Filter Systems for Brake Emission Reduction

June 29th, 2023

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Leadership in Filtration

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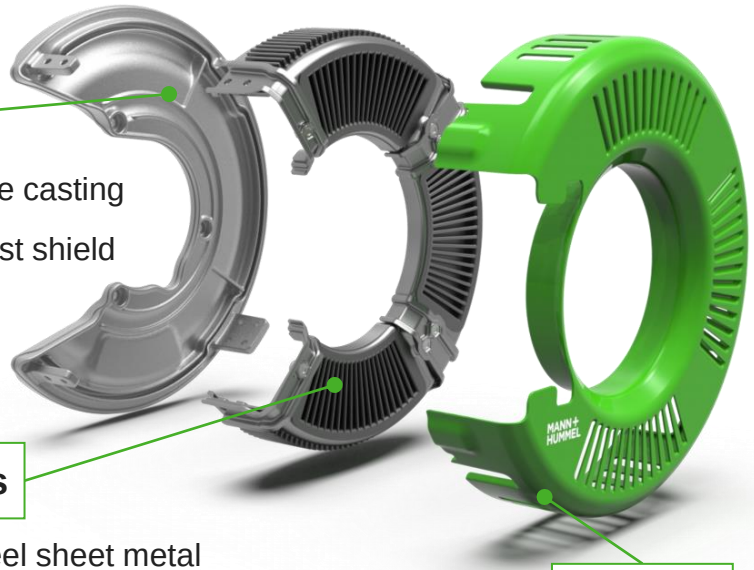
Agenda

- Brake Dust Particle Filter
  - Measurement strategy on brake dyno
  - Steps for GTR amendment

Overview Brake Dust Particle Filter

Passive Brake Dust Particle Filter System



Bracket

- Aluminum die casting
- Replaces dust shield
- Lifetime part

Filter Inserts

- Stainless steel sheet metal
- Stainless steel filter media (M+H development)

Housing

- Aluminum sheet metal
- Protective cover
- Lifetime part

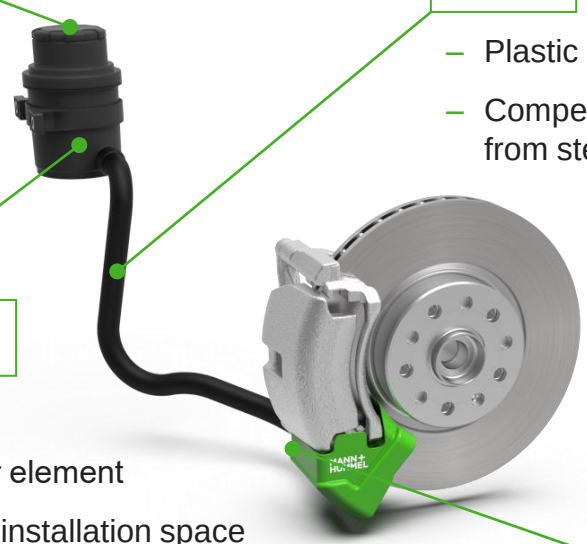
Active Brake Dust Particle Filter System

Blower

- Powerful
- Energy efficient

Piping

- Plastic + reinforcement
- Compensation of movement from steering and suspension



Filter Housing

- Plastic housing
- “standard” filter element
- Flexible use of installation space

Suction Geometry at the Brake

- Stainless steel or aluminum
- Specific for each brake

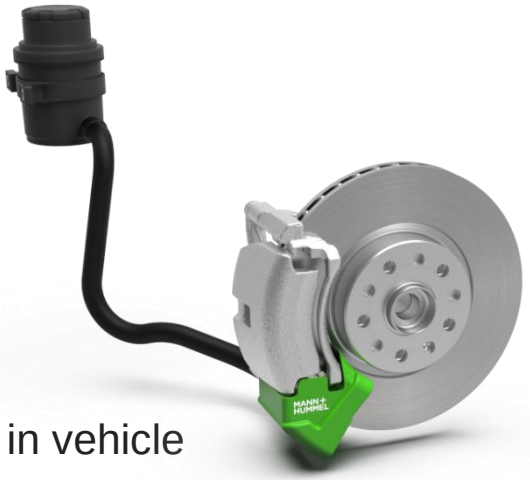
Overview Brake Dust Particle Filter

Passive Brake Dust Particle Filter System

Passive System can be mounted on brake system

Total emissions can be measured on brake dyno

Active Brake Dust Particle Filter System



Control strategy implemented in vehicle

Application on brake dyno set up needed

Currently filter devices not considered in GTR for brake emission measurements

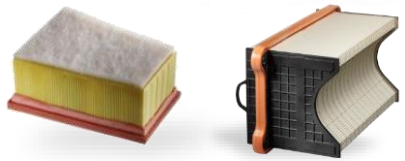
Overview Active System

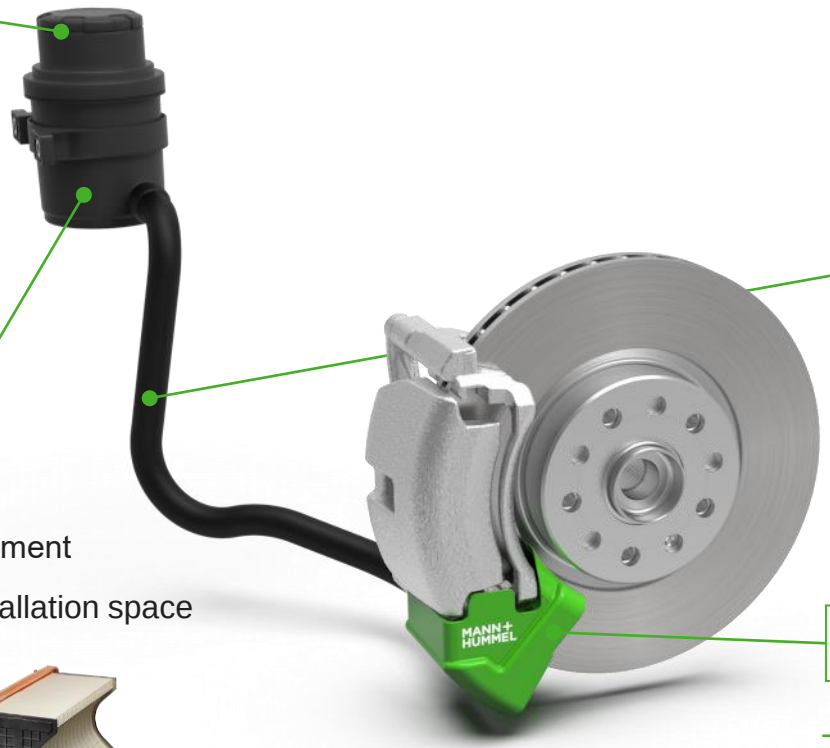
Blower

- Powerful
- Energy efficient

Filter Housing

- Plastic housing
- “standard” filter element
- Flexible use of installation space





Piping

- Plastic + reinforcement
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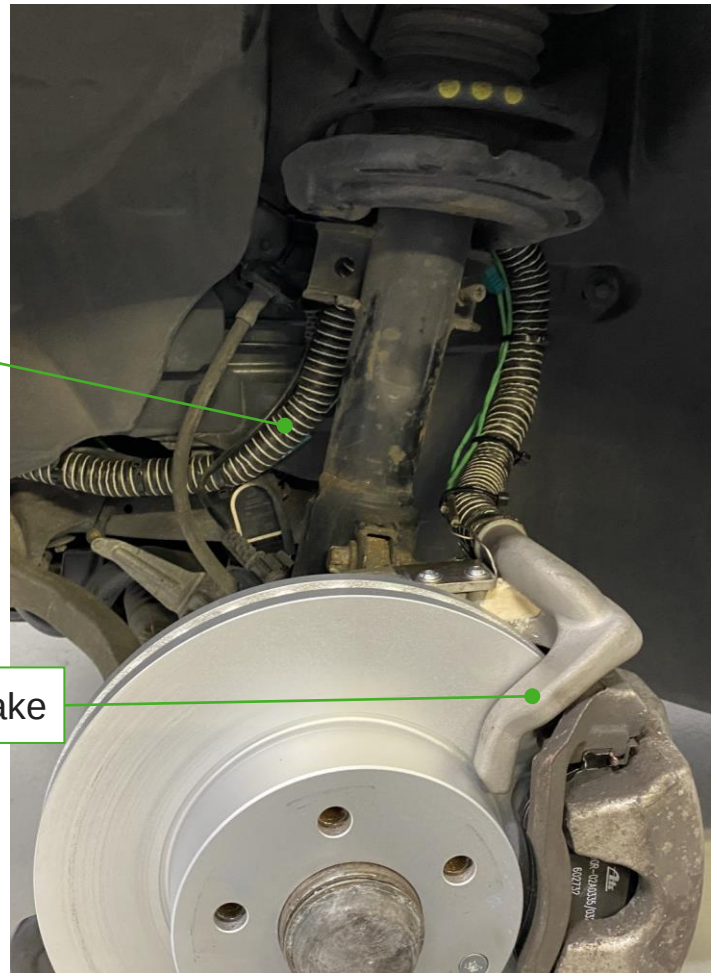
Suction Geometry at the Brake

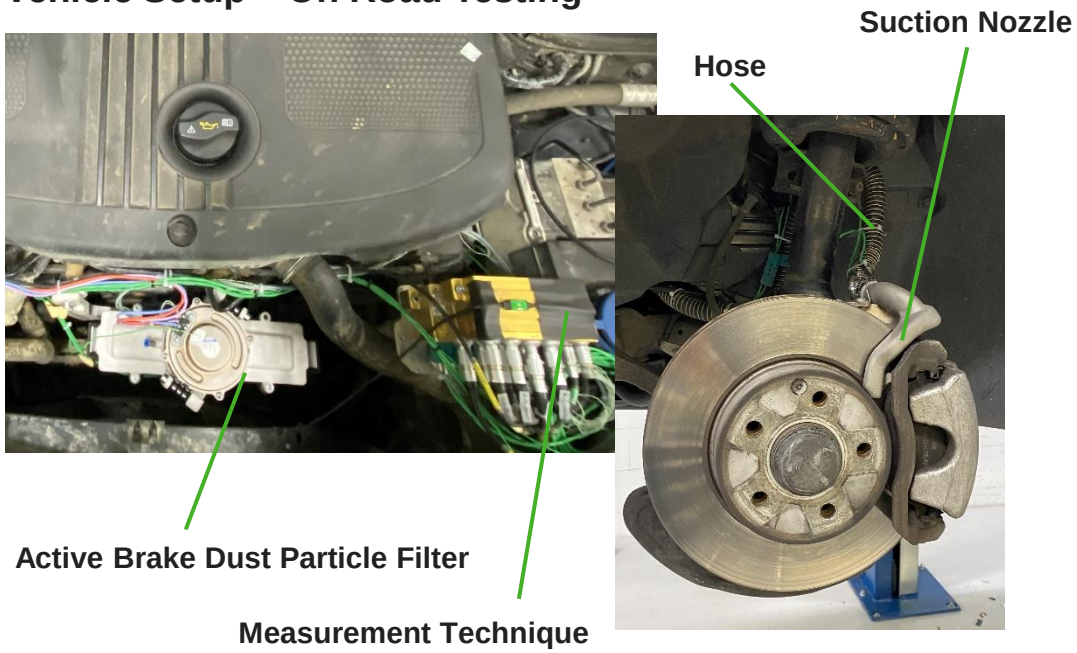
- Stainless steel or aluminum
- Specific for each brake



No changes on existing brake components!

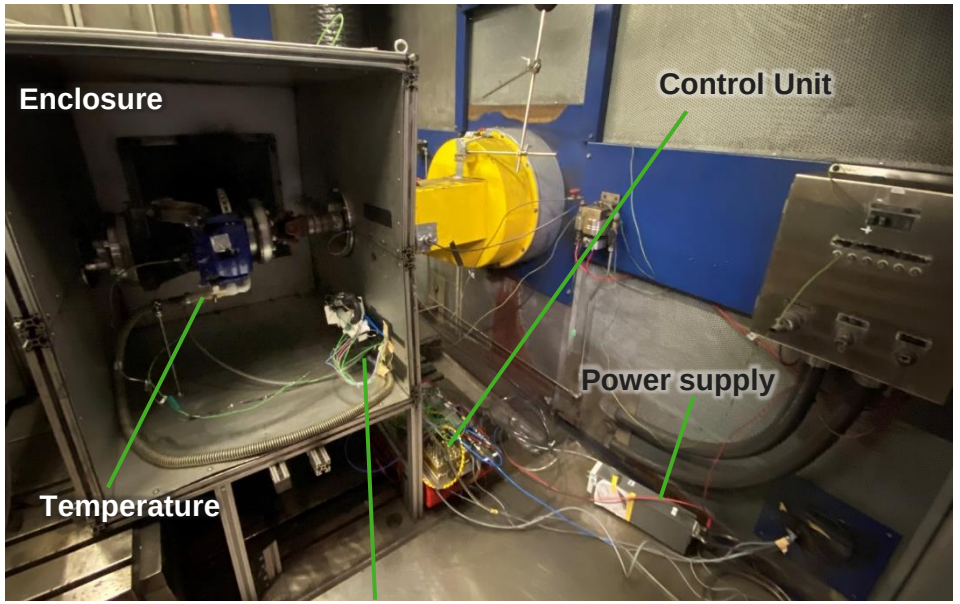
Active Brake Dust Particle Filter System

Vehicle Setup – On Road Testing



System installed in vehicle and tested on road

Vehicle Setup – Emission Measurement on Brake Dyno

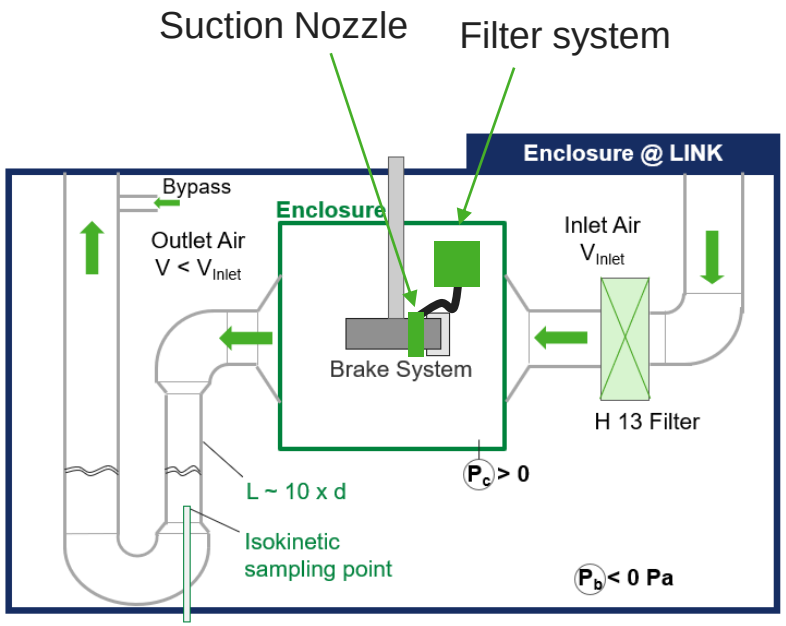


Emission measurement on brake dyno with vehicle parameters

MEASURED WITH WLTP EXHAUST CYCLE

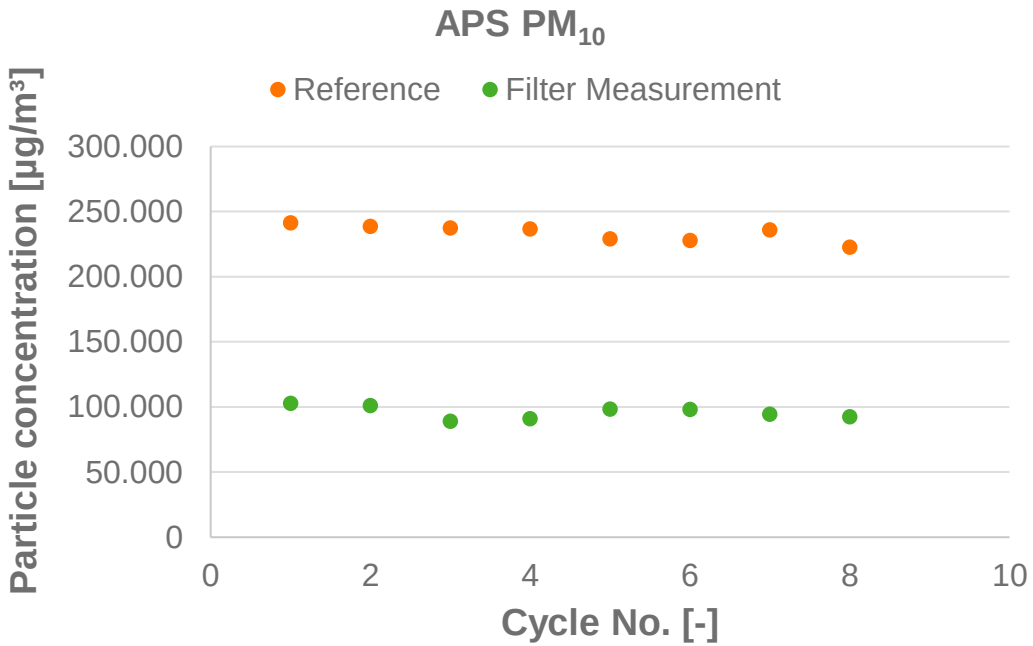
Separation Efficiency Results

Schematic Measurement Set Up for Emission Measurement



Emission measurement with enclosure on brake dyno

Vehicle Set Up – Example for PM10 Reduction



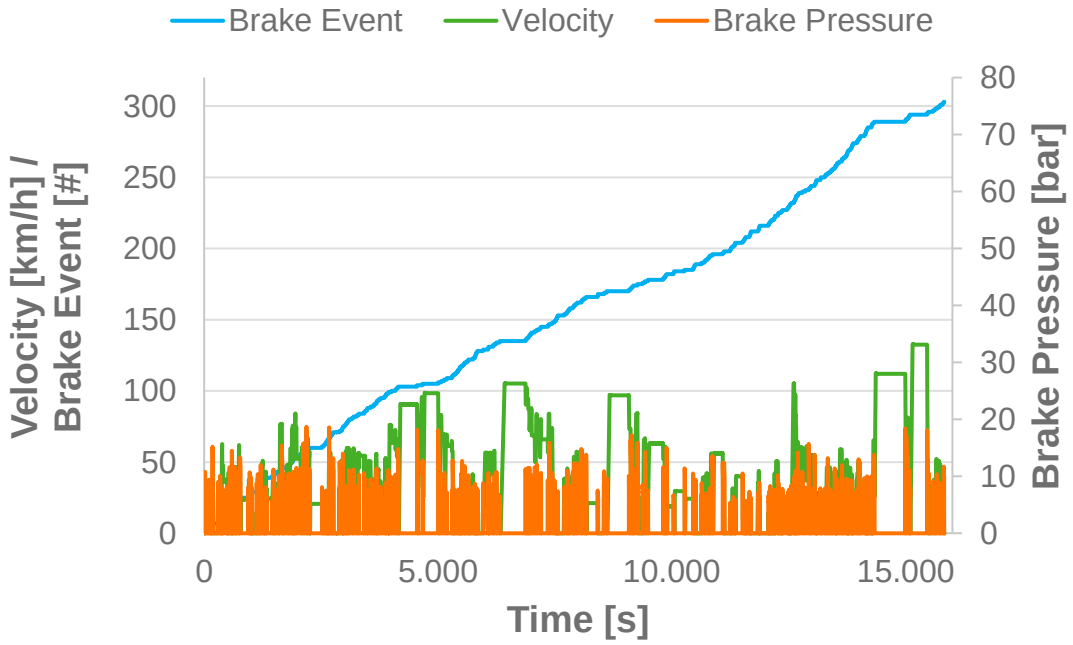
Significant emission reduction with active system

Measured with WLTP exhaust cycle due to time of cycle

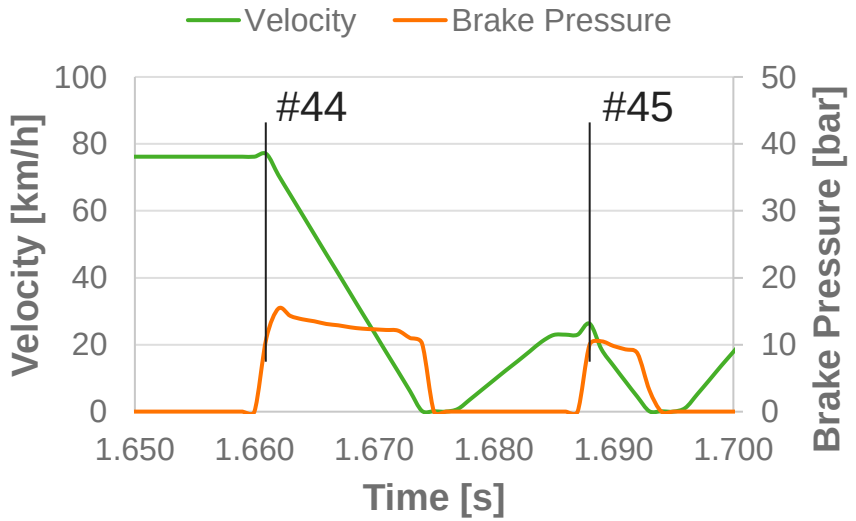
Evaluation of Brake Cycle and Control Strategy of Filter System on Dyno

Resistance of vehicle are considered in constant factor acc. Eq. 8.2 in GTR (ECE/TRANS/WP.29/AC.3/59)

Speed reduction initiated by activating the braking system, not by releasing the accelerator pedal as in a car.



Example Brake two brake events of section #2

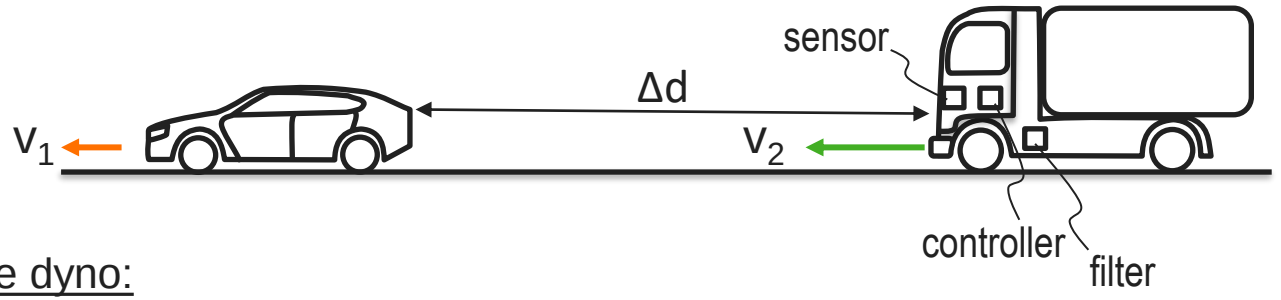


Speed reduction due to friction braking event at dyno

Control Strategy in Vehicle

Operation Strategy in Vehicle:

- Energy efficiency increased by using vehicle parameters related to the driving situation
- Example: Distance control can predict brake probability → blower ramp up to increase separation potential
- Further parameters: throttle paddle position, velocity, gear, …



Vehicle Control Strategy needs to be reflected on brake dyno:

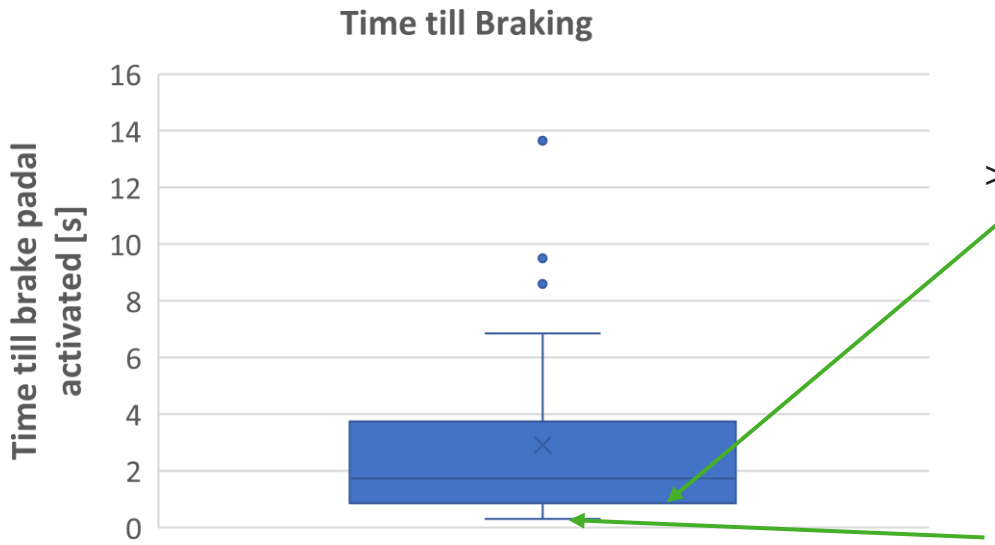
- Based on vehicle data control strategy for emission measurement is defined
- Ramp up characteristic for blower specified based on field data

Active System can operate on brake dyno comparable to vehicle usage
→ How to reflect operation strategy within homologation process (GTR)?

Operation of Brake Dyno - Proposal

Control Strategy:

- Cycle is time based
- Prediction of brake probability known from vehicle test
- Blower ramp up prior to the braking event possible
- Time prior to brake event evaluated with test vehicle needs to be validated with customer
- Example: Time till braking



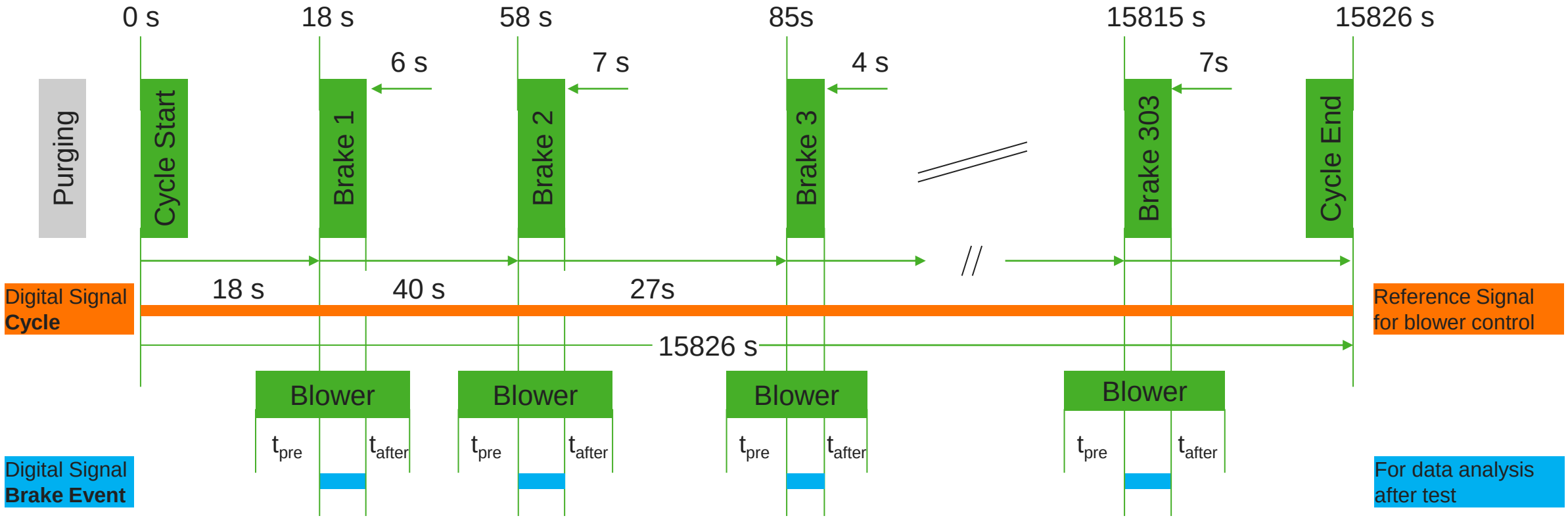
>1s for 75% of braking events

For those events throttle pedal deceleration can be used to activate blower

Active system can be activated prior to the braking event to achieve best separation efficiency

Control Unit of Filtration System at Brake Dyno WLTP

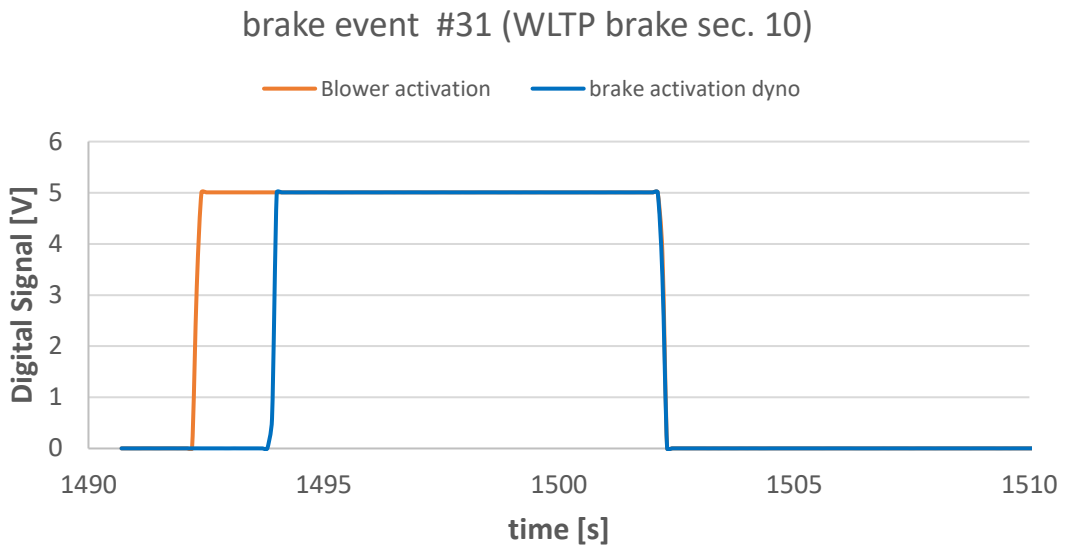
Based on vehicle data, brake prediction time is available → control strategy of filter system can be operated with time signal:



t_{pre} & t_{after} acc. vehicle data

Control Strategy Implementation at Brake Dyno

Time dependent control parameter can be realized at the brake dyno:



Standard value can be stated in GTR

Vehicle specific time value can be evaluated during development and should be used for emission measurement to show real performance of complete system

Conclusion

Active System should operate in **energy efficient** condition (blower activation only when needed)

Implementation of **control strategy** according to vehicle algorithm → will be reflected on brake dyno as **time dependent trigger signal** (time difference to be defined during vehicle development analog to vehicle specific friction share for regenerative braking)

If **acceleration** will be also investigated, system can operate as well during acceleration of vehicle to reduce off-brake emissions

Emissions reduction technology can operate efficiently and take into account the control strategy of the vehicle

Thank you

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