Bus Fleet of Santiago de Chile with DPF

Experience with Respect to Maintenance and Control.

Study in charge by Ministry of Environment

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OVERVIEW

• Partnership project
  – Chilean Ministry of the Environment (MMA).
  – Climate and Clean Air in Latin American Cities (CALAC).
  – Swiss Agency for Development and Cooperation (SDA/COSUDE).

• Follow up of DPF implementation project during 2005-2013.

• Target fleet of 3,200 buses with CRT-DPF systems (1,000 retrofitted + 2,200 OEM).

• DPF aged between 150,000 to 750,000 km (325,000 average).
OVERVIEW

• PN random roadside measurements of 400 buses (223 w/DPF), at the end of pipe.

• DPF-Efficiency, in-depot PN measurement, for 22 buses, at exhaust upstream and downstream of DPF, to compare with roadside results.

• Using NPET-TSI, new CH-METAS certified portable, low cost, highly sensitive PN number counting instrument (SR 941.242).

• Outcomes:
  – to evaluate DPF conditions after considerable milage.
  – to implement solid PN measurement for road side control.
• Historically road side opacity control has been important tool in order to enforce HDV inside of the city (to prevent cheating to pass periodic technical inspection).

• Shorter than 2 minutes control (similar to traffic red light).

• A more sensitive instruments than opacimeter is required (considering characteristics of modern engines and DPF).
Places of measurement campaign
Measurement Protocol

- **Roadside:** Opacity and PN at end of pipe during free acceleration, high idle and low idle.
- **In-Depot:** At low idle speed engine because low idle permits to measure PN of gross engine emissions inside of equipment range (\(< 5 \times 10^6\))
30% of opacity results were close to 0 [1/m] (or below 0.025 [1/m]) but with results between 10E+2 to 10E+9 [#/cm³] in PN (including W/DPF and WO/DPF).
End of pipe PN Limit to detect Abnormal Emissions

- Binned bus measurements into log-spaced concentration ranges.
- Separation in bimodal structure (normal and abnormal), clearest for low idle.
- Low Idle speed is easier to implement in road side control (no driver or RPM electronic control interferences).
- Bimodal structure determines limit of $2.2 \times 10^5$ [#/cm$^3$] as threshold.

<table>
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• 22 buses, PN measured at low idle downstream/upstream of DPF.
• All buses with $\eta>95\%$ passed limit ($\eta_{\text{Average}} = 99.5\%$)
• All but one bus with $\eta<90\%$ failed limit ($\eta_{\text{Average}} = 50\%$)
• Reference proposed limit of $2.2\times10^5$ $\#/\text{cm}^3$ could be a good indicator of low efficient DPF.

![Graph showing DPF Efficiency results vs end of pipe threshold](image-url)
Abnormal emissions are concentrated in early stage of implementation (more mileage DPF, wo/pressure monitoring, weak local support, best practices for engine and DPF maintenance not implemented yet).

Complementary specific efficiency test are necessary to discard high gross engine emitters like the cause.

Considering >95% of efficiency, gross engine emissions had to be > 4.4x10^6, in order to exceed the threshold.

Few cases of gross engine emissions > 4.4x10^6 were detected in same kind of buses measured without DPF (3%).
Conclusions

• Solid particle number concentration is a more sensitive metric than opacity for determining DPF condition.

• PN limit of $2.2 \times 10^5 \# / \text{cm}^3$, at Low Idle speed,
  • Could be a good indicator for detecting filters with $\eta < 90\%$, on road side control.
  • Additional data is necessary before set a final limit (end of pipe and efficiency tests).
  • For rejected buses a confirmation with Efficiency test, in depot, should be necessary (useful information about engine condition should be collected).
Conclusions

• In Santiago, buses above limit concentrated in early implementation stage.
  • When best practices had not been implemented yet.
  • More recent implementation show 9% of abnormal emissions (about 2% by year).
Conclusions

• Good maintenance of Engine is equal or more important than DPF maintenance

  • Cultural change from corrective to predictive maintenance had to be done in Santiago.

  • A periodic enforcement strategy using PN should be done since begging of project in order to detect any problem early (including above Euro 5b Passanger cars with DPF).

  • Additional improvement to backpressure monitoring (like centralized wireless monitor), and diagnosis (like protocols for DOC failures) are needed.
Conclusions

• New CH-METAS certified portable, low cost, highly sensitive PN counting instrument, is going to be a key tool to improve DPF benefits in real word functioning.
Acknowledgements

+ Ministry of Environment, Chile
+ Ministry of Transport.
+ Swiss Agency for Development and Cooperation.
+ CALAC program.
+ VERT.
+ TSI.

Particularly to CALAC Advisory Team:
- Rene Grossman.
- Gerhard Leutert.
- Thomas Lutz.
- Andreas Mayer.
Thank you for your attention!