A Strategy for Deployment of Diesel Particulate Filters (DPFs)

An Overview of the NIOSH-MSHA DPF Selection Guide

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Situation I

- Area/personal sampling resulted in TC levels in neighborhood of 500 µg/m^3
- Vehicle deployment, and ventilation analysis has targeted a vehicle
- Use new engine, de-rate engine, increase ventilation, biodiesel fuel (affects all vehicles), may be all that is needed for now

Situation II

- Area/personal sampling resulted in TC levels in neighborhood of >800 µg/m^3
- Vehicle deployment, and ventilation analysis has targeted a vehicle for substantial emissions reduction by diesel particulate filter (DPF)
- You were picked to handle this…What do you do now?

You're it! What now?

- Attending this workshop is a good start
- Use the new NIOSH-MSHA filter selection guide available *now* on the web …
- Let's consider the DPF system:
  - Device installed on engine-vehicle
  - May affect vehicle operation and schedule
  - Vehicle operator will have responsibilities
  - Will require routine maintenance – engine & DPF
  - May require increased technical skills
  - May require changes to ventilation (unlikely)

Coordination Required

- DPF Selection: based upon exhaust temp, vehicle deployment & schedule, available systems – MUST BE A FIT between DPF and equipment
- Installation: location, mounting, vibration isolation, insulation (in some cases), isolated from combustibles, not block engine maintenance, etc.

Coordination Required

- Maintenance: New procedures and tasks both to engine and to the DPF. Additional pressure monitoring systems, electric regeneration systems will require service. – additional daily or PM tasks
- Equipment operator: DPF may need daily attention; back pressure monitoring and actions to be taken when it alarms…

Coordination Required

- Site alterations for regeneration—electrical, space, ventilation
- Training: Maintenance & engine mechanics (could be a contractor), vehicle operator.
- Follow-up environmental measurements: Ventilation, DPM, gas measurements if affected by DPF (NO_2 for example)

Multidisciplinary task requiring coordination of several mine departments or persons who must work as a team.

DPF "Champion" is needed

- DPF deployment is not the "norm."
- Requires additional knowledge
- Demands teamwork and cooperation of many mine people and functions
- Mine management must provide the authority and responsibility
- Must be part of the job, not incidental, not treated superficially, at least initially

DPF Requirements -- Engine

DPFs collect soot → the more the engine produces the more must be trapped and must be gotten rid of

Ensure Lowest Engine PM Emissions

- If 2-stroke engine, consider replacing it
- Check oil consumption & fix if above normal
- Check CO emissions from bare engine (w/o DOC) and reduce to "normal" for that engine model; use emissions based maintenance
- Continually track & correct above items if using DPFs (best that it be done for all diesel equipment) – institute emission-based maintenance

…Low Engine PM Emissions

- De-rate the engine, if possible.
  - Lower PM emissions – less soot to deal with
  - Smaller DPF possible
  - Less fuel consumption
  - Less wear & tear on the tires, etc.
  - Consequence: may have to change torque converter and/or gearing, and
  - May not need DPF!

Exhaust Temperature Profiling

- Why profile?
- Who should do it?
- How to do it yourself

Why profile?

- DPF selection

Whether a DPF can self-regenerate or must be manually regenerated depends entirely on the exhaust temperatures over the shift

- Provide details of engine loading over the shift; engine idle vs. work times, etc. – duty cycle profile

Who should do it - alternatives

- Yourself or your staff
- Hire a contractor
- Use a DPF supplier

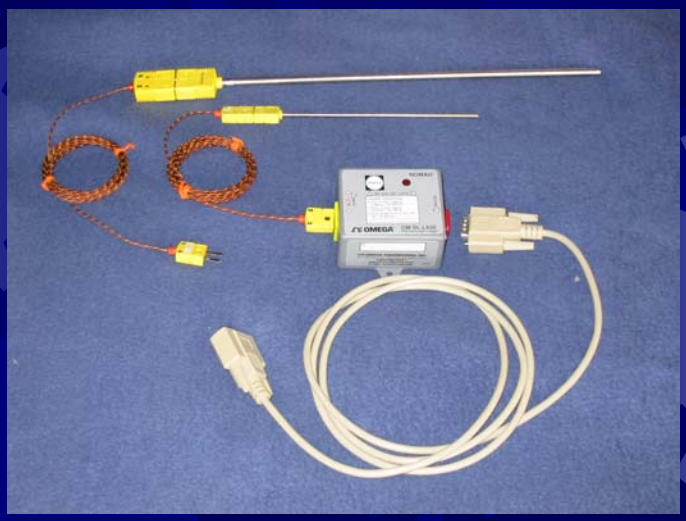
Weigh the pros and cons of each, but whatever your choice, *make certain that you own the data*.

How to do temp profiling yourself, -1

Mention of any company name or product does not constitute endorsement by the National Institute for Occupational Safety and Health.

- Purchase the following:
  - Type K, stainless jacketed thermocouple (TC)
  - Miniature battery-powered data logger
    - OMEGA OM-SL L620
    - HOBO H12-002 + BC3_7-ON
  - 10’ TC extension with Plug and Jack connectors
  - Pipe to compression fitting to hold TC

Temp Profiling Equipment



Temp Profiling, How to, – 2

- Locate TC in exhaust system where inlet to DPF would be
- Locate a place on the circumference where there is clear access for TC
- Perforate exhaust pipe with ½" hole and weld ½" pipe coupling to surface over the hole
- Install TC in fitting and adjust so tip is in the center of the exhaust pipe

Temp Profiling, How to – 3

- Mount the data logger in a protected location away from heat
- Route extension between logger and TC in exhaust keeping clear of moving parts
- Use tie wraps or bailing wire to secure logger and extension wire

Temp Profiling, How to – 4

- Start logger at start of shift; stop logger at end of shift; identify vehicle and shift in a record book
- At end of each shift, download data according to logger instructions; reset logger
- Repeat so that the full variety of shifts for this equipment is represented several times
- Use logger software to save temperature data in degrees C as a *.txt file compatible with Excel® or other spreadsheet software.

Temperature data analysis

- Load/import data into a blank spreadsheet
- Open the NIOSH analysis spreadsheet
- Copy data
- Look at results:
  - What is the temperature where 30% of the data points are higher?
  - Look at many of the shift logs and note the lowest "30%" temperature, $T_{30\%}$ of the bunch.
- Select a DPF system

Caveat: The above is an unsophisticated analysis; DPF suppliers may use a more comprehensive analysis

Exhaust temperature implications

- $T_{30\%}$ is >325°C – a self-regenerating "passive" DPF is possible
- $T_{30\%}$ is <325°C – a manually regenerated "active" DPF is required

Passive (self-regenerating) DPFs

- $T_{30\%}$ >550-600° C, uncatalyzed "bare" trap
- $T_{30\%}$ >380-420° C, base-metal catalyzed trap
- $T_{30\%}$ >3xx° C, "5g" Pt-catalyzed trap
- $T_{30\%}$ >330° C, lightly Pt-catalyzed trap + fuel borne catalyst (new information)
- $T_{30\%}$ >325°C, "50g" Pt-catalyzed trap

The above temperatures are approximate; only the DPF supplier can properly make the recommendation.

~~UPDATED INFORMATION~~

Self-regenerating (Passive) DPFs

$T_{30\%}$	*System*
>550-600°C	Uncatalyzed "bare" DPF
>380-420°C	Base-metal catalyzed DPF
>3xx°C	"5g" Pt catalyzed DPF
>340 °C	Lightly Pt-catalyzed DPF + fuel borne catalyst
>325°C	"50g" Pt-catalyzed DPF

The above temperatures are approximate; only the DPF supplier can recommend the proper DPF system.

Passive DPF Considerations

- Consistent work cycle required; exhaust temperatures must always be high enough several times during shift to ensure proper soot removal
- Consequence of insufficient regeneration is the increase in exhaust backpressure
  - Increases forces on DPF (164 lbs @ 12" dia, 42 in WG)
  - May invalidate engine warranty

MUST INSTALL BACK PRESSURE MONITOR and ALARM

- PT-catalysts (50g loading)

  Observed increase in NO_2 emissions depending on Pt loading

SAMPLE WORKPLACE FOR NO_2 AFTER INSTALLING A Pt-Catalyzed DPF

Passive DPF Installation Considerations

- Minimize the exhaust run between engine and DPF
- Ensure upstream pipe connections do not leak
- Insulate exhaust pipe between engine and DPF
- Insulate DPF
- Reminder: Install Back Pressure Monitor & Alarm with logging
- Continue: Temperature logging

Post DPF Installation Tasks

- At engine PM, make Bacharach smoke number measurement downstream of DPF – keep records
- Examine back pressure logs or interview operator about normalcy of BP readings or alarms
- Periodically (~1000 hrs) rid the DPF of ash build up (DPF Cleaning) in method approved by manufacturer

Bacharach True Spot Smoke Test

Back

Manually Regenerated (Active) DPFs

- Can be used at *any* exhaust temperature
- *Must* be used if exhaust temperature profile indicates that the temperature is under 325 to 350 °C for more than 70% of the time (equivalent to saying only 30% of the temp data lies over 325-350°C).

Manually (Actively) Regenerated DPFs

Regeneration Location	*Options*
Off-board	DPF Exchange
On-board	On-board controllers
	Off-board controllers

Off-board Regen Considerations ~DPF Exchange~

- DPF size – keep small enough for one person to handle easily; use multiple DPFs for large engines
- Locate DPF on equipment for easy access
- Gas-tight flange, quick disconnect
- Develop DPF exchange logistics
  - When (between shifts)
  - Who
  - Where
  - DPF transport
- Regeneration station location

Off-Board Regen – Vehicle

Off-board regen station

On-board regeneration with On-board regeneration controller

- DPF can be located anywhere on vehicle
- Keep combustibles clear of DPF
- Need 1 – 2 hr of equipment off-duty time daily or between shifts
- Requires only a connection to electrical power for regeneration → flexible regen locations
- Moderate ventilation required during regen
- On-board controller subjected to vehicle shock and vibration → must be robust

On-board regeneration Off-board regeneration controller

- DPF can be located anywhere on vehicle
- Keep combustibles clear of DPF
- Need 1 – 2 hr of equipment off-duty time daily or between shifts
- Requires air, sensor, power connections to a regeneration control station
- Vehicle must be parked at a control station for that system model → restricts end-of-shift parking locations
- Moderate ventilation required during regen

Post DPF Installation Tasks Manually regenerated DPFs

- At engine PM, make Bacharach smoke number measurement downstream of DPF – keep records
- Interview operator about normalcy of BP readings or alarms; do not operate vehicle for extended periods with high back pressures
- Stress to operator the need to exchange or regenerate DPF at the prescribed intervals
- Periodically (~1000 hrs) rid the DPF of ash build up (DPF Cleaning) in method approved by manufacturer

Filter Selection Guide

- Demo – go there

Resources

- Diesel-underground-L listserver
  JOIN diesels-underground-L *your name*
  Listserv@listserv.cdc.gov
- DPF Selection Guide – hot exhaust filters
  - MSHA web site
  - NIOSH, mining toolbox
- www.dieselnet.com
- NIOSH IC9462