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Inspiring science, enhancing life

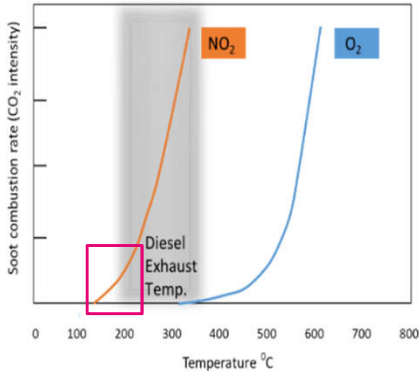


Electrically regenerated DPF for low temperature DPM control
2019 MDEC Conference

For a cleaner and healthier mining environment

Stan Mack, Commercial Manager; Peter Werth, Product Manager, Non Road DPF

Diesel particulate filter regeneration

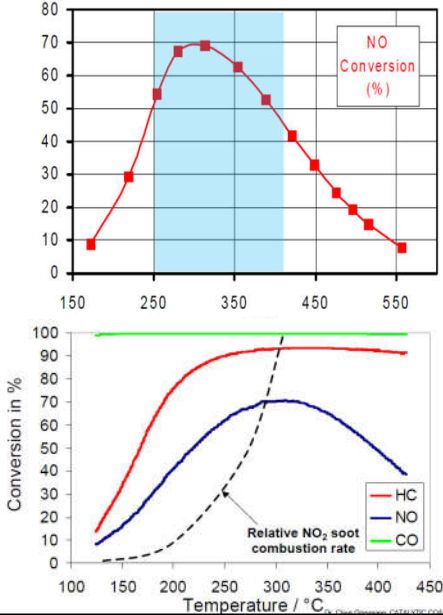


Oxygen vs. NO₂

Many underground mining diesel equipment cannot operate at temperatures sufficient to allow regeneration with NO₂.

JM's DPFI™ electrically heated DPF will allow O₂ regeneration on or off board the vehicle.

Oxidation of NO as a function of temperature



Using a catalyst to form NO₂ below 250°C will have minimal impact on DPF regeneration

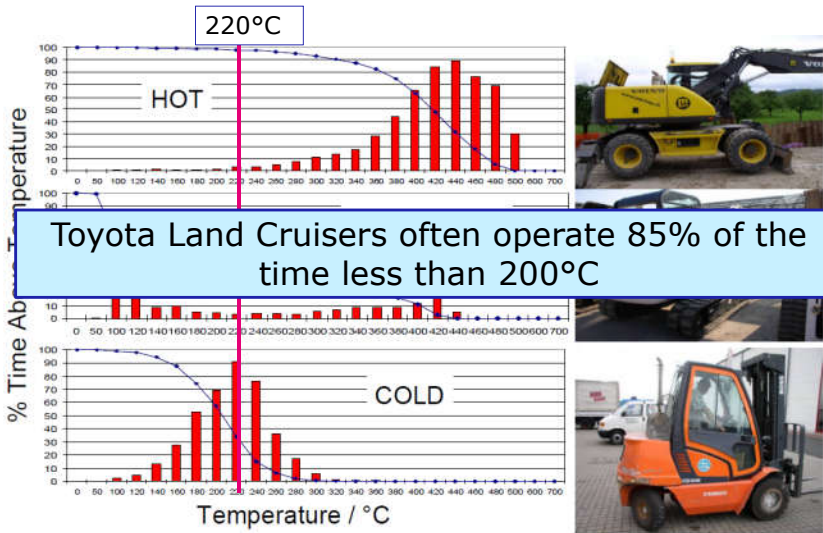
The optimum temperatures for NO₂ formation are in the 250-375°C range. Below 250°C soot combustion is too low to regenerate

Catalyzed DPF's have not (and will not) regenerate below 220°C exhaust temperature and cause premature fouling.

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Examples of very different duty cycles



Toyota Land Cruisers often operate 85% of the time less than 200°C

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Electrical regeneration

Solving the low temperature PM control with no NO₂

Oxygen regeneration is required for many of the smaller diesel engines with low exhaust temperatures.

Johnson Matthey has deployed electrically regenerated filters capable of regeneration in 30 – 90 minutes:

- Toyota Land Cruisers
- Fork lift trucks
- Wheel loaders

“On-board” and “off-board” models available.



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Electrical regeneration

Confined space diesel particulate filtration with no NO₂

- **JM DPFi™** diesel particulate filters are used exclusively for filtration of particles from diesel engines operated in closed environments such as underground mines.
- **Swiss VERT** regulations have been met.
- **EMPA** (Swiss Federal Laboratories for Materials Science and Technology) certification
- Meets the requirements of **EST-London, TRGS554 (Technical Regulations for Dangerous Substances)** and the **TBG (Technology Participation Society)**



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DPFi verification

VERT Summary

- Average particle number filtration efficiency of 99.93
- Outstanding particle number filtration (more than 2 scales) in all modes
- Very good dynamic filtration at free acceleration
- Effective electrical regeneration

The tested Johnson Matthey Particulate Filter fulfills the criteria of VERT suitability test.



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DPFi Verification

Secondary emissions

The DPFi does not produce secondary emissions during vehicle operation.

During the regeneration cycle it will produce a small amount of emissions (CO₂ and H₂O) by burning the collected soot, depending on the soot loading. Secondary emissions from non-catalyzed filters are not evaluated under the VERT testing method.

Abstract from the VERT/BAFU:

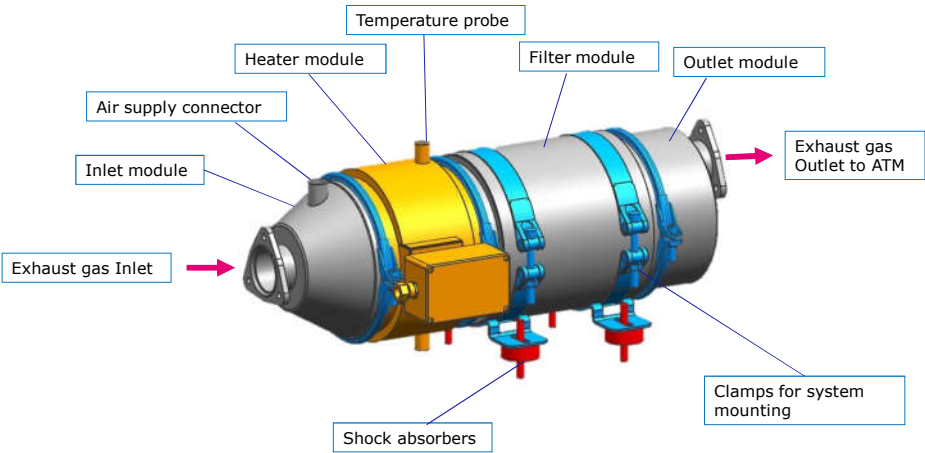
"Internal Combustion Engines – Exhaust Gas After-treatment – Particle Filter Systems – Testing Method"

5.4 If the particle filter system includes catalytically active components (e.g. a catalytic coating or a catalytically active additive), a test has to be carried out concerning the occurrence of secondary emissions.

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What is a DPFi filter?
Electrically regenerated particulate filter



Approximate length 26 1/2"



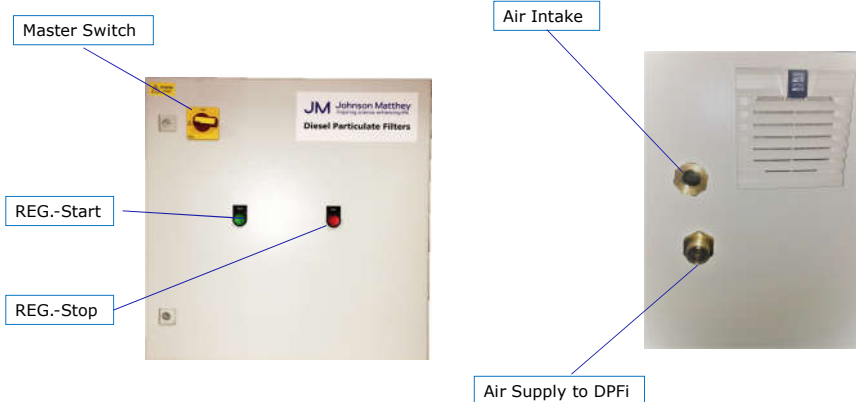
What is a DPFi filter?
Electrically regenerated particulate filter



What is a DPFi filter?

Off-board multiple unit regeneration control station

For mines with large fleets of low temperature engine equipment
 Wall mounting regeneration station can regenerate multiple filters sequentially



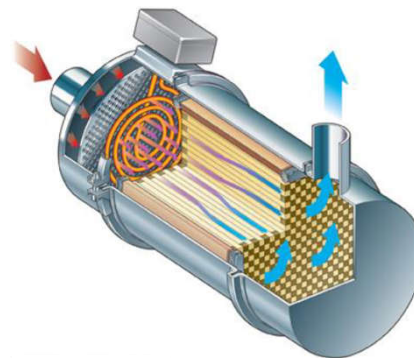
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What is a DPFi filter?

On-board regeneration system

- Regeneration method: electric current supplied by battery with engine turned off
- Regeneration period: 30 - 90 minutes (depending on the design)
- Filter operational time: ~8 hours, depending on filter type and PM emissions
- Filter control with pressure and temperature recording; visual continual filter filling level display
- Acoustic warning signal for monitoring the maximum permitted exhaust gas back pressure during vehicle operation.



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What is a DPFi filter?

On-board regeneration system components

Filter
Control
Monitor – in
cab



Relay box –
in vehicle



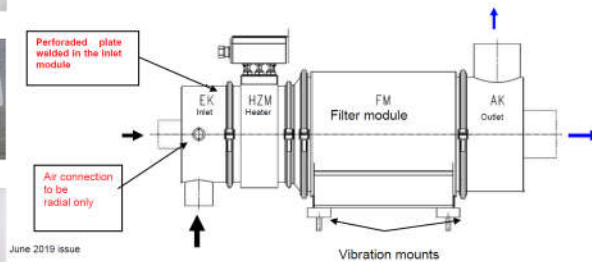
Compressor
Set – in
vehicle



Connector-
Set



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DPFi filter

Operating parameters

The regeneration of the filter should be carried out on a regular basis determined by the typical operating conditions of the vehicle to ensure that the maximum operating time is available.

After longer standstills of the vehicle, a regeneration should be carried out prior to taking the vehicle into operation.

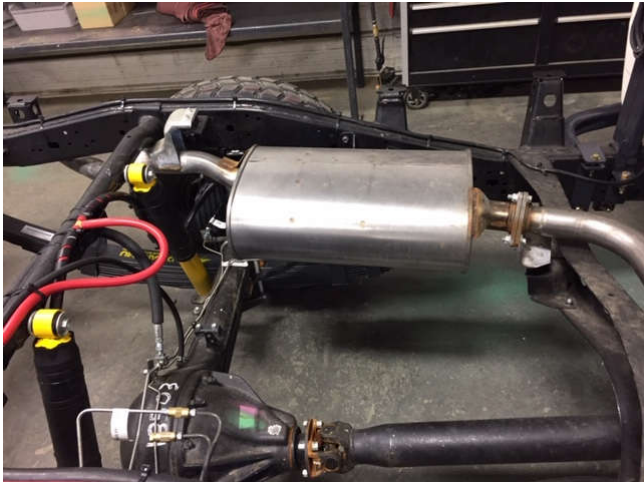
Regeneration should occur at temperatures between 5°C and 35°C to allow optimal operation of the electrical heater.

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DPFi Installation DPFi on a Toyota Land Cruiser

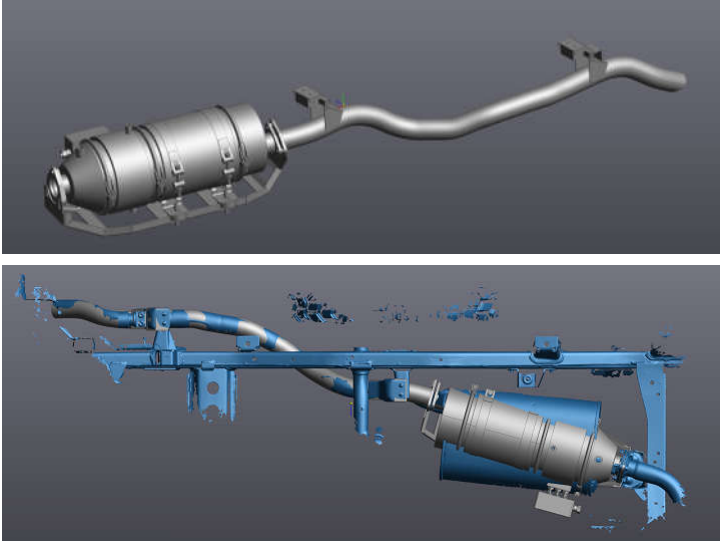
The Toyota Land Cruiser muffler is an ideal location to install the DPFi. Minimal adjustment to fit in this space.



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DPFi Installation DPFi on a Toyota Land Cruiser



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DPFi case study #1

DPFi with electrical regeneration installed on a wheel loader



Summary

Product: DPFi 2011SL, electrical regeneration
Application: Volvo wheel loader L60E

Engine: Volvo D6D, 103 kW, 5.7L

Location: Germany

Installation Date: 2010

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DPFi case study #2

DPFi with electrical regeneration installed on a forklift truck

To fulfil the regulation TRGS554 a Toyota forklift truck was equipped with a DPFi system.

In general these material handling applications often operate at very low exhaust gas temperature (below 200°C) and cannot be fitted with a continuously regenerating filter system.

The truck can operate until the filter monitor informs the operator to stop and connect to the external regeneration box.

The regeneration program runs for 60 minutes and shuts down automatically.



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DPFi Systems

Advantages:

- Independent of the exhaust gas temperature of the engine.
- Robust and simple construction for a long life.
- Service-friendly modular design with quick-release fasteners.
- Electronic filter monitoring for increased reliability in the off-road area.
- Flexible mounting option - horizontal as well as vertical.
- Available product series for use with motors in the power range > 1 kW to > 250 kW.
- Silencer can be eliminated because the DPFi system achieves nearly equivalent damping.
- Optionally available in "off-board" or "on-board" control version

Registration and Testing

VERT®, EMPA, BAFU-Switzerland and EST-London

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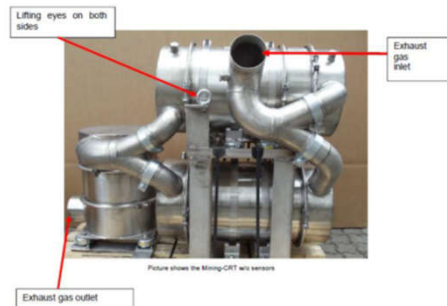


Mining CRT®

Original JM/DPF system installed Apr 2014 – May 2015

- Operating hours = 2,000, total hours with idling = 2,500
- Original DPF filter sent from Sudbury to JM/Germany to be cleaned (as per project requirement criteria) - JM/Germany issued technical report & recommendation.
- The amount of oil ash and unburnable deposits found during the filter cleaning are still in a normal range.
- Testing of the NO₂ decomposition catalyst had shown no decrease in activity.

Reference: MDEC 2015, J Stachulak, C. Allen, History of Diesel Emission Projects



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Mining CRT®

Back up DPF filter installed May 2015 – Sep 2017

- Operating hours = 2,576, total hours with idling = 3,220
- Back-up DPF filter sent to JM/Germany to be cleaned- JM/Germany issued technical report & recommendation
- A filter cleaning interval at above 3,000 hours is reachable.
- Testing of the decomposition catalyst has shown a good activity and no degeneration for NO₂.

Reference: Technical report, Peter Werth, Johnson Matthey, 23rd January 2018



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Mining CRT®

Original DPF filter reinstalled March 2017 – Aug 2019

Operating hours = 4,400, total hours with idling = 5,500

No cleaning required yet.

Original DPF accumulated 6,400 total operating hours or **8,000 total hours** with idling

Only one cleaning and one catalyst replacement (due to destructive testing in original program)

Average 281°C temperature
Back pressure 59 mbar average

Reference: Technical report, Peter Werth, Johnson Matthey, Aug 2019



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Thank You
Questions?
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