Mining Emissions/Control Technologies

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Overview

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

- On-road heavy duty trucks lead emissions changes from 1988 to 2010 reducing NOx (NO + NO₂) and Particulate Matter (PM)
  - Combination of: engine, fuel, aftertreatment, etc.
- Off-road applications have followed similar trends and technology from 1996 to 2014.

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

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

- 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
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
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
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)

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)

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)

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.
THANK YOU
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