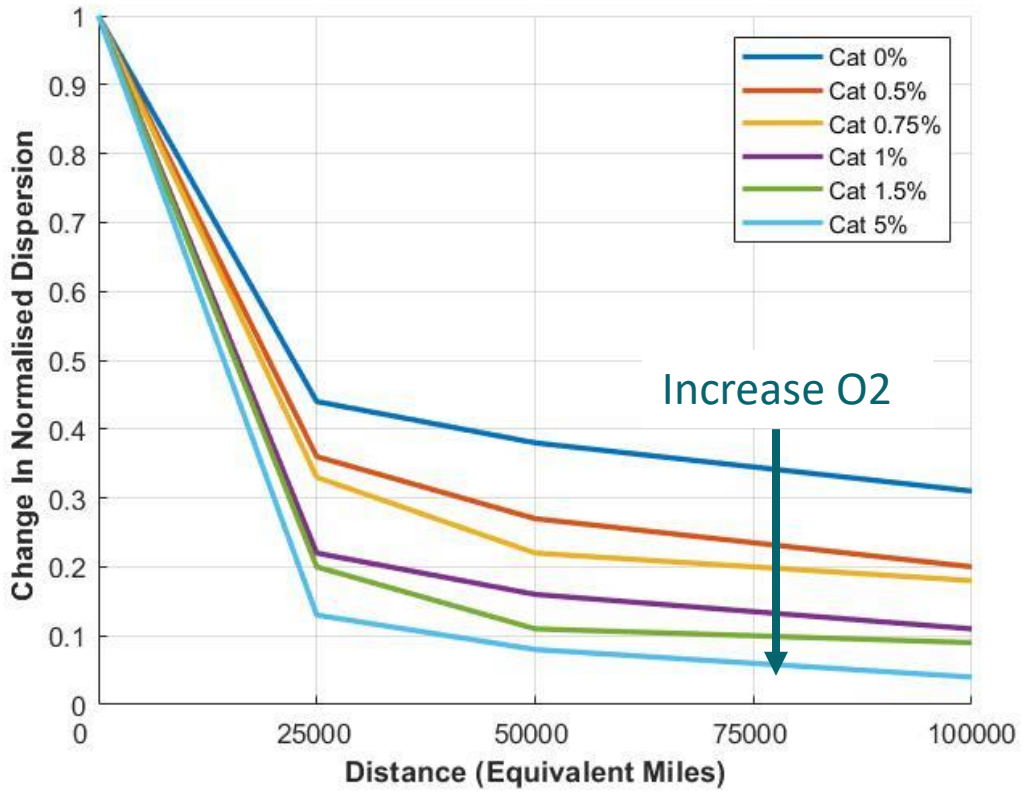
Analysis - Change in Dispersion Throughout Ageing

Catalyst Sample		Ageing Distance (Equivalent Miles)			
		0	25,000	50,000	100,000
Catalyst 0%	Light-Off Temperature (°C)	225	238	243	250
	Normalised Dispersion (%)	1.00	0.44	0.38	0.31
Catalyst 0.5%	Light-Off Temperature (°C)	224	240	245	252
	Normalised Dispersion (%)	1.00	0.36	0.27	0.20
Catalyst 0.75%	Light-Off Temperature (°C)	225	245	252	259
	Normalised Dispersion (%)	1.00	0.33	0.22	0.18
Catalyst 1%	Light-Off Temperature (°C)	223	245	255	265
	Normalised Dispersion (%)	1.00	0.22	0.16	0.11
Catalyst 1.5%	Light-Off Temperature (°C)	220	245	256	267
	Normalised Dispersion (%)	1.00	0.20	0.11	0.09
Catalyst 5%	Light-Off Temperature (°C)	229	260	276	290
	Normalised Dispersion (%)	1.00	0.13	0.08	0.04



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Conclusions

- Oxygen has a significant effect on degradation of catalyst performance and efficiency.
- It is not a linear relationship between an increase in oxygen and increase in deactivation.
- More severe ageing during the initial stages of deactivation.
- Current ageing theory does not accurately correlate with varying oxygen concentrations for palladium catalysts.
- Cored light-off tests concluded that the front of the catalysts were experiencing more ageing.
- Oxygen also has a significant effect on the change in dispersion on the catalyst.

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