



CATERPILLAR GLOBAL MINING | TRENT KAPENE | 07JUL2018

## DIESEL EMISSION OPTIONS FOR UNDERGROUND MINING HARD ROCK VEHICLES



MDEC 2018

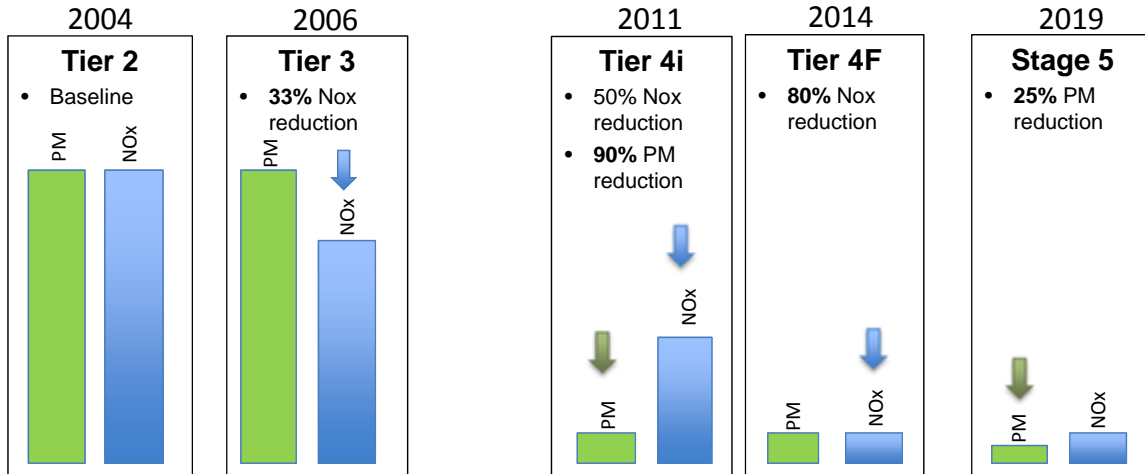
### OUTLINE



- Emission progression
- Available solutions
- Development & Field Follow
- Future for diesels machines



## HIGH LEVEL - EMISSION REDUCTION – 130-560 KW CLASS

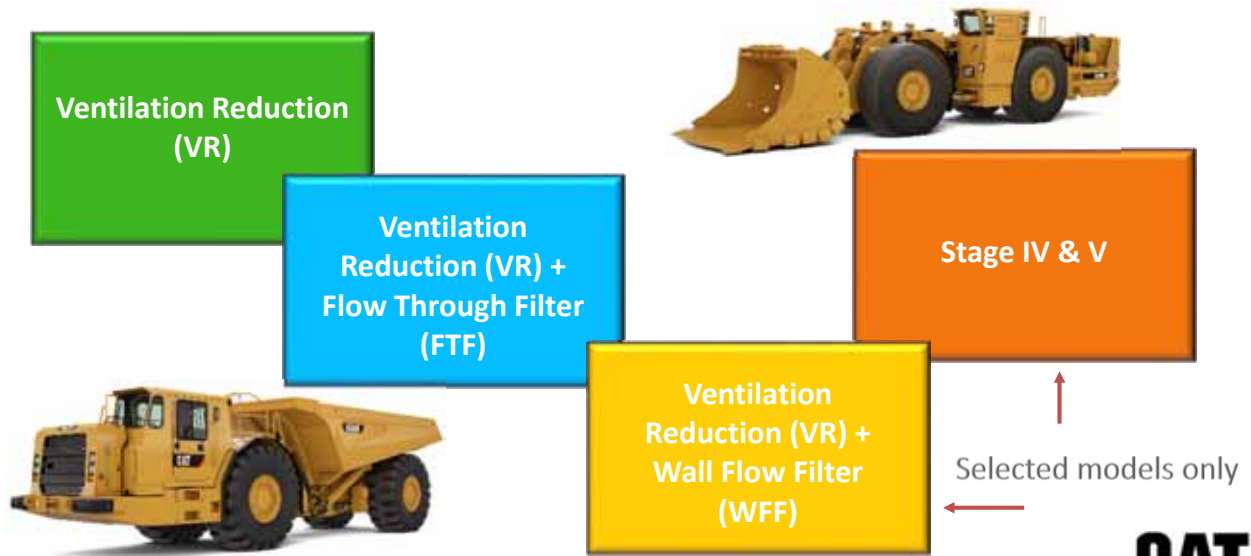


Emission progressions through the timeline of Tiers



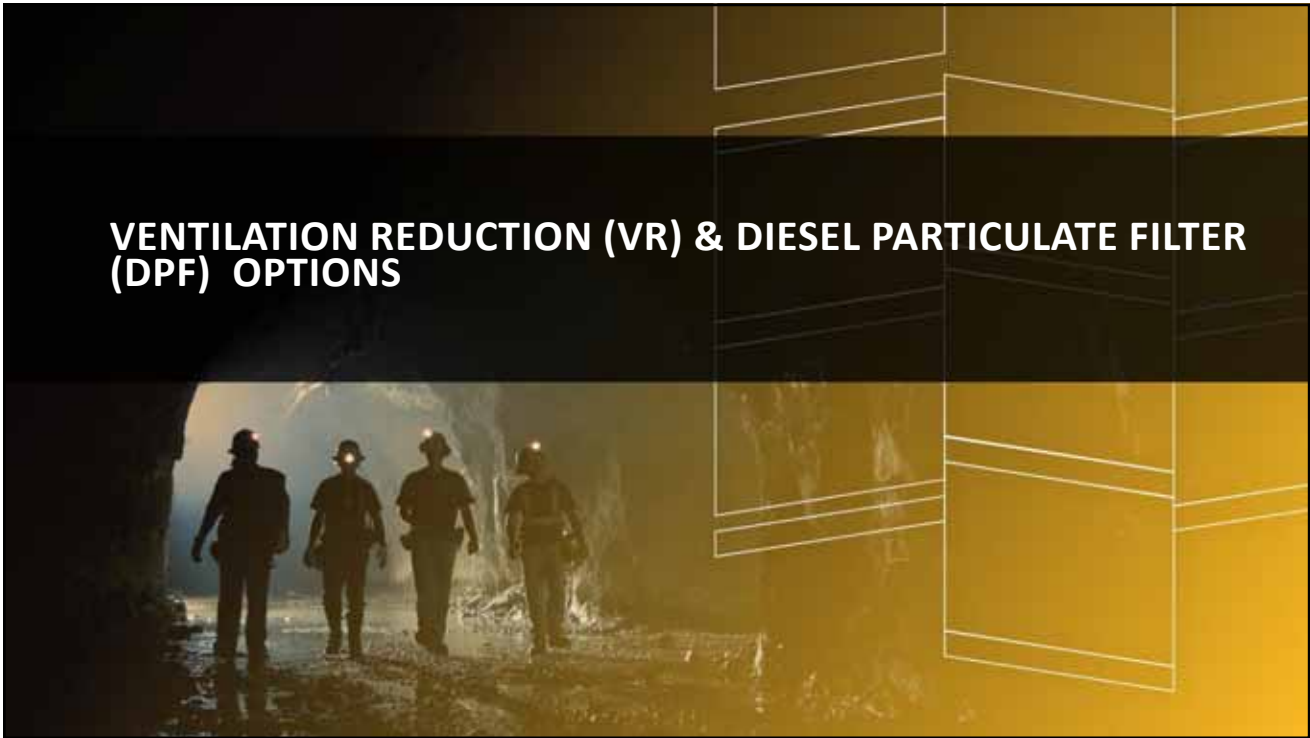
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## CURRENT CATERPILLAR EMISSION SOLUTIONS FOR UNDERGROUND EQUIPMENT



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## VENTILATION REDUCTION (VR) & DIESEL PARTICULATE FILTER (DPF) OPTIONS



### TIER 3 VS. VENTILATION REDUCTION (VR) ENGINE CAPABILITY

Cat VR engines are designed for lower vent rates, greater power density/ performance and fuel efficiency

- Up to a 42% vent rate reduction
- 3-7% fuel improvement (machine model dependent)
- Increased dual stall rim pull (R2900G)
- Retrofittable to existing fleets



## FLOW THRU FILTER (FTF) VS. WALL FLOW FILTER (WFF)

- Diesel Particulate Matter (DPM) capture is increased from 50% to 98%
- Filter medium changed to a ceramic substrate (as opposed to sintered metal of the FTF)
- No increase to noise attenuation
- Service interval required for WFF
- WFF has an integrated monitoring system for product health management – uses cab dash display
- Both use a Diesel Oxidisation Catalyst (DOC)



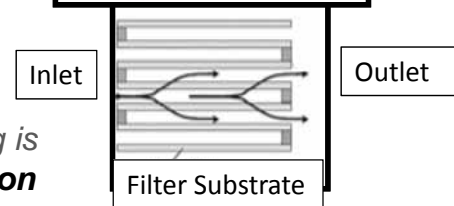
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## NOT ALL DIESEL PARTICULATE FILTER SYSTEMS ARE CREATED EQUALLY

How a DPF works:

Using a catalytic-coated filter medium, the exhaust gas is directed through channels which are closed at one end. This forces the gases to pass through the filter medium, capturing the DPM. This is then burned off via passive regeneration.

*The difference we bring to the WFF design is a Caterpillar proprietary catalytic coating. This coating is chemically engineered to allow **passive regeneration at a lower temperature**, equating to longer filter life.*



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## DPF DURABILITY AND RELIABILITY



Building a filter that can withstand the application requires us to:

1. Endurance test for structural integrity and long-term durability
  - Shake table and on machine strain analysis (OMSA)
2. Integrate monitoring systems (WFF)
  - Incorporating Cat sensors and displays
  - Machine specific monitoring strategy
  - Product health monitoring



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## BHP OLYMPIC DAM OPERATION – FIELD TRIAL



BHP approached Caterpillar for a Tier 4 Final solution - the root cause of their concern was diesel particulate matter levels. Rather than replace their fleet of over 60 Cat machines, our solution was the development of the wall flow filter. It was a dramatically less complicated, lower-tech solution that could be implemented without significantly impacting their operations.

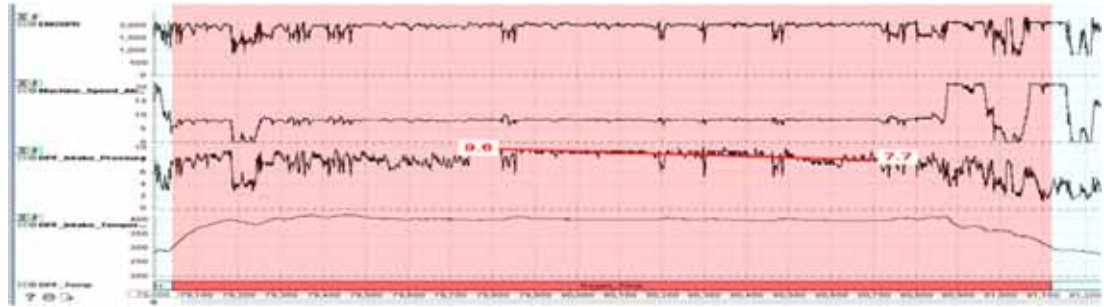
*A compressed timeline was the greatest challenge - our conversations started in 2016 with BHP requiring a full fleet fitment by July 1<sup>st</sup> 2017*



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## REGEN TRUCK AND ODO SERVICING INTERVAL

Incredible team work by BHP, Caterpillar and Cat Dealer, CavPower, enabled us to deliver and validate the product by the July 2017 deadline. More importantly, the results have been excellent. This image shows regeneration occurring above 300 deg C.



Current maintenance intervals on the filters:  
**LHD Application: 3k hrs before clean**  
**UAT Application: 3k hrs before clean, which equates to 6 months.**



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### VR+FTF (Baseline)



### VR+ Wall Flow Filter



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## Program results

DPM Reduction Project		
Test Type	AD60 VR+pDPF	AD60 Wall Flow
High Idle	3.6 mg/m <sup>3</sup>	0.0 mg/m <sup>3</sup>
Stall	2.1 mg/m <sup>3</sup>	0.0 mg/m <sup>3</sup>
Test Type	R3000H VR+pDPF	R3000H Wall Flow
High Idle	1.3 mg/m <sup>3</sup>	0.0 mg/m <sup>3</sup>
Stall	0.7 mg/m <sup>3</sup>	0.0 mg/m <sup>3</sup>

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## TIER 4 FINAL VS. EU STAGE V

Stage V engines take the very best technology from our Tier 4 Final solution and build on it to further lower emissions.

- 25% DPM reduction – (0.020 to 0.015 gr/kW/hr – 130-560 kW class)
- Introduction of a particle number (PN) limit
  - The PN limit is designed to ensure that a highly efficient particle control technology—such as wall-flow particulate filter— is used.



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## ENGINE DEVELOPMENT

Development consideration taken into account for underground

- Peak cylinder pressure
- Emission compliance at negative and positive altitudes
- Vent rate effects
  - Limiting factors
  - Target vent rate
- Component robustness
  - Electrical system
- Targeted Emission reduction
  - DPM , Gaseous (NO/NO2)
- Fluid consumption
  - Fuel and DEF (if required)
- Support network



R2900G Stage V engine testing



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## STAGE IV & V VENT RATES



Stage V vs. VR vent rate \* Pending final certification

R1700 KT4 >>>>> ~10% reduction in ventilation

R2900G >>>>> ~25% reduction in ventilation\*

AD45B >>>>>> ~25% reduction in ventilation\*



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## NEAR FUTURE SOLUTIONS FROM CATERPILLAR

- All newly updated products for our hard rock vehicle product line will offer a Stage V certified engine option (we are bypassing Tier 4 Final).
- Caterpillar has a number of in-production Diesel/Electric machines like the 988XE large wheel loader. This technology translates well into our LHD product line, and our engineers are actively engaged in this space.
- We've just completed a proof of concept program on a zero emissions, battery electric R1300. This technology will go to market in our next generation, R1700 platform. You will hear more about the results of this proof of concept program from Jay Armbrurger.



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## OUR PARTNERSHIP GOES BEYOND THE IRON

### SEE WHAT WE CAN ACCOMPLISH TOGETHER

Machines will always be essential to success in the mining industry — and we're committed to making quality products that are productive, safe and reliable. But we're also committed to being a true partner beyond the iron — helping you address the challenges that are having the greatest impact on your operation today, and working with you to create big-picture strategies of where you want to be in the future.

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