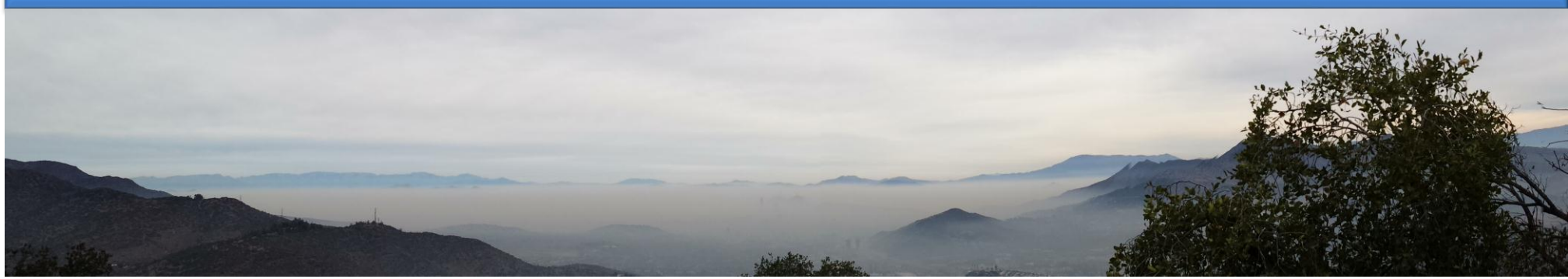
400 Buses Tested following the new concept in Santiago de Chile.



Aliosha Reinoso – Geasur
aliosha.reinoso@geasur.cl
Santiago - Chile

Geasur
TECNOLOGIA Y MEDIOAMBIENTE

OVERVIEW

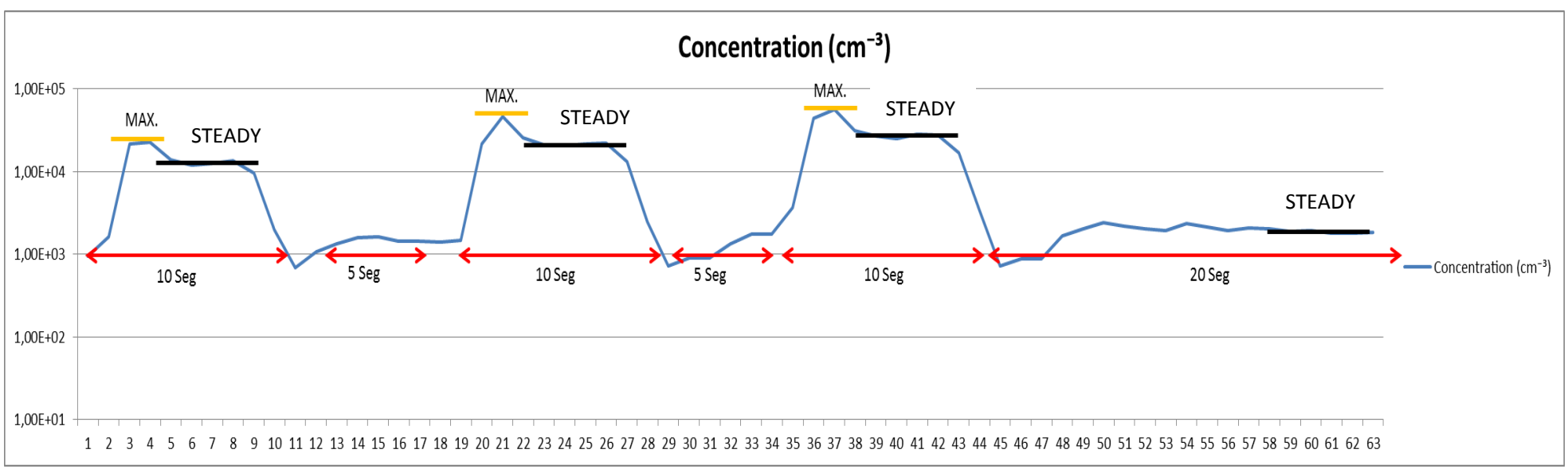
- Partnership between
  - Chilean Ministry of the Environment (MMA).
  - Climate and Clean Air in Latin American Cities (CALAC).
  - Swiss Agency for Development and Cooperation (SDA/COSUDE).
- 3,200 buses with CRT-DPF systems (1,000 retrofitted + 2,200 OEM).
- Follow up of DPF implementation program 2005-2013.
- DPF aged between 150,000 to 750,000 km (325,000 average).

OVERVIEW

- PN random roadside measurements of 400 buses, at end of pipe, to check DPF-quality.
- 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).
- Goal: implement solid PN measurement for inspection.

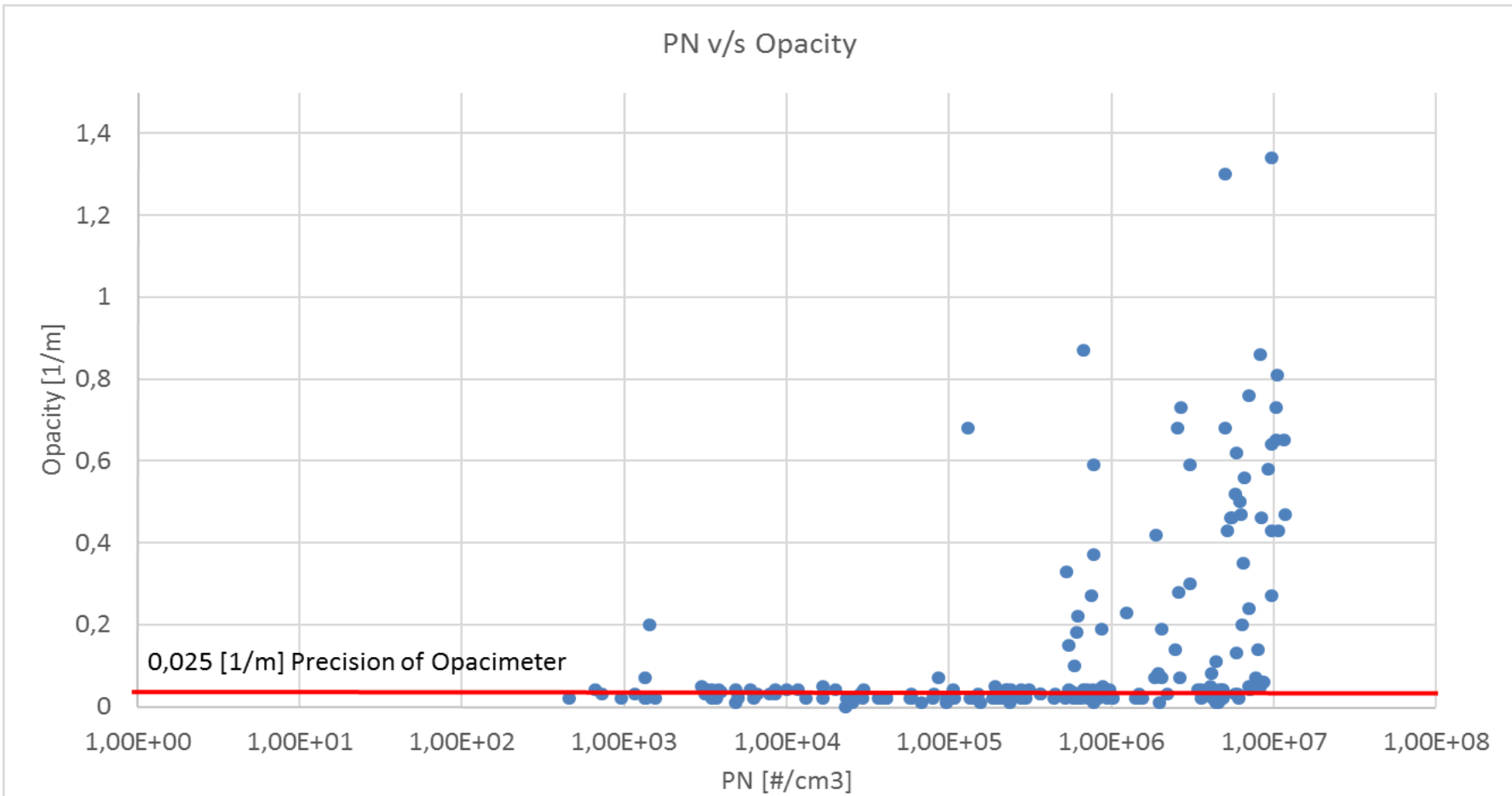
Measurement Protocol

- Roadside: Opacity and PN at exhaust exit during free acceleration, high idle and low idle.
- In-Depot: At low idle speed engine because low idle permit to measure PN of gross engine emissions inside of equipment range (< 5x10E+6)



Places of measurement campaign

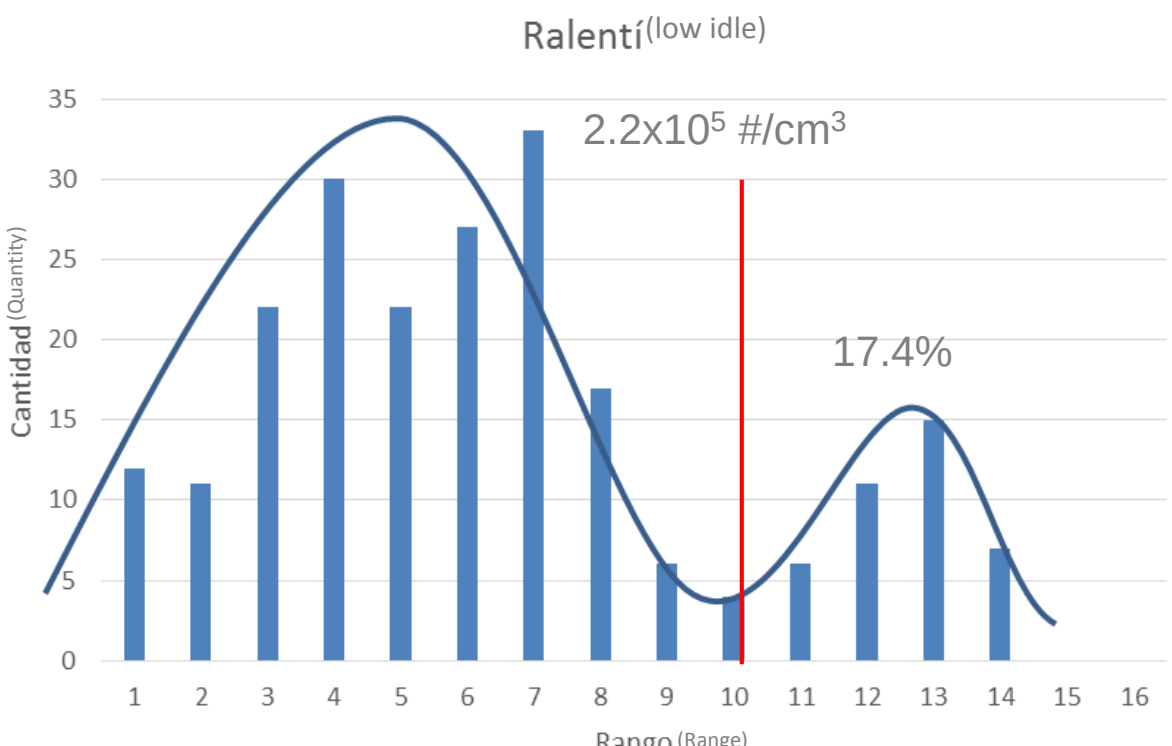
Comparison PN v/s Opacity at Free Acceleration



- 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.

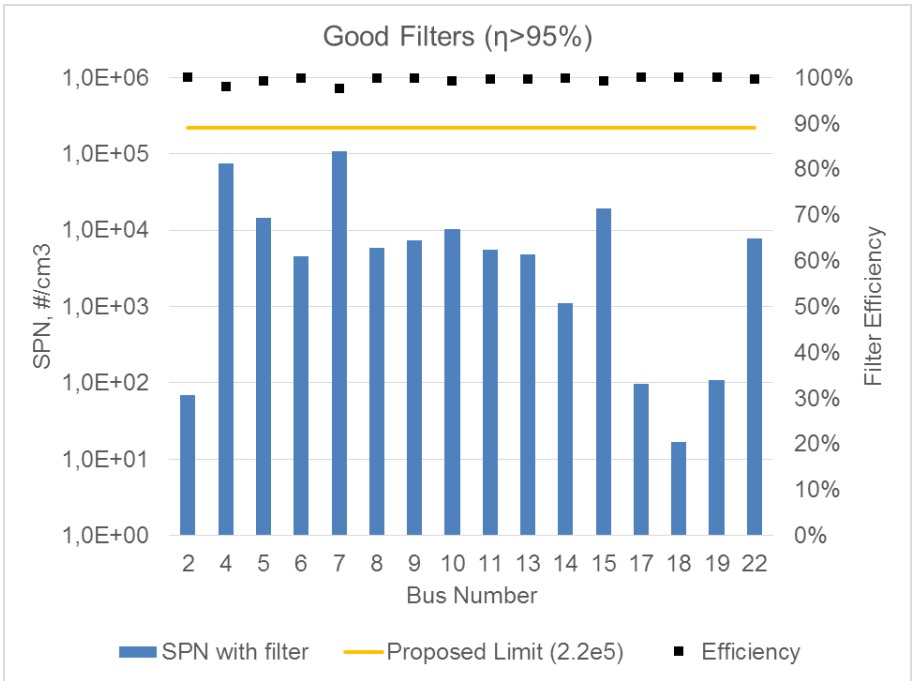
End of pipe PN Limit to detect Abnormal Emissions

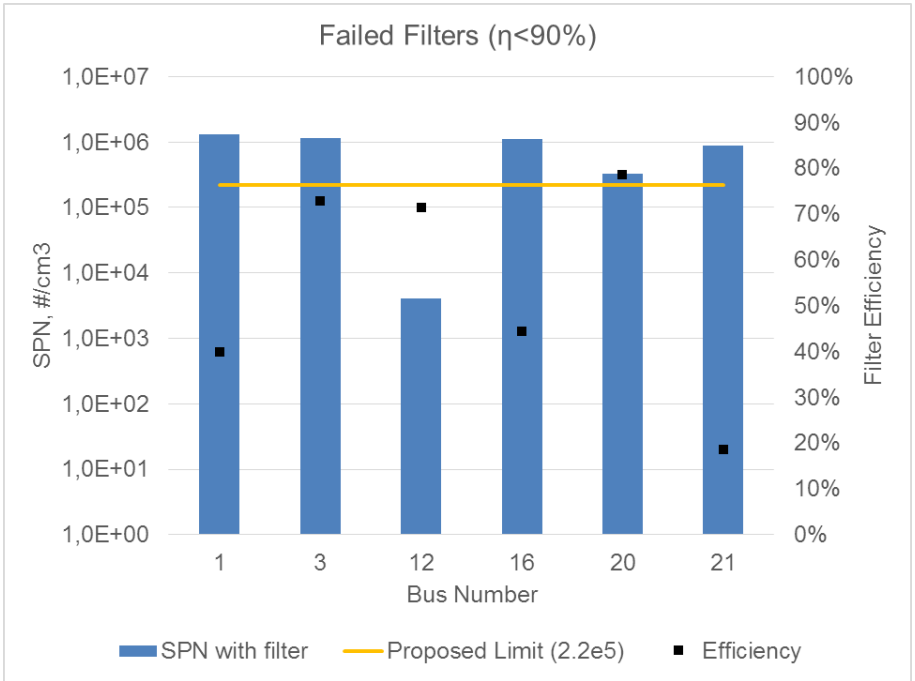
- Binned bus measurements into log-spaced concentration ranges.
- Separation in bimodal structure (normal and abnormal), clearest for low idle.
- Low Idle speed is easier to implement in road side control (no driver or RPM electronic control interferences)
- Bimodal structure determines limit of 2.2x10E+5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



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 $2.2x10^5$ #/cm^3 could be a good indicator of low efficient DPF.





Fleet summary considering proposed threshold

Model With DPF	Number of Abnormal Emissions	Buses Tested	Rate of Abnormal Emissions	Average DPF Age [km]
A	0	26	0,0%	224.651
B	9	127	7,1%	329.673
C	6	32	18,8%	225.000
D	10	14	71,4%	374.865
E	11	11	100,0%	714.583
F	3	13	23,1%	301.023
Total	39	223	17,5%	325.920

- Abnormal emissions are concentrated in two model types (older DPF).
- Specific efficiency test are necessary to discard high gross engine emitters.
- Some cases of high gross engine emissions (> $4.4x10^6$ with 95% efficiency => end of pipe > 2.2x10E5), 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 $2.2x10^5$ #/cm^3 , at Low Idle speed,
  - Could be a good indicator for detecting filters with $\eta<90\%$.
  - 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 two specific models
  - Which were implemented in early stage of project.
  - When best practices had not been implemented yet.
  - More recent implementation (for instance Model D) show 0% of abnormal emissions.

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).
  - New strategies which permits more centralized and comprehensive monitoring are needed (like wireless monitor).
  - Protocols to detect DOC failures are needed (DOC efficiency test).

Conclusions

- New CH-METAS certified portable, low cost, highly sensitive PN number counting instrument, puts ahead challenges for manufacturers competing for improving product durability and customer support closer in order to introduce best maintenance practices.

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