Mining Emissions/Control Technologies

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Overview

- Donaldson’s background
- Emissions overview
- Emissions technologies for underground mines
  - Current
  - Options for the future

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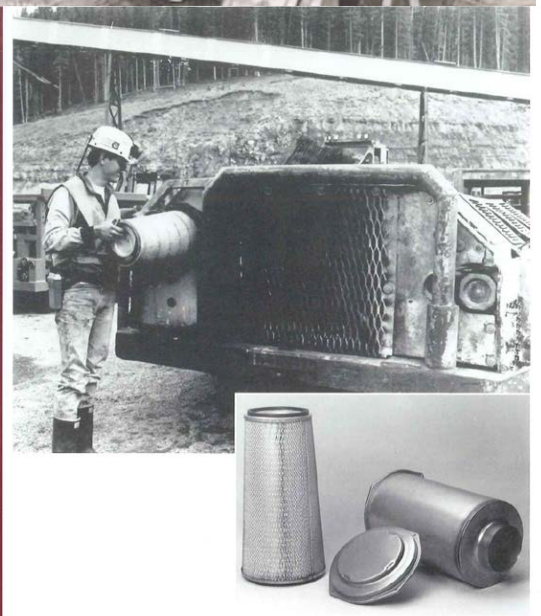
Donaldson at a glance

- Founded in 1915
- Global company with 14,000+ employees in 37 countries
- Diversified product range, focused on filtration
- Since 1950's manufacturing mufflers
- Exhaust aftertreatment for Heavy Duty Diesel market since 1990
- Developed the first underground exhaust filter with the Bureau of Mines in 1991

Frank Donaldson's first air cleaner design



Donaldson disposable diesel exhaust filter for coal mines

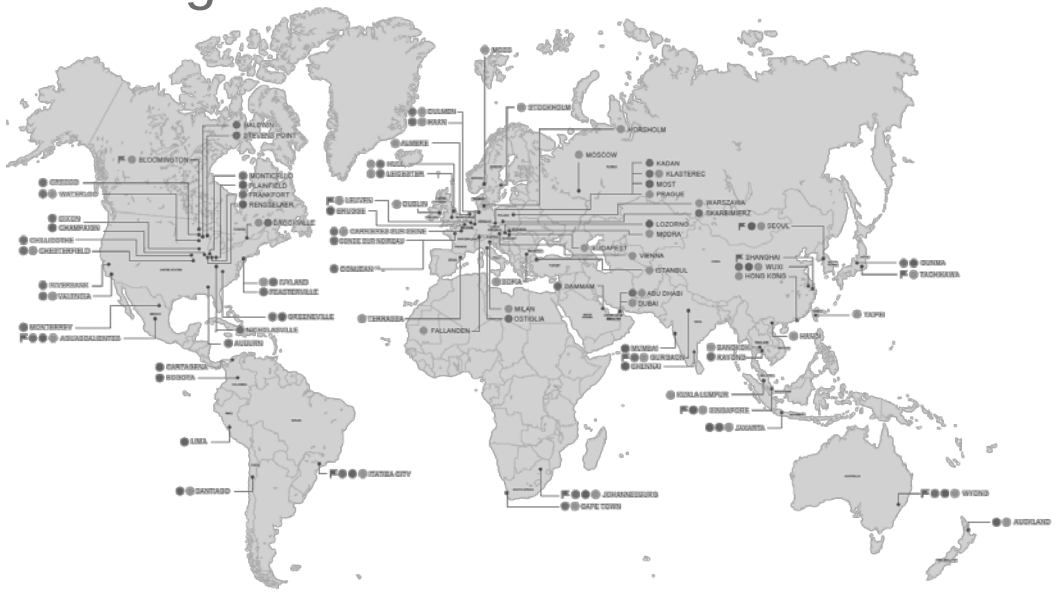


Image from Donaldson bulletin #50-341

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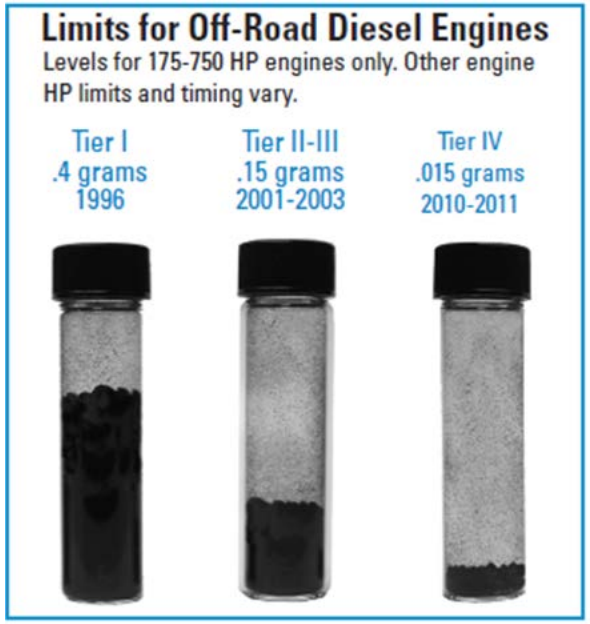
Emissions Overview

- On-road heavy duty trucks lead emissions changes from 1988 to 2010 reducing NOx ($NO + NO_2$) and Particulate Matter (PM)
  - Combination of: engine, fuel, aftertreatment, etc.
- Off-road applications have followed similar trends and technology from 1996 to 2014.



PM limits
(grams per horsepower hour)

Off Road Emissions Requirements

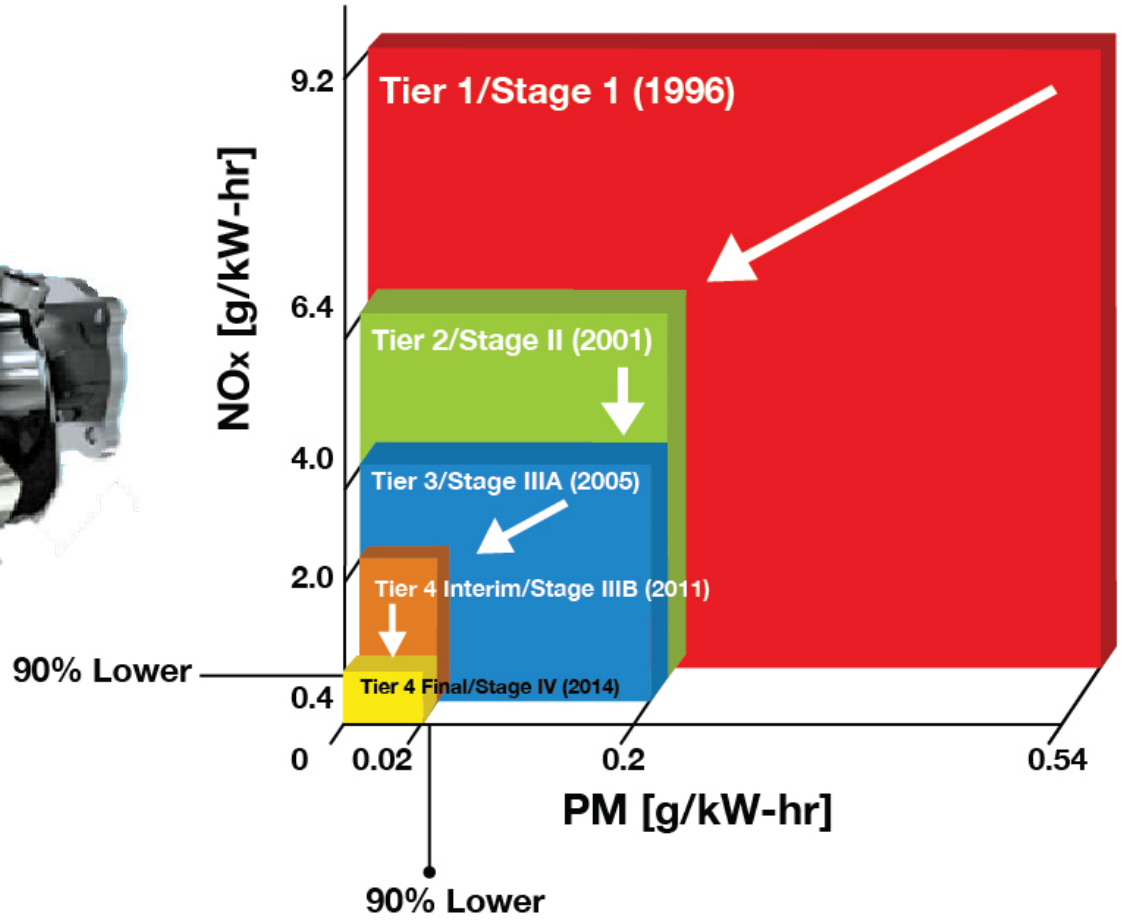


Image from https://www.perfectfuel.ca/understanding-clean-green-fuel/

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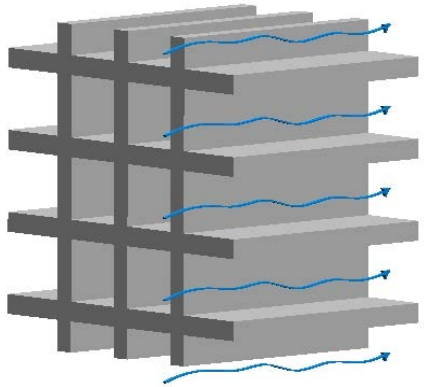
Emissions Overview

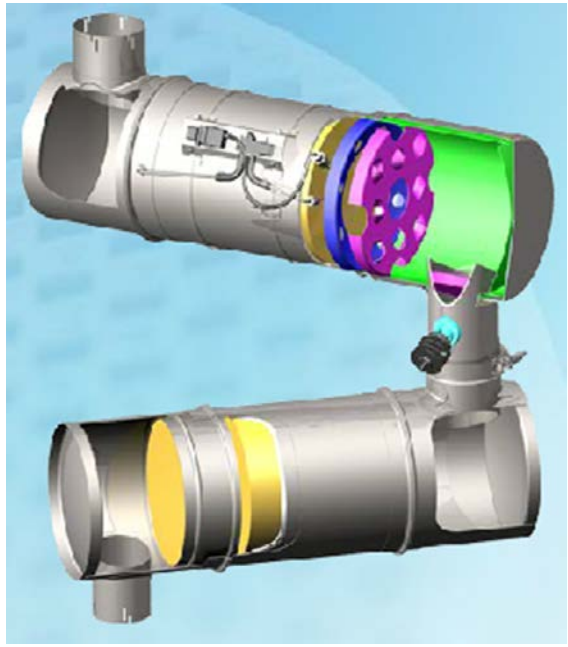
- Diesel Oxidation Catalyst (DOC)
  - Oxidizes: particulate matter (PM), CO, and Hydrocarbons
  - Flow through substrate
  - 15-20% PM reduction

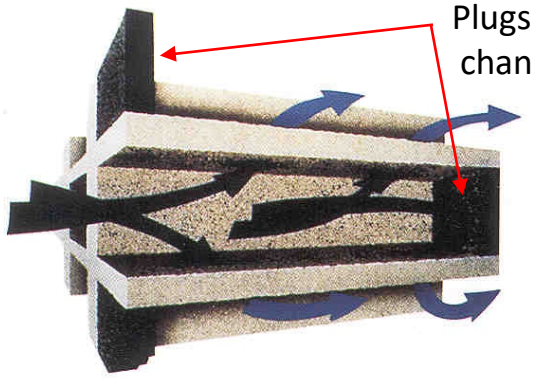


Flow through substrate

- Diesel Particulate Filter (DPF)
  - Traps PM, then burns it off (regenerates), leaving only ash
  - Regeneration can be active (added heat) or passive
  - Wall flow substrate
  - 85-90+% reduction in tailpipe PM

- Selective Catalytic Reduction (SCR)
  - Requires injection of Diesel Exhaust Fluid (DEF = 32% Urea)
  - Converts urea to ammonia (NH3) so NOx can be reduced on the SCR
  - Flow through or wall flow substrate
  - 80-99+% reduction in tailpipe NOx





Wall flow substrate

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Current Mining Emissions Technology

Used in permissible and non-permissible applications

Dry Scrubber

- Description: Uses a shell and tube heat exchanger to cool exhaust gas before collecting soot on a disposable exhaust filter
- Requirements: Heat exchanger and filter housing
- Pros:
  - Low surface and exhaust temperature
  - Permissible
- Cons:
  - High cooling load on engine
  - Maintenance: cleaning heat exchanger
  - Replacing exhaust filter
  - High cost
- Barriers: None

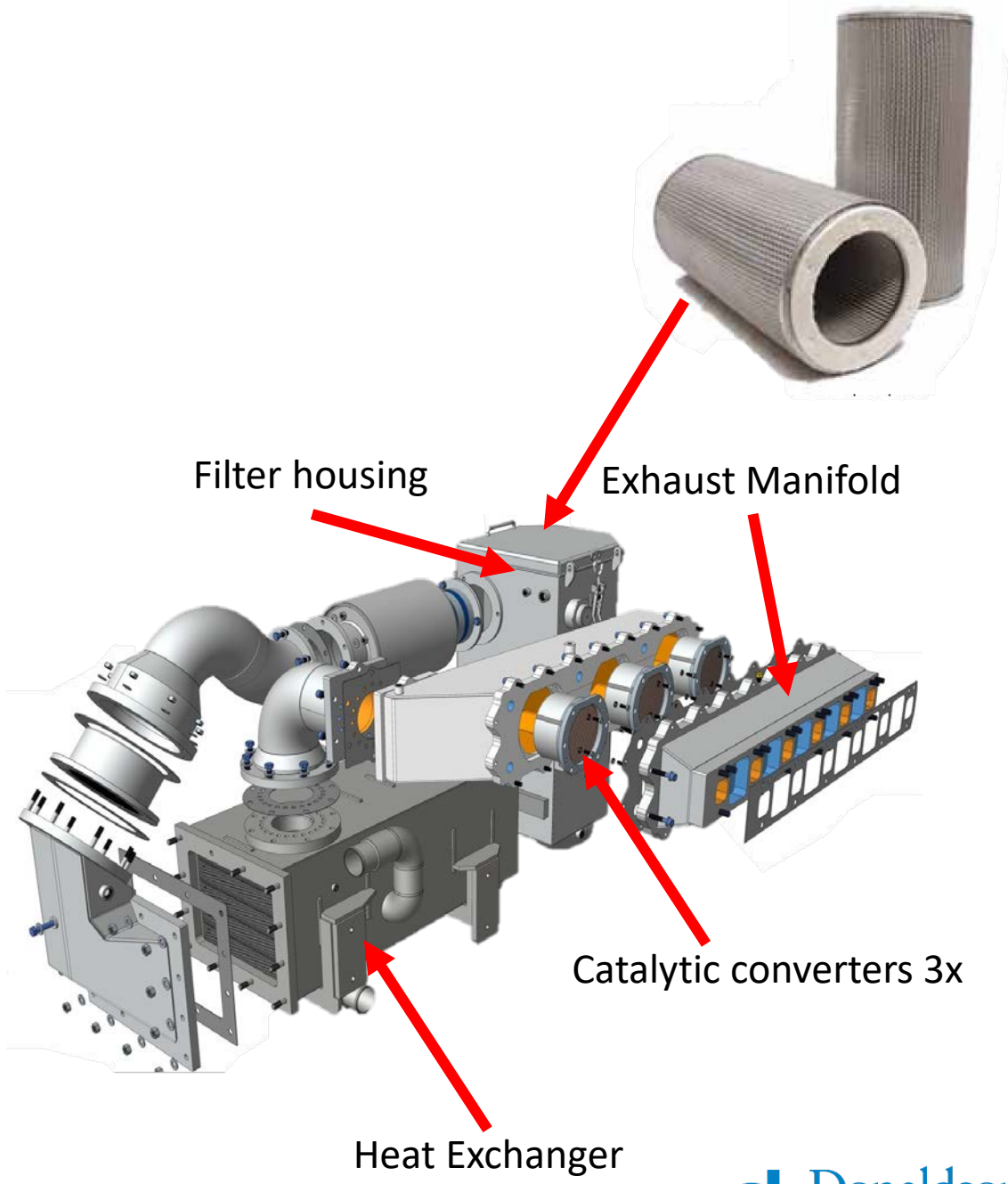

Image curtesy of Torque Enterprises

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Wet Scrubber

- Description: Uses a water bath to cool exhaust gas before collecting soot on a disposable exhaust filter
- Requirements: Scrubber housing
- Pros:
  - Low surface and exhaust temperature
- Cons:
  - Maintenance: Refill water tank and clean scrubber housing
  - Weight of water housing
  - Wet sludge is produced
  - Humidity and water affects filter life
  - Replacing exhaust filter
  - High cost
- Barriers: None

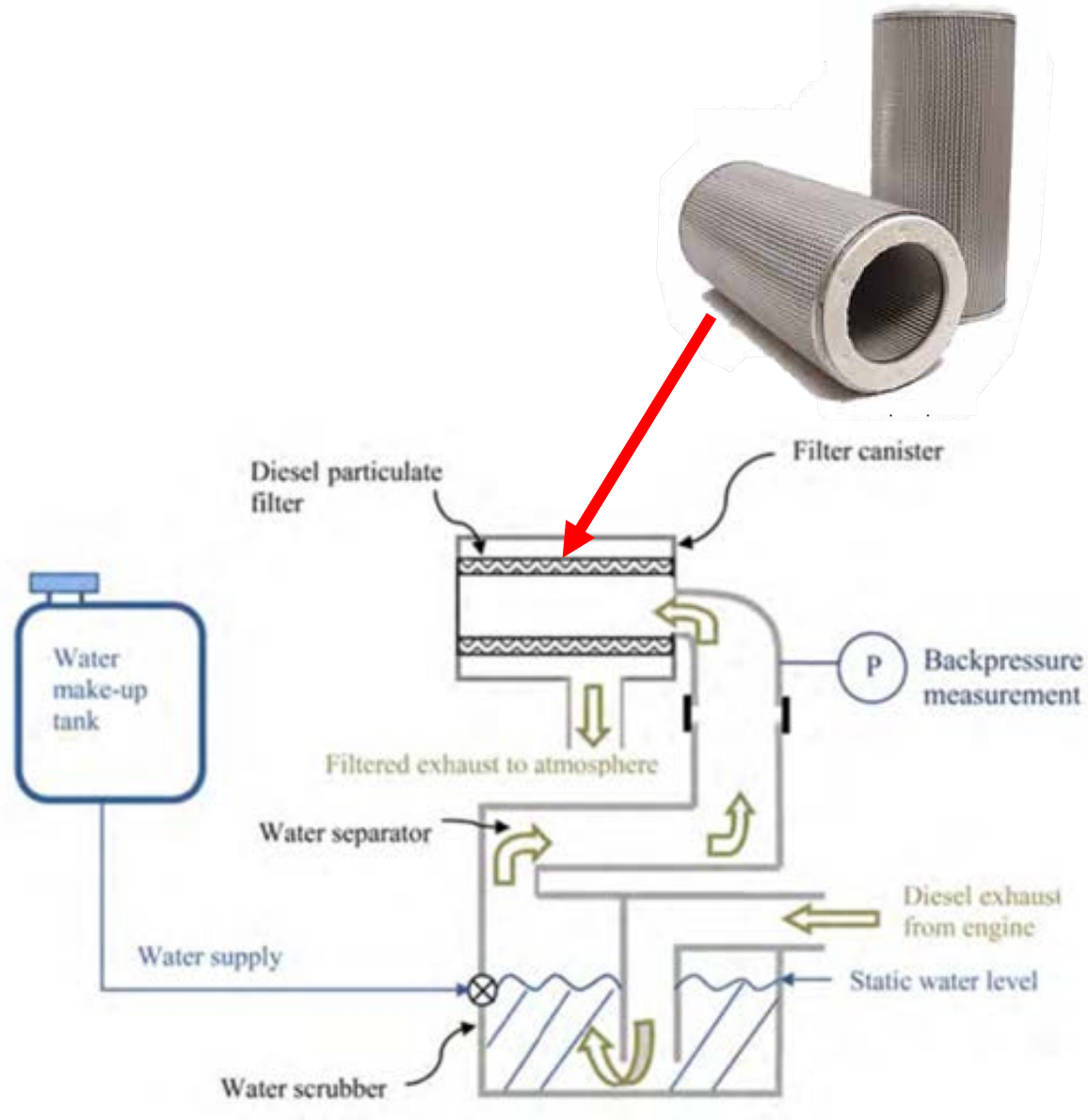

Image from https://www.researchgate.net/publication/328678284_Underground_Diesel_Exhaust_Wet_Scrubbers_Current_Status_and_Future_Prospects

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Options for the Future

Used in non-permissible applications

Modifications required for permissible applications

Passive Regenerated Ceramic Filters (DOC and DPF)

- Description: DOC and DPF system that runs at elevated temperatures to regenerate.
- Requirements:
  - Typical full load exhaust temperatures are up to 600°C (1112° F)
  - Sensors: Temperature and delta pressure
  - Electronically controlled engine
- Pros:
  - Lower operating costs than wet or dry scrubber.
  - High PM and HC reduction no break in period
  - No downtime for regeneration
- Cons:
  - Exhaust gas is not cooled
  - Requires high duty cycle (hot exhaust to clean filter)
  - May require filter removal if regeneration is not adequate
  - Ceramics are fragile
  - Potential for NO2 production
- Barriers:
  - Surface temperature of components
  - Electronics (Permissible locations)

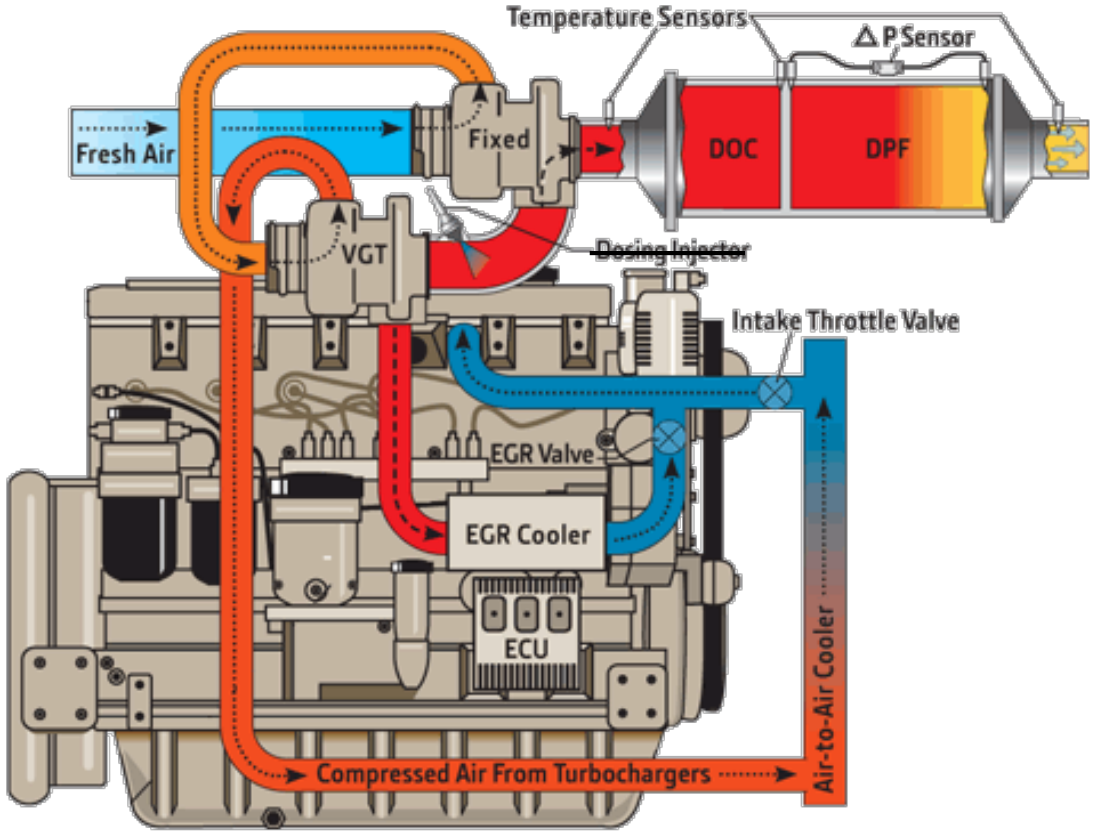

Image from https://www.deere.com/en/campaigns/engines-and-drivetrain/diesel-engine-technology/

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Active Regenerated Ceramic Filters (DOC/DPF)

- Description: DOC and DPF system that increases temperatures at set limits (time or backpressure) to regenerate.
- Requirements:
  - Electronically controlled engine
  - Requires either fuel injection into exhaust or electrical heater for regeneration.
  - Sensors: Temperature and delta pressure
- Pros:
  - Very high PM and HC reduction
  - Can control when regeneration will occur (i.e. outside of mine)
  - Lower operating costs than wet or dry scrubber.
- Cons:
  - Exhaust gas is not cooled
  - Additional energy in exhaust for regeneration
  - Down time for stationary regeneration
  - Ceramics are fragile
  - Potential for NO2 production
- Barriers:
  - Surface temperature of components
  - Electronics (Permissible locations)

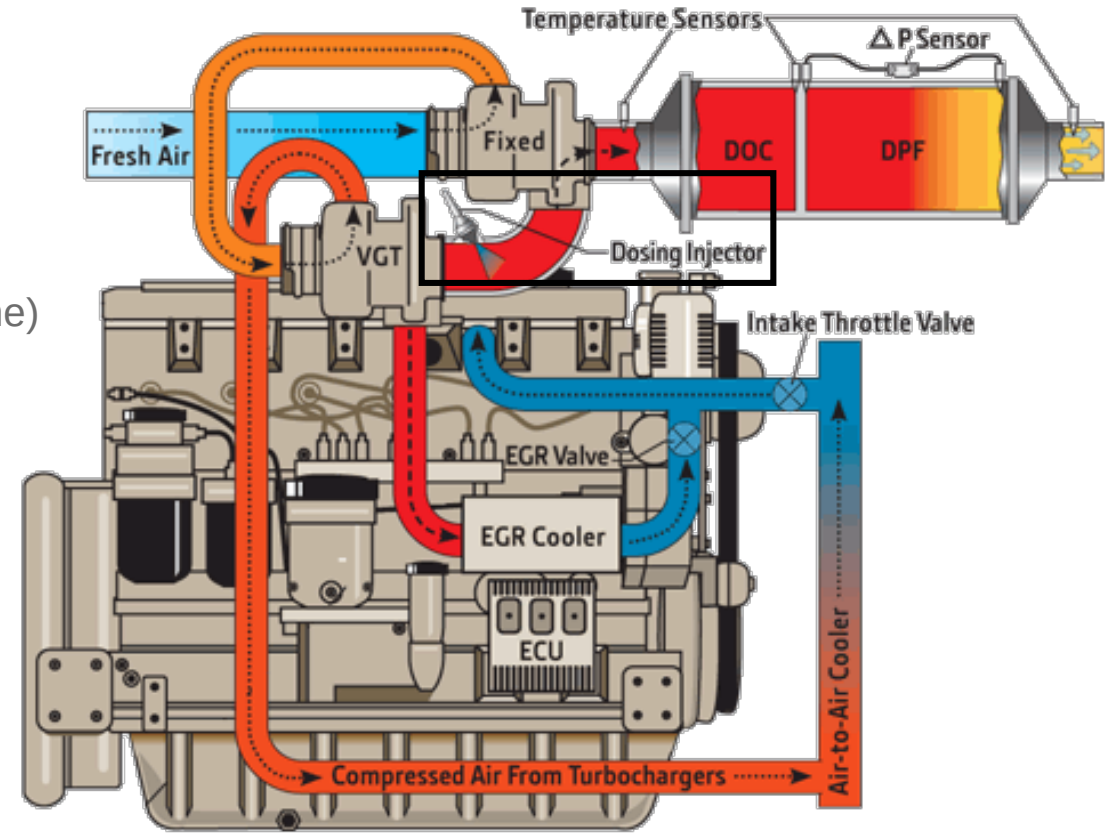

Image from https://www.deere.com/en/campaigns/engines-and-drivetrain/diesel-engine-technology/

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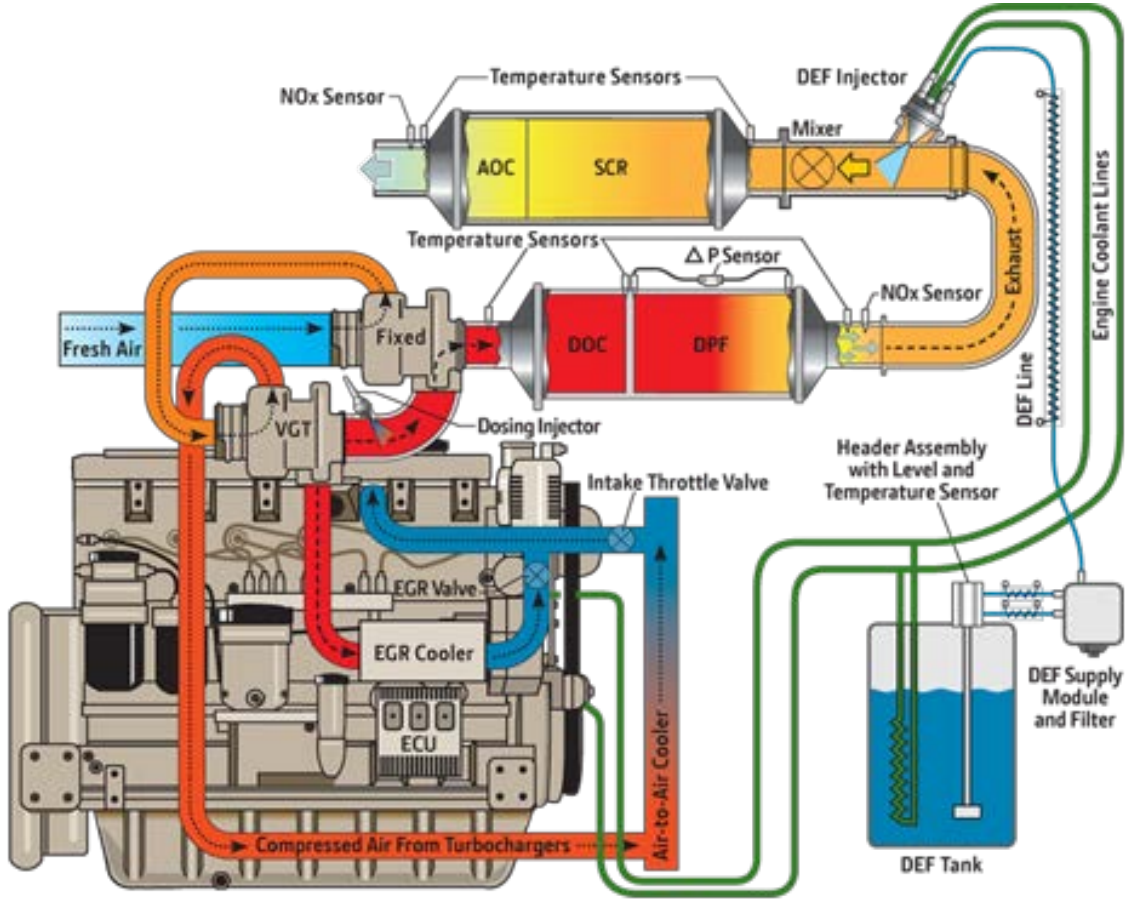
Active Regenerated Ceramic Filters (DOC/DPF/SCR)

- Description: DOC, DPF and SCR system that increases temperatures at set limits (time or backpressure) to regenerate.
- Requirements:
  - Electronically controlled engine
  - Sensors: Temperature, delta pressure, NOx
  - DEF (Urea) tank, pump, injector, mixer, SCR
- Pros:
  - Very high PM, HC and NOx reduction
  - Can control when regeneration will occur (i.e. outside of mine)
  - Lower operating costs than wet or dry scrubber.
- Cons:
  - Exhaust gas is not cooled
  - Additional components and need to refill DEF tank
  - DEF will freeze at -11°C (12°F)
  - Poor mixing or low temperatures can form DEF deposits in tailpipe
  - Potential for ammonia in exhaust
  - More expensive than DOC/DPF
  - Ceramics are fragile
  - Potential for NO2 production
- Barriers:
  - Surface temperature of components
  - Electronics (Permissible locations)



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Questions for Industry

- To improve wet and dry scrubber filters design:
  - What is a typical duty cycle of the equipment?
  - What are your targets for:
    - Life (replacement interval)
    - Operation cost
    - Efficiency
    - Permissible or non-permissible location
  - Are there special requirements?
- To implement new technology
  - Retrofit existing or new engine?
  - Surface and exhaust temperature requirements?
    - 30 CFR
  - Are there special requirements?
    - Low sulfur fuel at mines?
  - Permissible or non-permissible location?

Summary

- Donaldson developed the initial underground exhaust filters.
- Improvements to existing dry and wet scrubbers can be made but we need feedback on the targets customers want.
- Higher PM and NOx efficiency are available for mining applications using Tier 4/Stage 5 aftertreatment technology.
  - Clear customer specifications and requirements are needed to correctly implement this technology underground.
  - Certain applications will require additional changes (and validation) for underground mines.

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THANK YOU

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