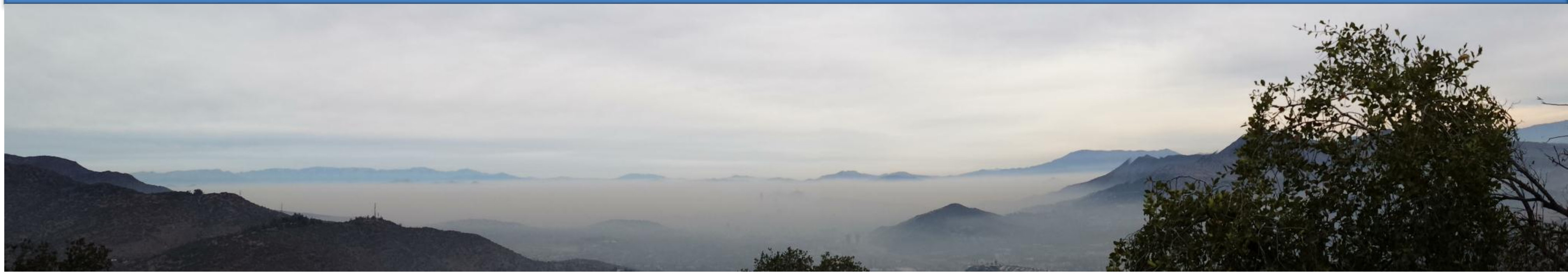
20th ETH-Conference on Combustion Generated Nanoparticles
Focus Event: Particle Filter Quality under Real World Conditions

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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Geasur TECNOLOGIA Y MEDIOAMBIENTE

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.

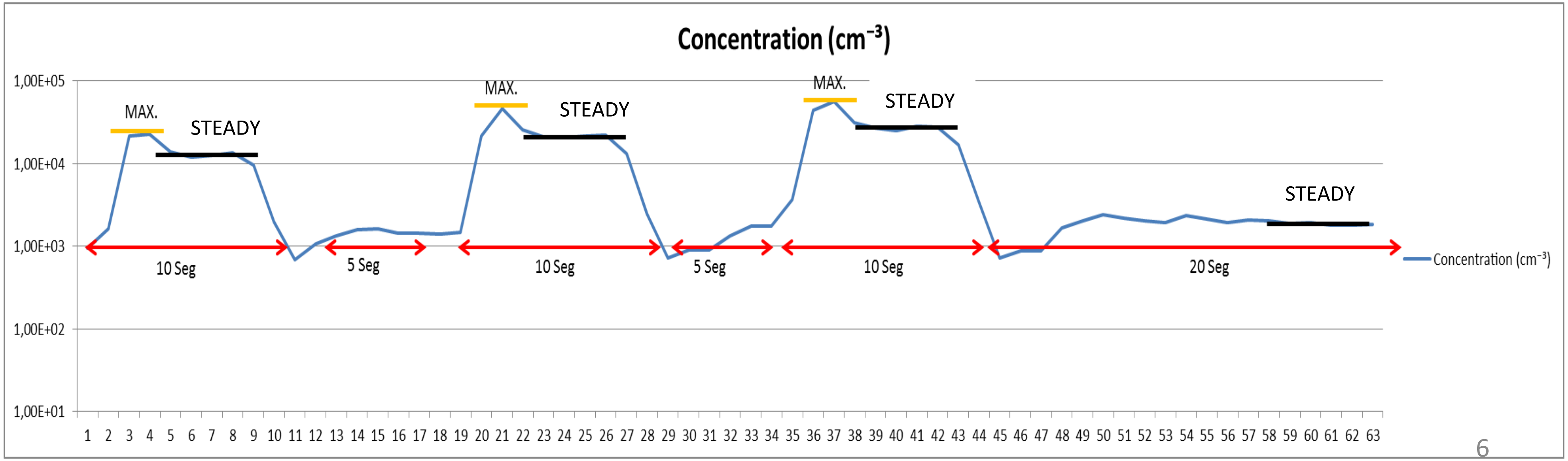
OVERVIEW

- 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).

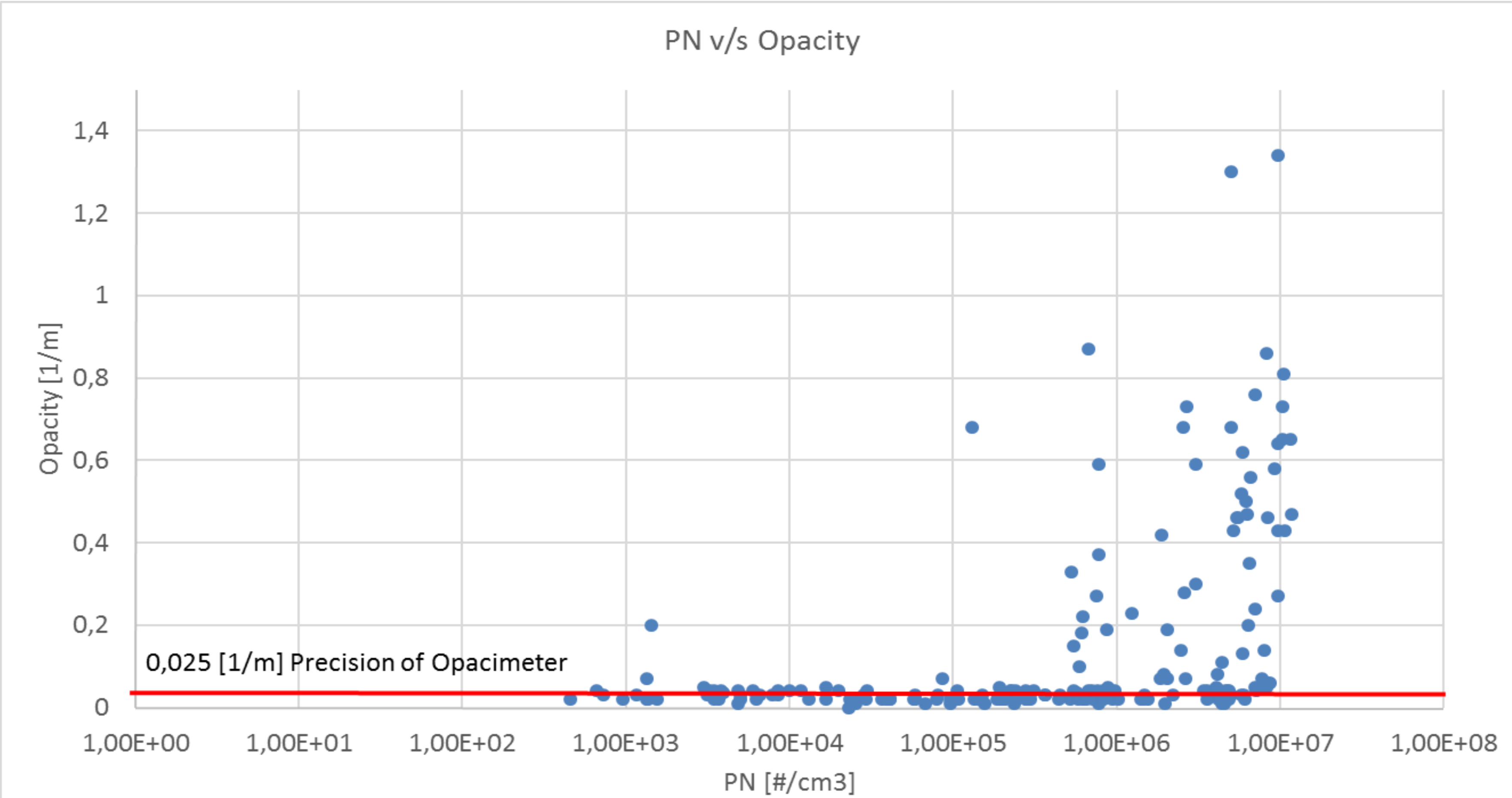
Places of measurement campaign

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 (< 5x10E+6)



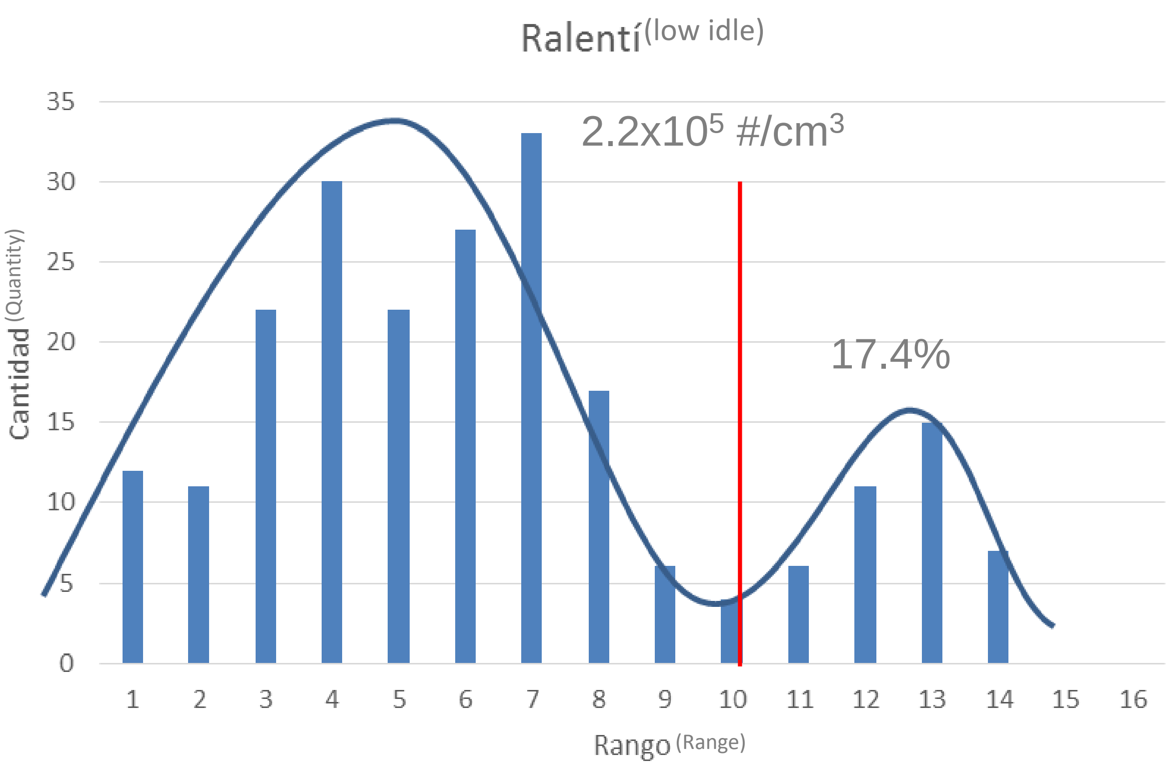
Comparison PN v/s Opacity at Free Acceleration



- 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

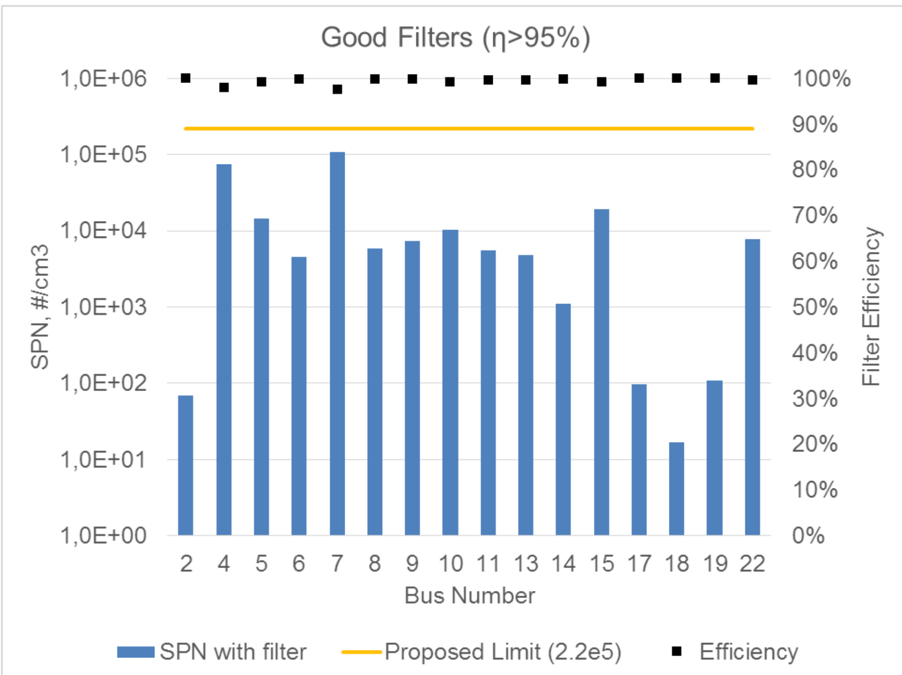
- Binned bus measurements into log-spaced concentration ranges.
- Separation in bimodal structure (normal and abnormal), clearest for low idle.
- Low Idle speed is easier to implement in road side control (no driver or RPM electronic control interferences).
- Bimodal structure determines limit of 2.2x10E+5 [#/cm^3] as threshold.

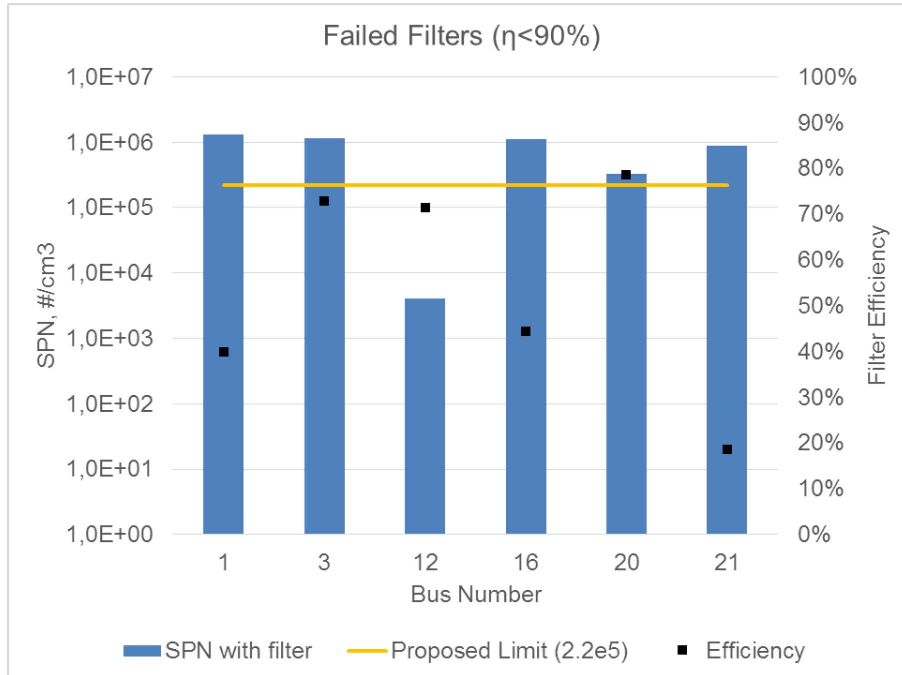


Range	≥	<	N	Condition
1	1,00E+02	2,20E+02	12	Normal
2	2,20E+02	4,70E+02	11	Normal
3	4,70E+02	1,00E+03	22	Normal
4	1,00E+03	2,20E+03	30	Normal
5	2,20E+03	4,70E+03	22	Normal
6	4,70E+03	1,00E+04	27	Normal
7	1,00E+04	2,20E+04	33	Normal
8	2,20E+04	4,70E+04	17	Normal
9	4,70E+04	1,00E+05	6	Normal
10	1,00E+05	2,20E+05	4	Indifferent
11	2,20E+05	4,70E+05	6	Abnormal
12	4,70E+05	1,00E+06	11	Abnormal
13	1,00E+06	2,20E+06	15	Abnormal
14	2,20E+06	4,70E+06	7	Abnormal
15	4,70E+06	1,00E+07	0	Abnormal
16	1,00E+07	2,20E+07	0	Abnormal
		TOTAL	223	

DPF Efficiency results v/s end of pipe threshold

- 22 buses, PN measured at low idle downstream/upstream of DPF.
- All buses with η>95% passed limit ($\eta_{Average}$ = 99.5%)
- All but one bus with η<90% failed limit ($\eta_{Average}$ = 50%)
- Reference proposed limit of 2.2×10^5 #/cm^3 could be a good indicator of low efficient DPF.





Fleet summary considering proposed threshold

Implementation Stage	Number of Abnormal Emissions	Buses Tested	Rate of Abnormal Emissions	Average DPF Milage [km]
2005-2009	21	25	84%	524,341
2010-2013	18	198	9%	297,084
Total	39	223	17,5%	325,920

- 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 2.2×10^5 #/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.

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Thank you for your attention!