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# Regeneration of Palladium Based Catalyst for Methane Abatement

Thierry Leprince

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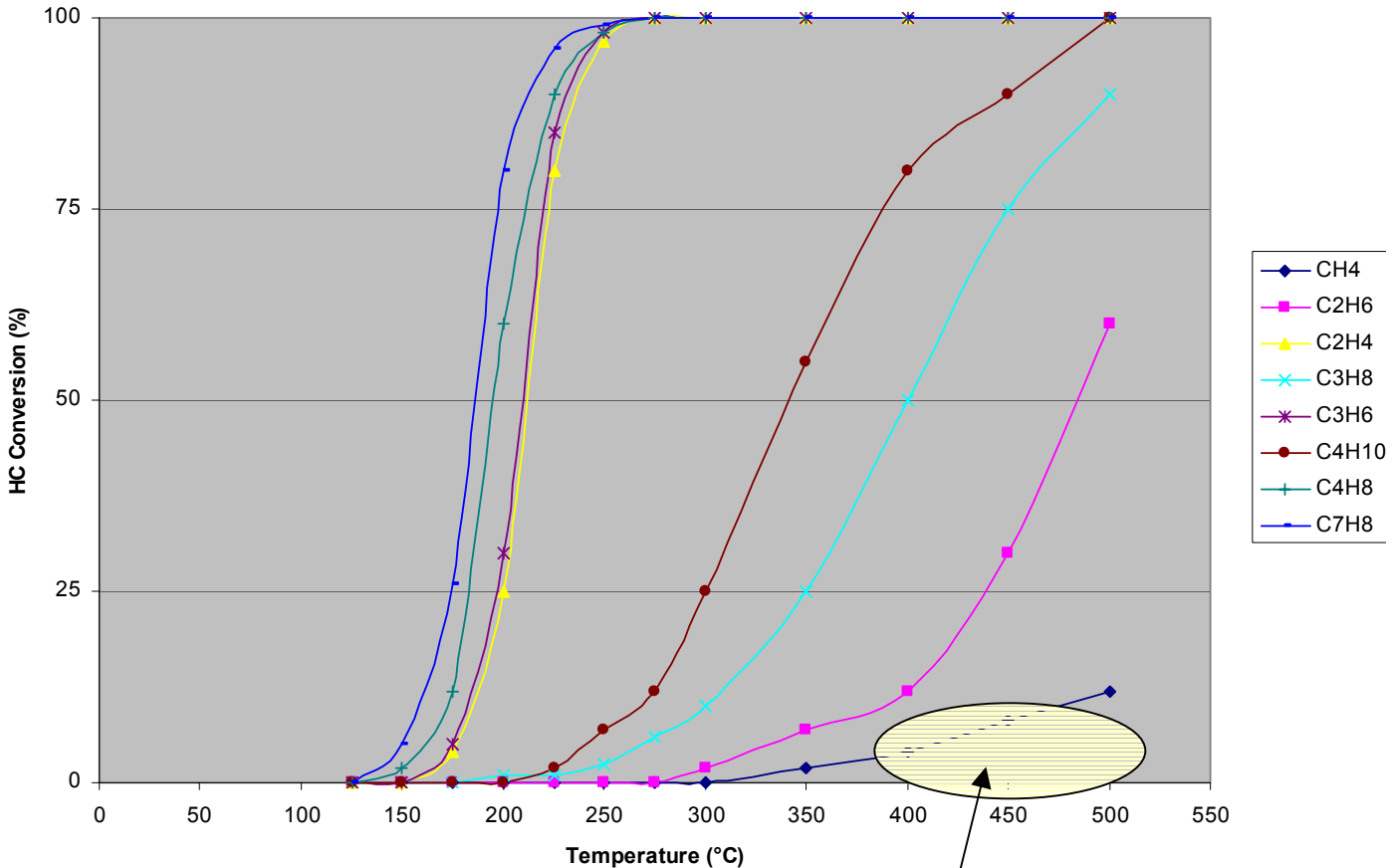
- **Introduction**
- Deactivation mechanisms
- Regeneration strategies
- Conclusion

# Introduction

- Methane is a green house gas [ $1 \text{ t}_{\text{CH}_4} \sim 20 \text{ t}_{\text{CO}_2}$ ]
- A 4 MW lean burn engine emits up to 300 tonnes of methane per year, or 6000 tonnes of CO<sub>2</sub>
- If we were able to oxidize this methane with a catalyst, we could generate a € 30,000 credit
- Furthermore, in case of co-generation application, heat resulting for methane slip oxidation will be recovered in the exhaust, thus improving overall system efficiency
- Problem: methane is most stable hydrocarbon, therefore most difficult to oxidize with a catalyst
- How can we get 90% CH<sub>4</sub> conversion?

# CH<sub>4</sub> Oxidation with Platinum catalyst

(Pt Alumina Catalyst SAE930735)

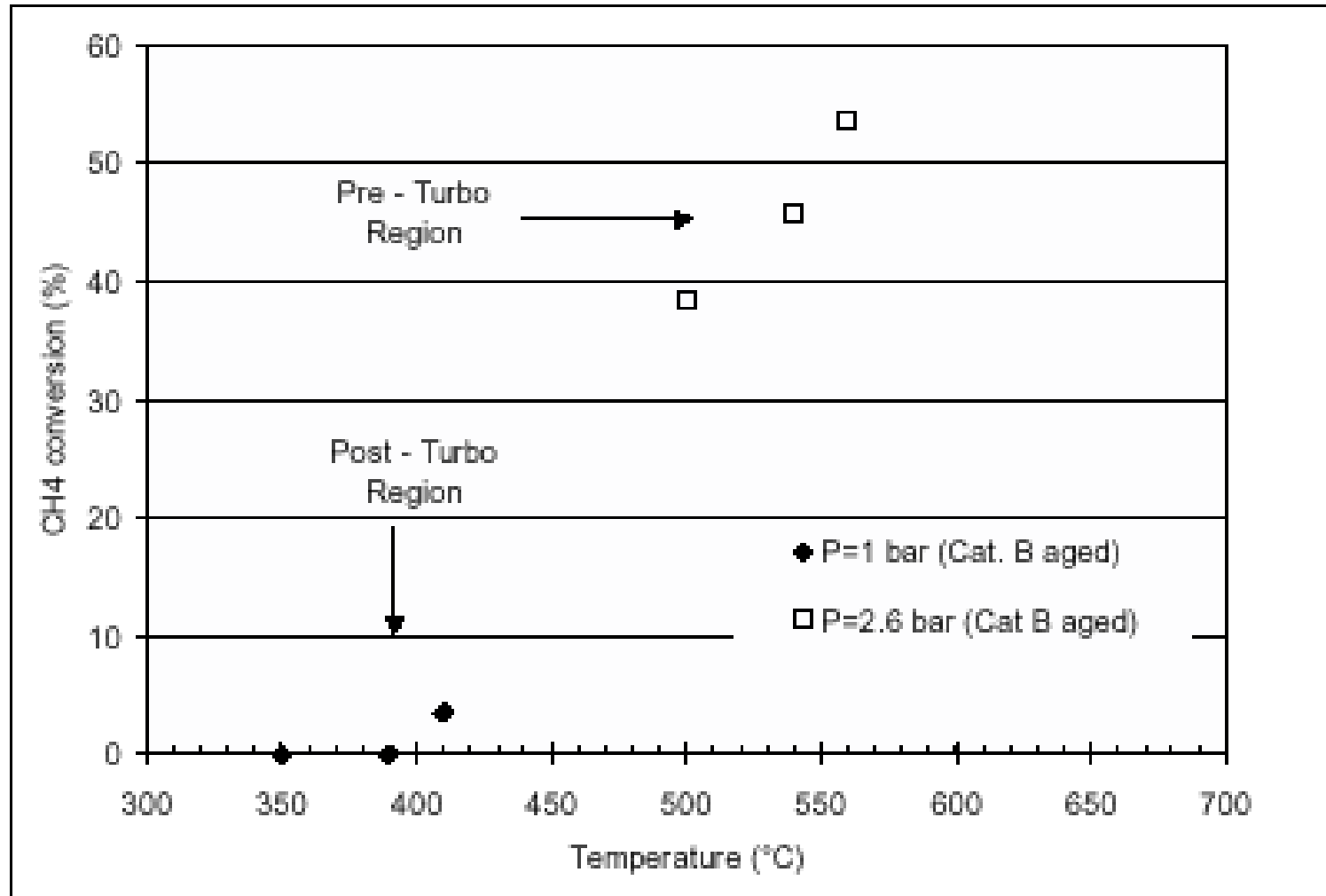


Operating window yields to little conversion

Need to install catalyst upstream of turbo

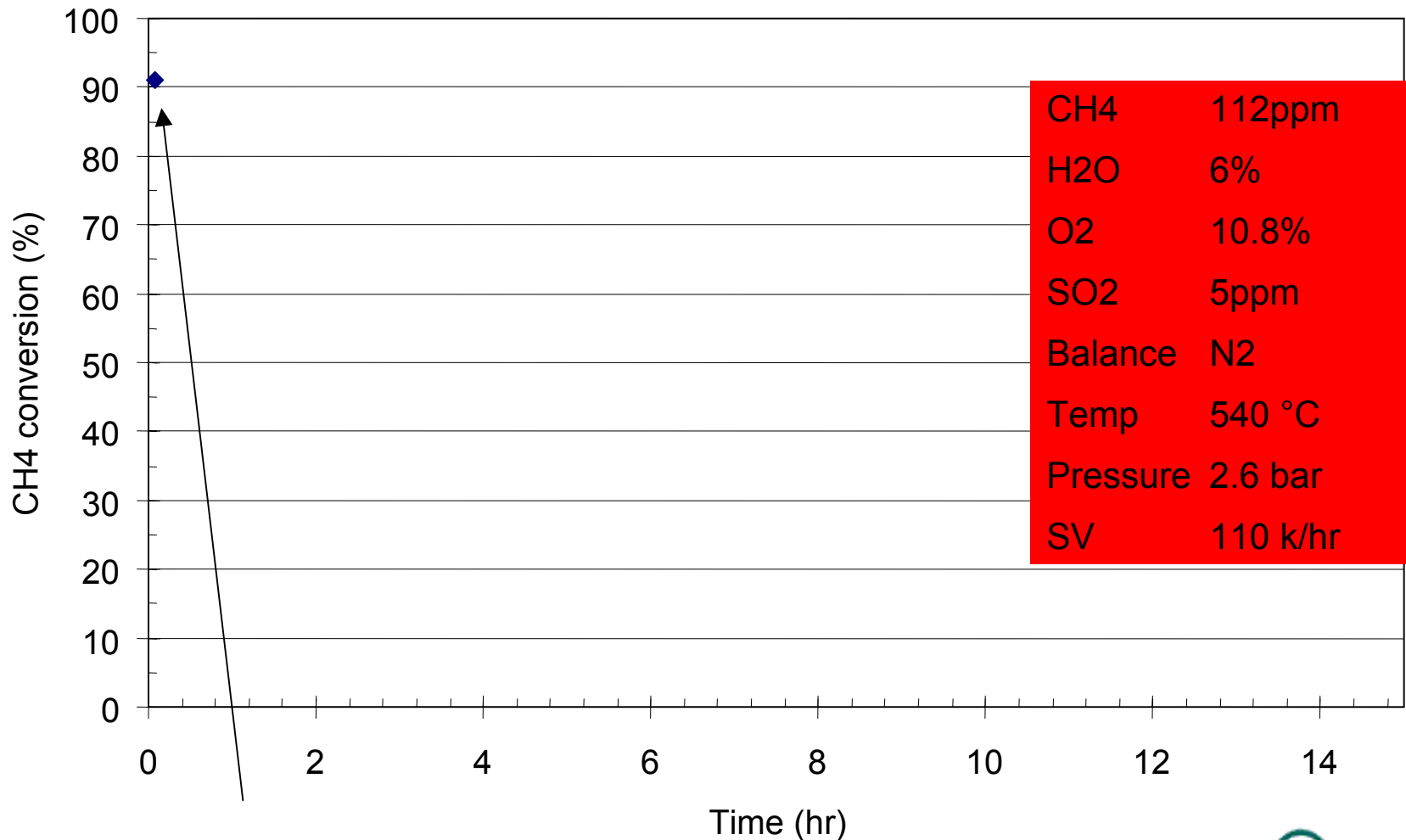
Need to use another type of catalyst

# Pre-turbo catalyst



Higher conversions will require a different catalyst

# CH<sub>4</sub> conversion and Pd catalyst



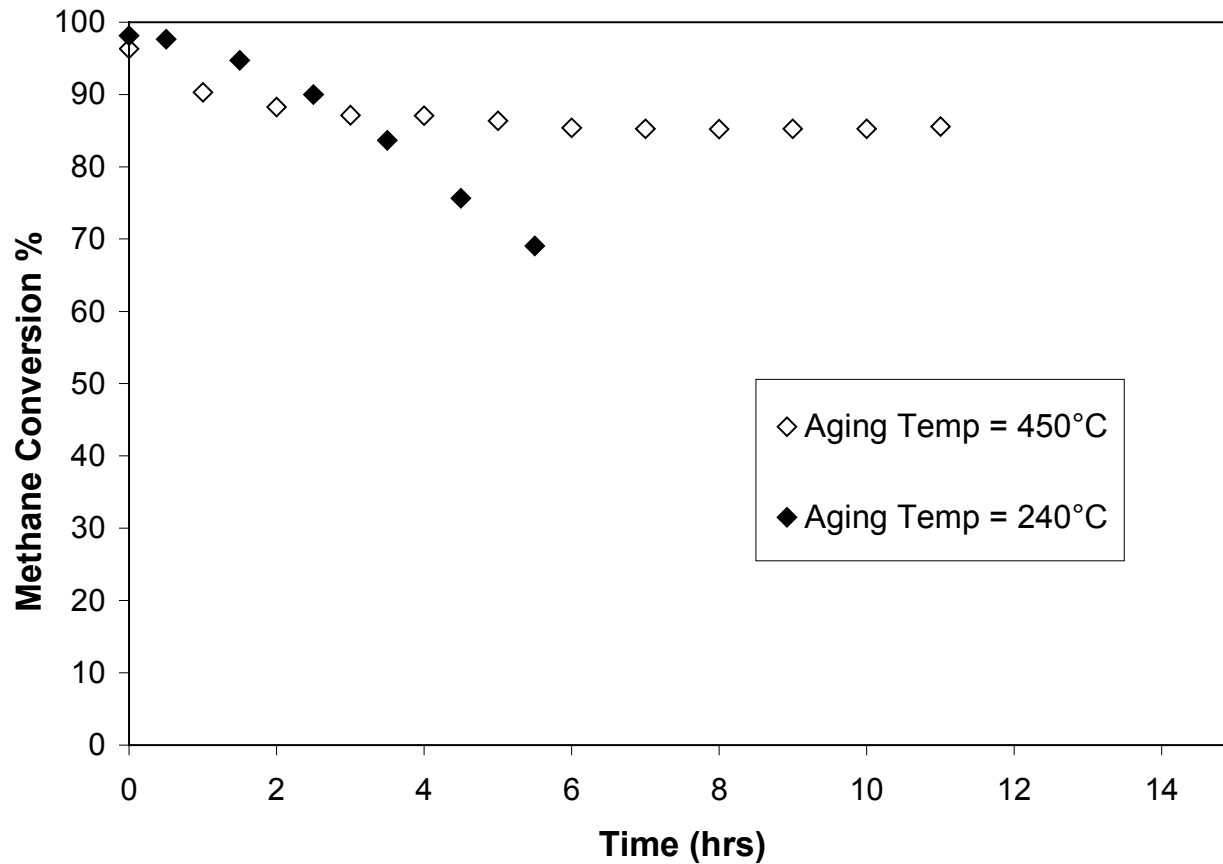
Pd catalyst can provide fairly high conversions of CH<sub>4</sub>

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# Deactivation with time



**Aging with 5 ppm SO<sub>2</sub>**



# Role of sulfur in catalyst deactivation

- $\text{SO}_2$  adsorbs strongly on Pd
- The resulting PdO- $\text{SO}_3$  sites possess low activity for HC oxidation



- Methane is the most sensitive to  $\text{SO}_2$  poisoning

# What do we do next?

- Pd based catalyst is an interesting alternative but has serious durability issues
- Need to frequently replace catalyst
- Need to regenerate catalyst on a regular basis
  - Similar strategies have been developed for NO<sub>x</sub> storage catalysts in GDI engines
  - Use of Diesel NO<sub>x</sub> storage catalysts also require periodic catalyst regeneration
  - Will need system approach between engine OEM and catalyst supplier
- Can we actually regenerate methane catalyst?

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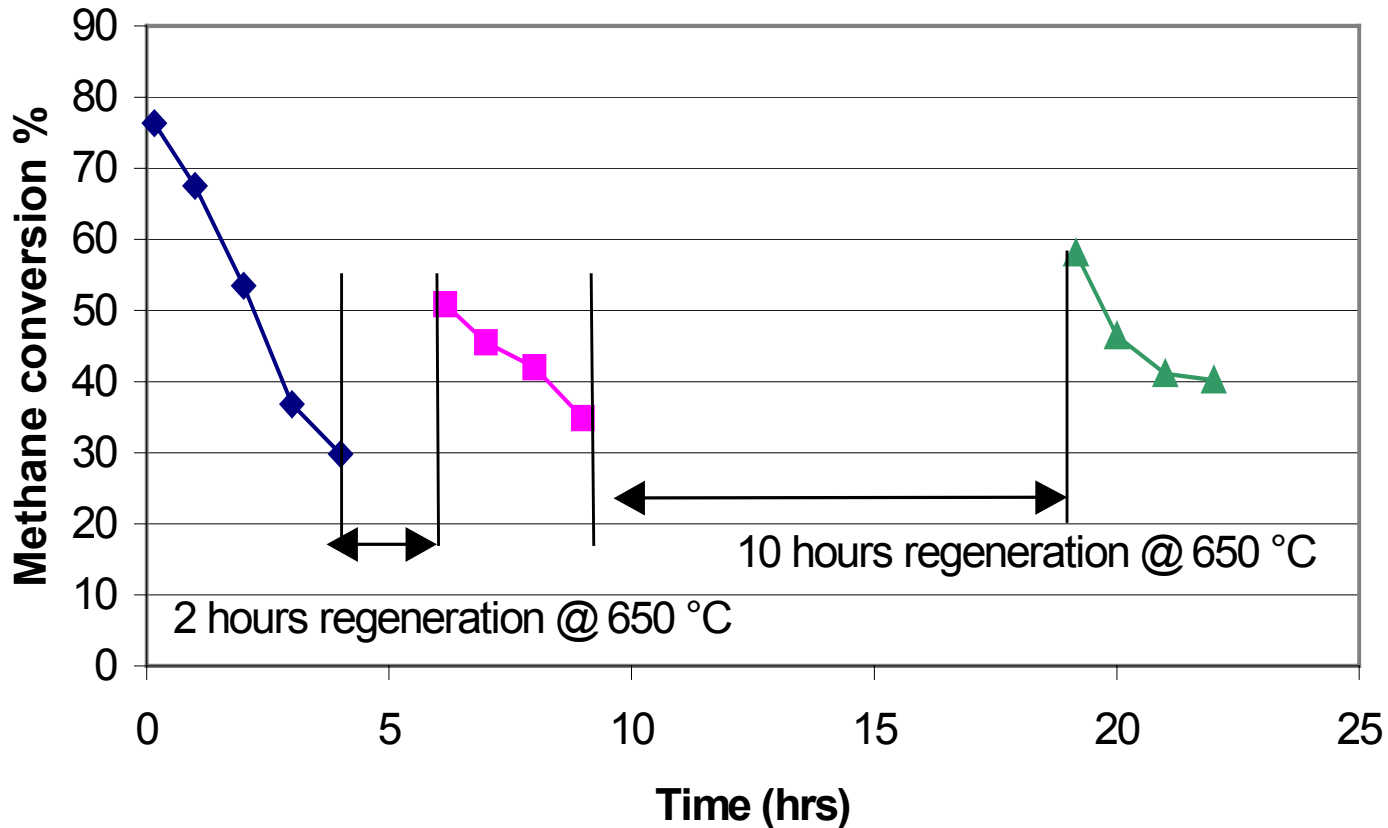
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# Methane catalyst regeneration

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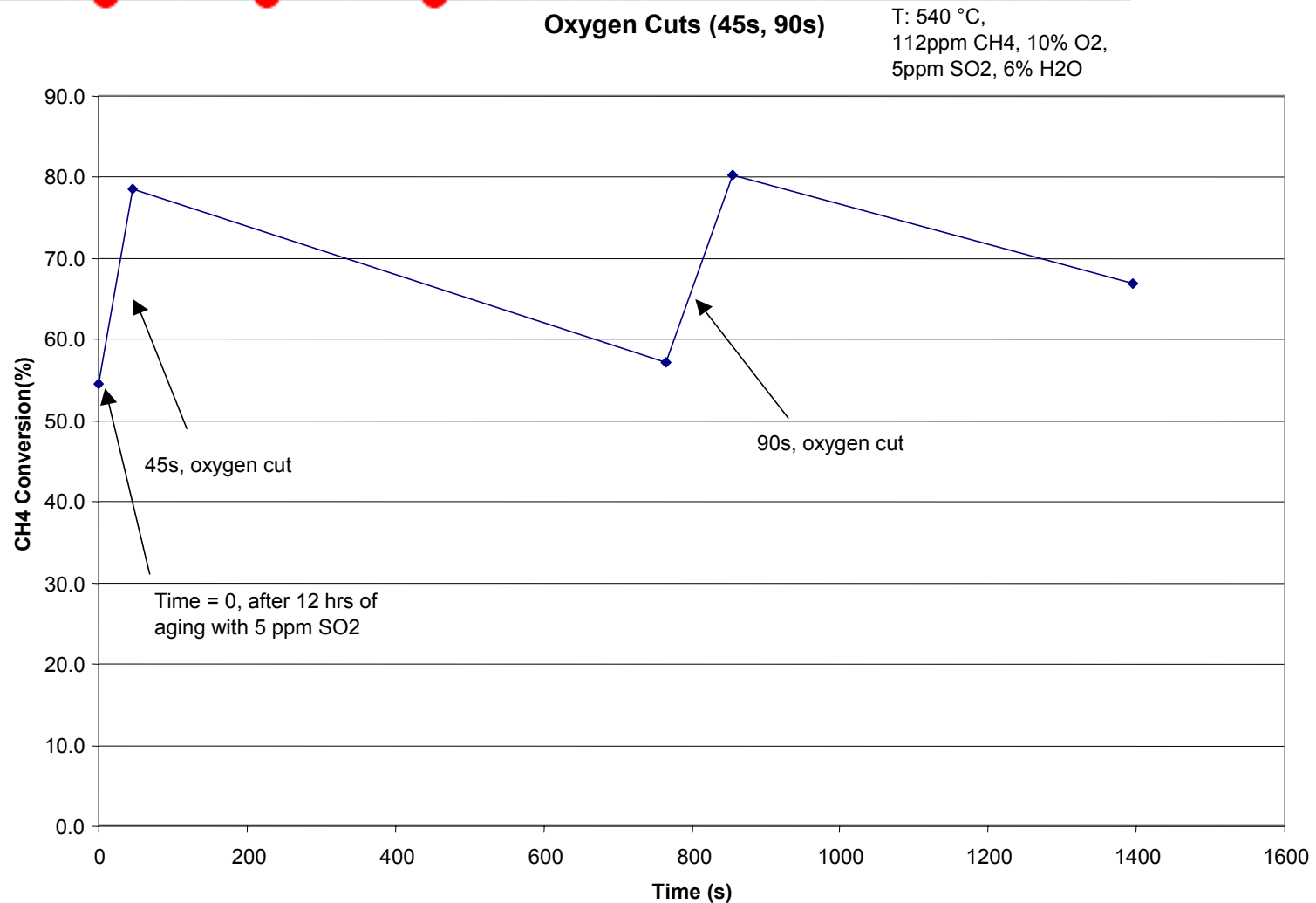
- Thermal regenerations
- Rich regeneration strategies
  - With oxygen cuts
  - With H<sub>2</sub>
  - With H<sub>2</sub> & CO
  - With gas mixtures

# Thermal regeneration



**Thermal regeneration is not an option**

# Rich regeneration (oxygen cuts)



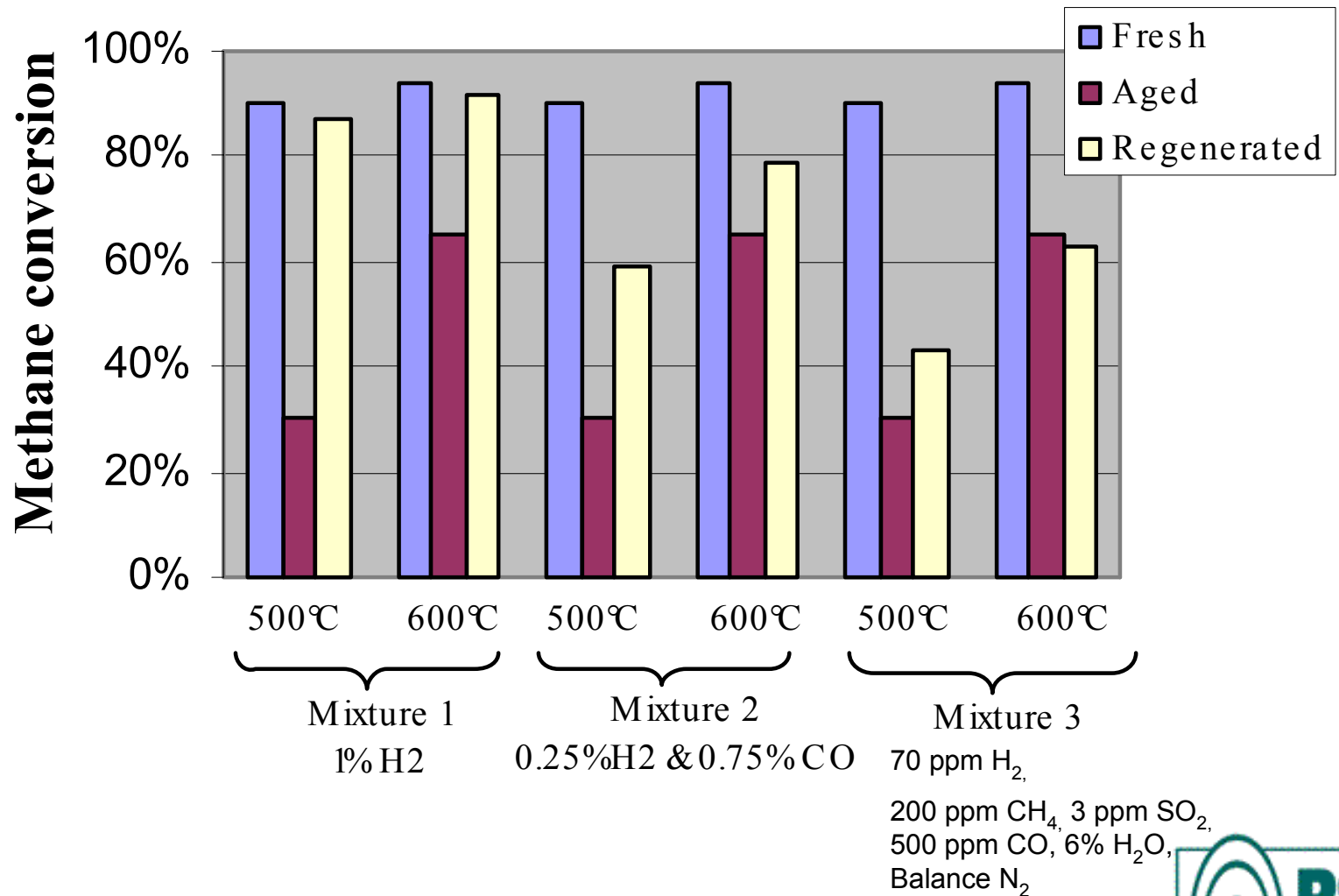
**Oxygen cut is an option but is not practical**

# Regeneration considerations

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- From literature, H<sub>2</sub> is a good chemical for regenerating Pd catalysts
- H<sub>2</sub> could be produced by the engine when  $\lambda < 1$
- CO can also be used as a reducing agent but is less efficient than H<sub>2</sub>

# Regeneration results





# Results

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- Mixture 1: complete regeneration
- Mixture 2: partial regeneration
- Mixture 3: partial/lower regeneration than mixture 2
  
- In actual engine conditions (mixture 3), catalyst will have to be exposed longer to regeneration conditions



Questions?