# State-of-the-Art Filter Regeneration Management

Concepts realized by LDV companies

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# Agenda

- Introduction
  - Primary task and elements of DPF system management
- Overview of actual active DPF system designs
- DPF system management concepts
  - Temperature control & management
  - Regeneration management concepts
- Summary

# Elements of Filter Regeneration Management: *Control DPF soot load **and** regeneration*

- Monitor, detect, and control filter loading conditions
  - Primarily: Soot
  - Secondarily: Ash
- Initiate and control regeneration to targeted inlet temperatures
  - Within entire engine map and at transient conditions

# DPF Soot loading considerations

- Targeted operational soot load
  - Regeneration frequency
    - Driven by e.g. engine parameters (e.g. oil dilution)
  - Fuel economy
    - Driven by regeneration frequency and pressure drop
- Filter model
  - Soot accumulated as function of engine-out performance
  - “Vehicle mission profile”
  - Residual soot from previous regeneration
- DPF pressure drop vs. soot load characteristics
- Impact of ash load shifting Δp “calibration”

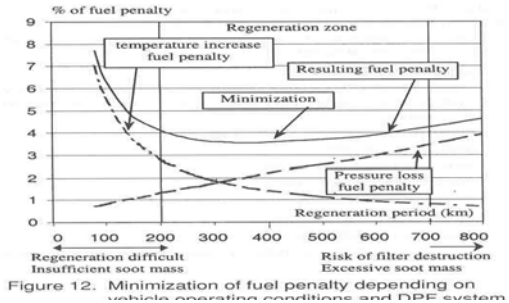
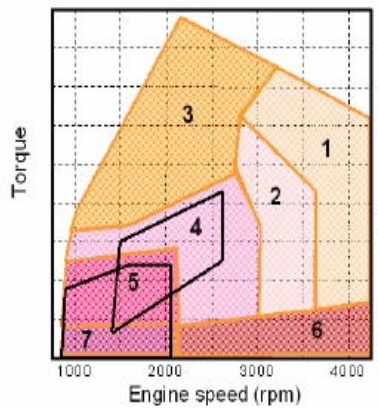


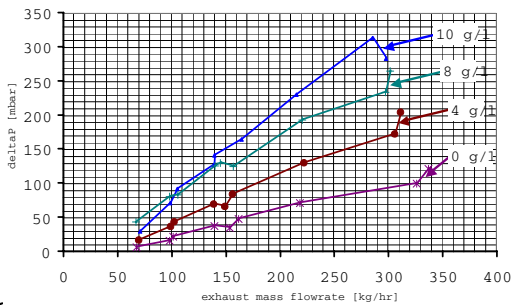
Figure 12. Minimization of fuel penalty depending on

Ref.: PSA



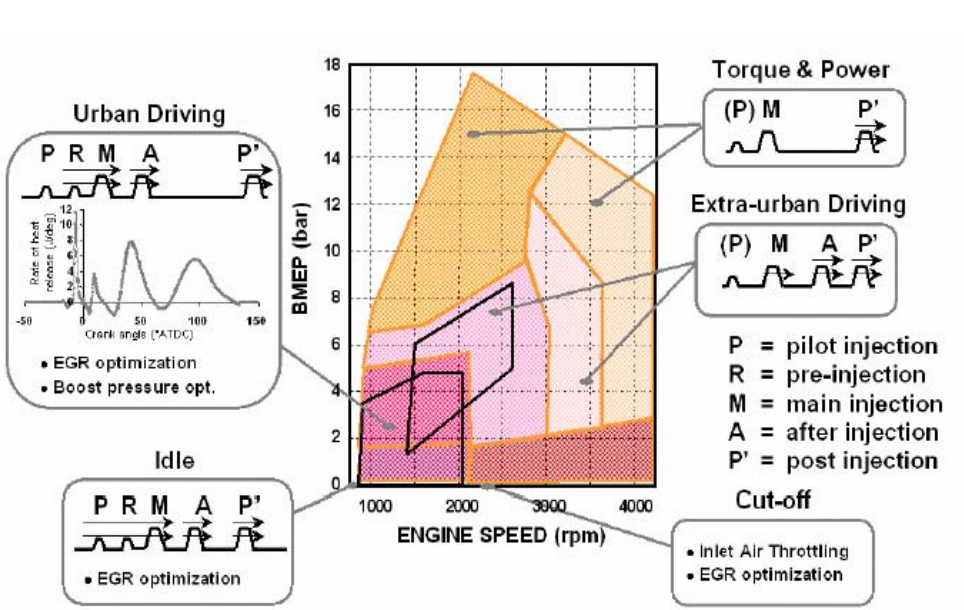
Ref.: Fiat GM Powertrain (1)

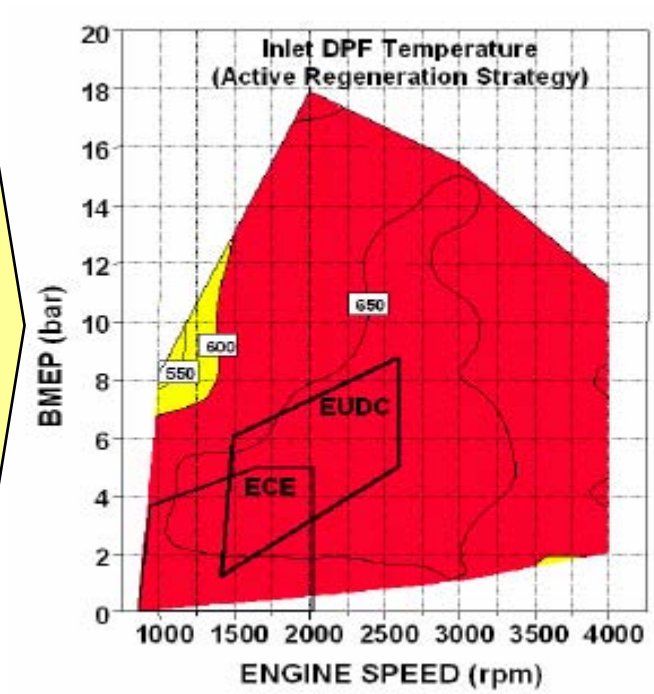
DPF Differential Pressure as Function of Exhaust Mass Flo



# Engine management strategy based upon multiple injections ensures DPF inlet temperature across wide range of engine map

Source: Fiat GM Powertrain (1)



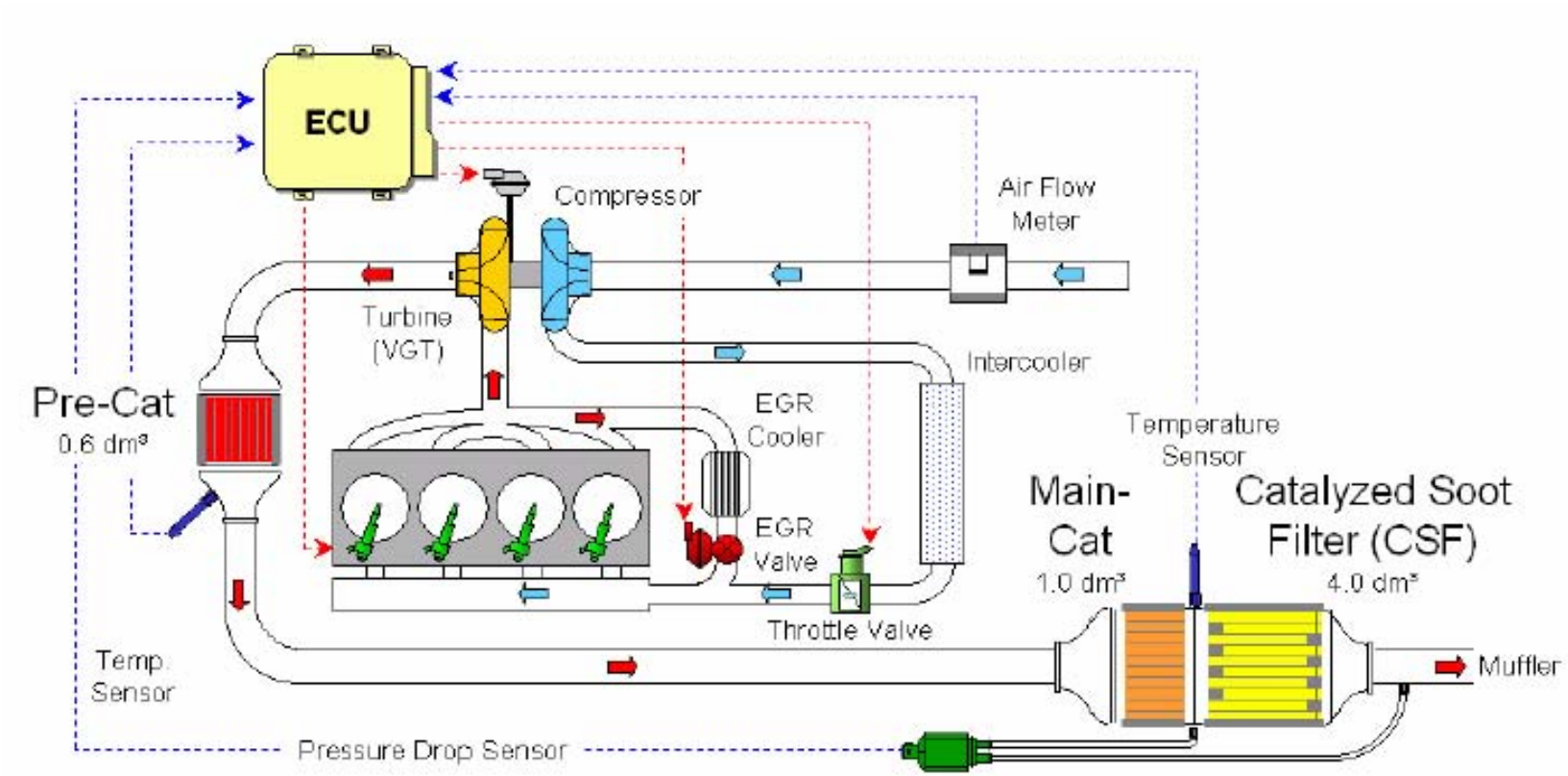

Different injection variants employed at different engine load conditions to ensure required filter inlet temperature

Note: Two DOCs upfront of catalyzed DPF

# Overview of Actual Active DPF Systems

# Active DPF System

Source: Fiat GM Powertrain (1)



# Active DPF System

Source: DCX (3)

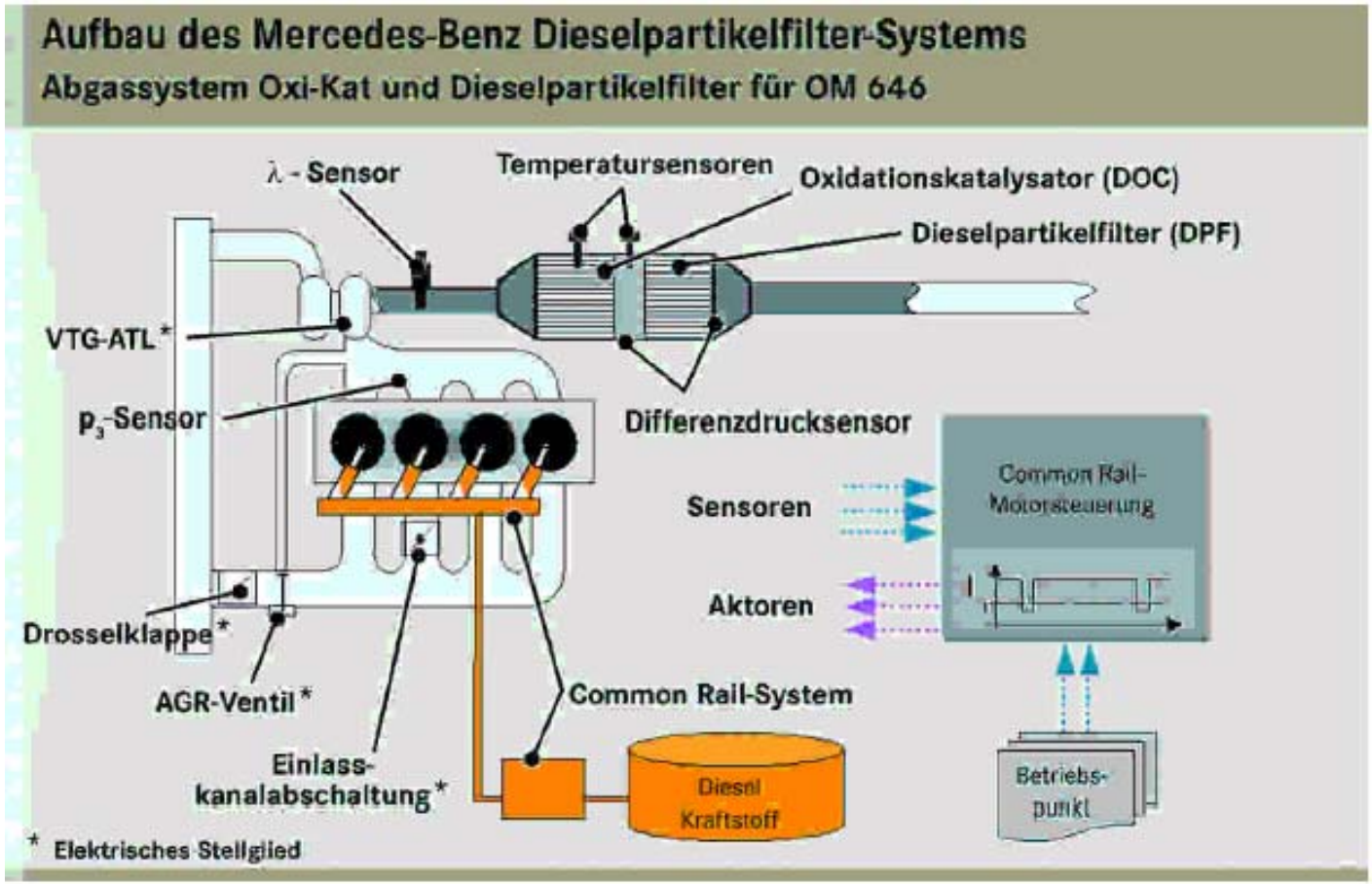
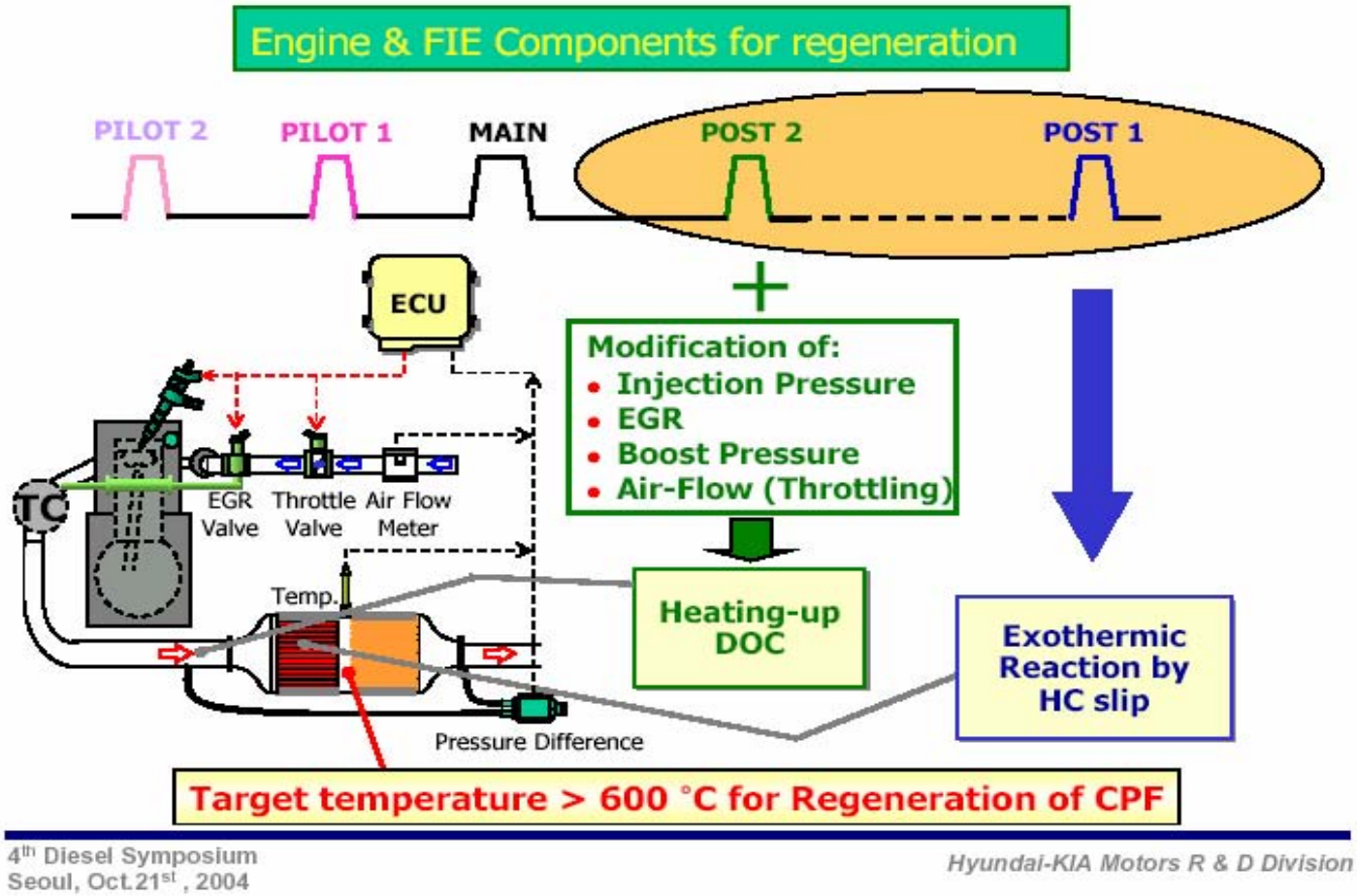



Bild 5: Aufbau des Dieselpartikelfilter-Systems

# DOC + CDPF System at Hyundai-Kia

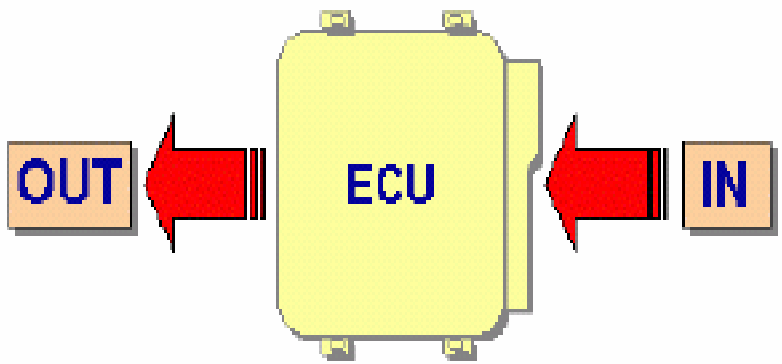
Source: HMC-Kia presentation (5)



# Commonality of Active Systems: System Monitoring and Control, ECU is the key

## Main Input/Output Signals processed by ECU for DPF control

Rail Pressure Regulator valve
Rail Flow Control valve
EGR valve
Proportional Throttle valve
Turbo Charger Actuator
Injectors

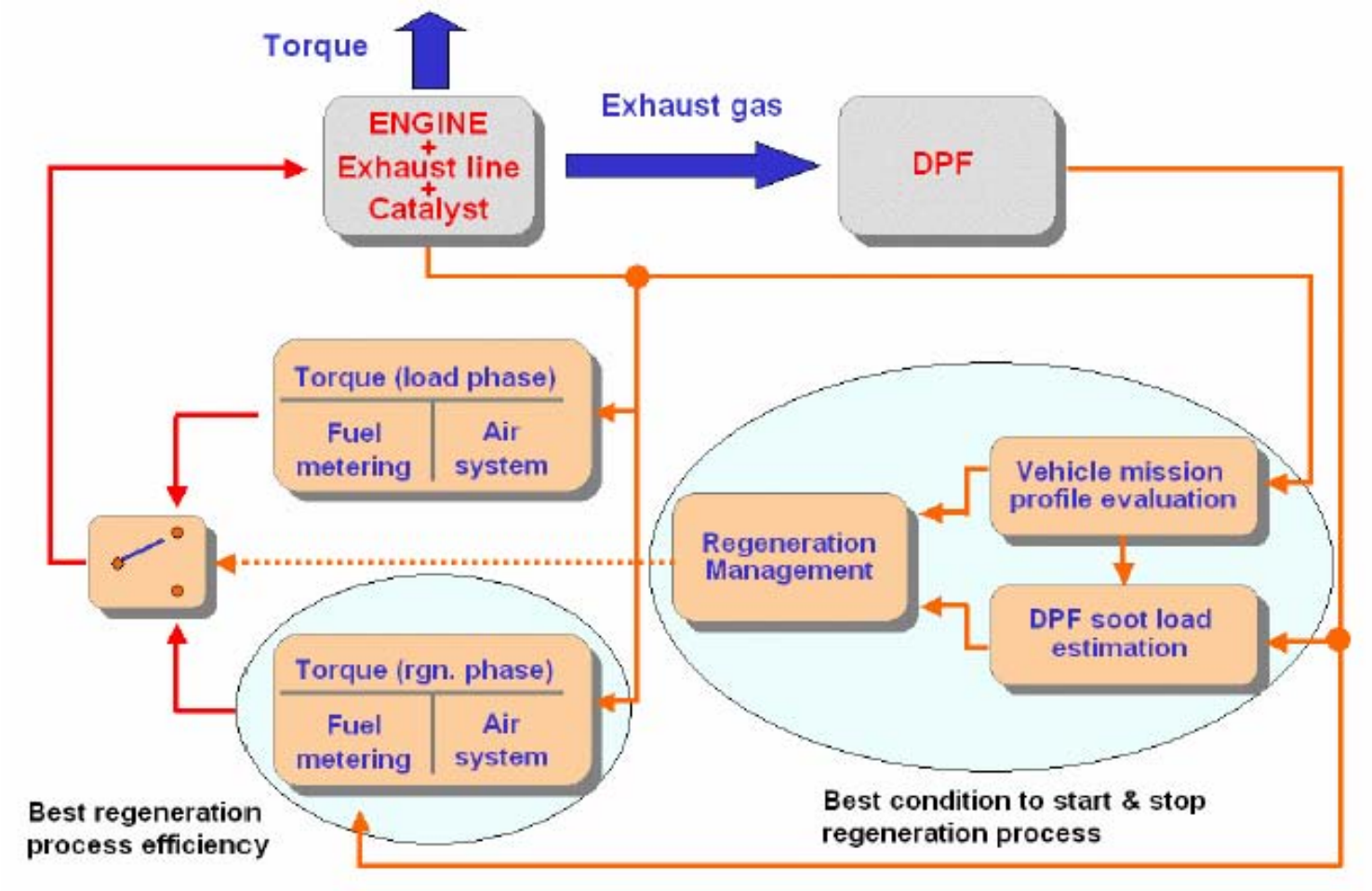



Exhaust Temperature sensors
CSF Pressure Drop sensor
Rail Fuel Pressure
Atmospheric Air Pressure
Coolant Temperature
Boost Pressure
Intake Air Mass Flow
Vehicle speed

Source: Fiat GM Powertrain (1)

# DPF Control Software Architecture

Source: Fiat GM Powertrain (1)



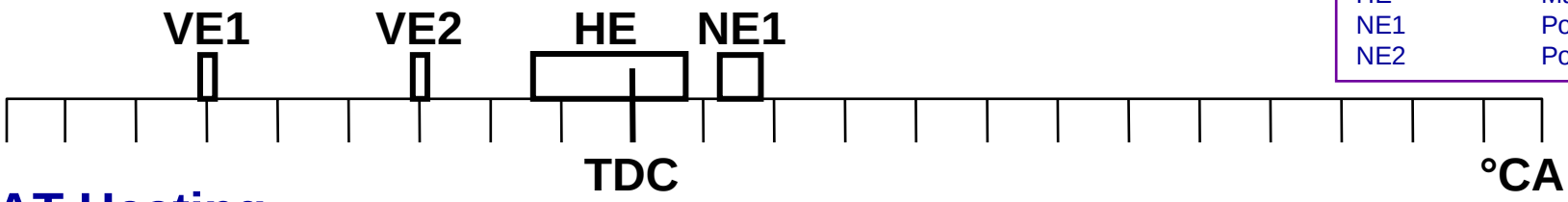
# Approaches to ensure sufficient filter inlet temperature

# Filter Heating Strategies
# Injection Variants for DPF Regeneration

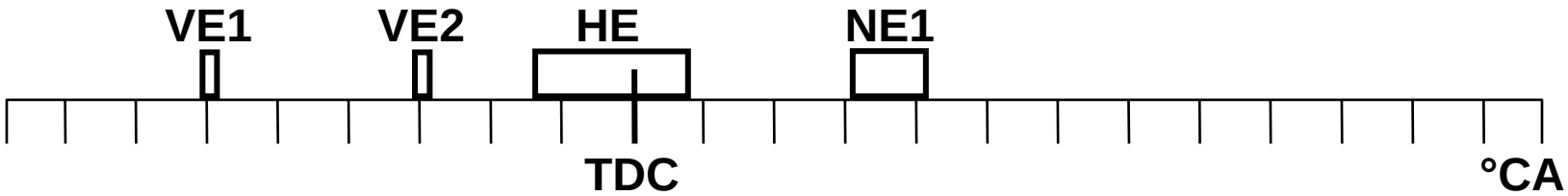
Source: DCX (2)

| | |
|---|---|
| VE1 | Pilot Injection 1 |
| VE2 | Pilot Injection 2 |
| HE | Main Injection |
| NE1 | Post Injection 1 |
| NE2 | Post Injection 2 |

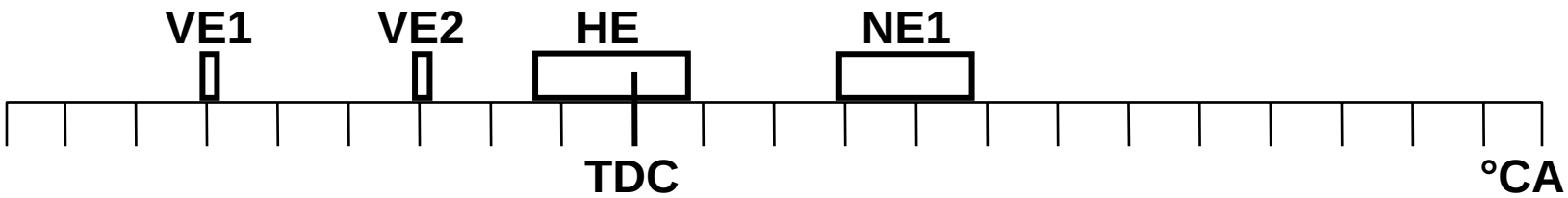
## Normal Operation



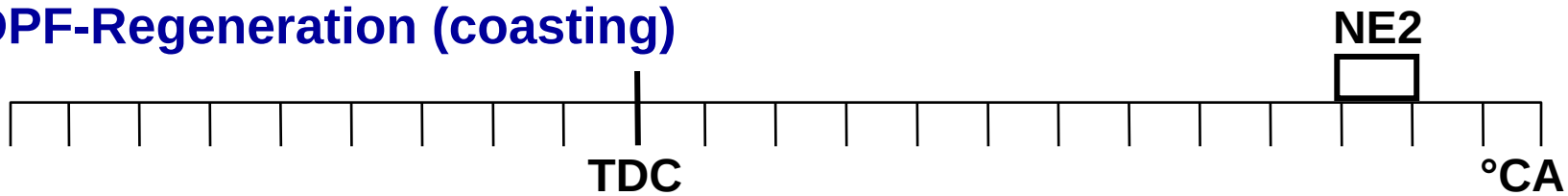

## CAT Heating




## DPF-Regeneration

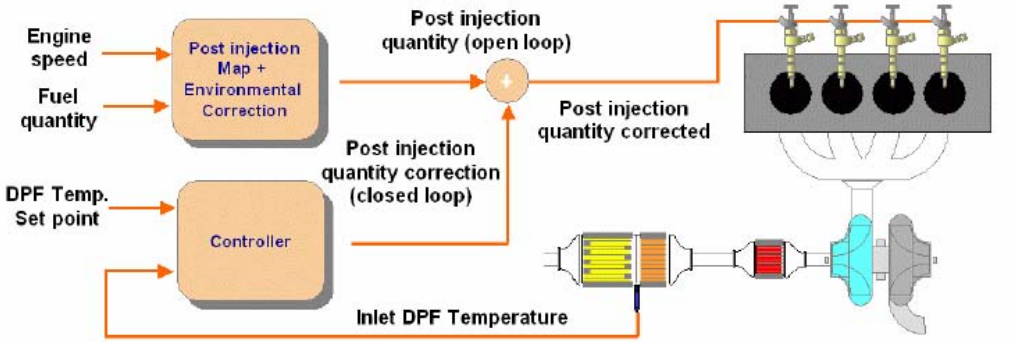


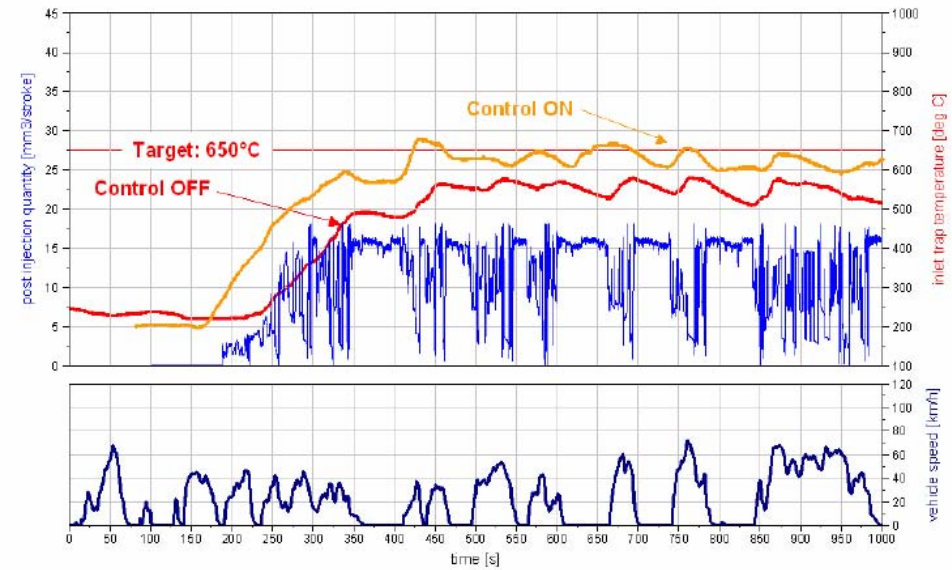

## DPF-Regeneration (coasting)



# Closed loop control of exhaust gas temperature ensures reliable regeneration process also during transient operation

Source: Fiat GM Powertrain (1)



# Regeneration Management

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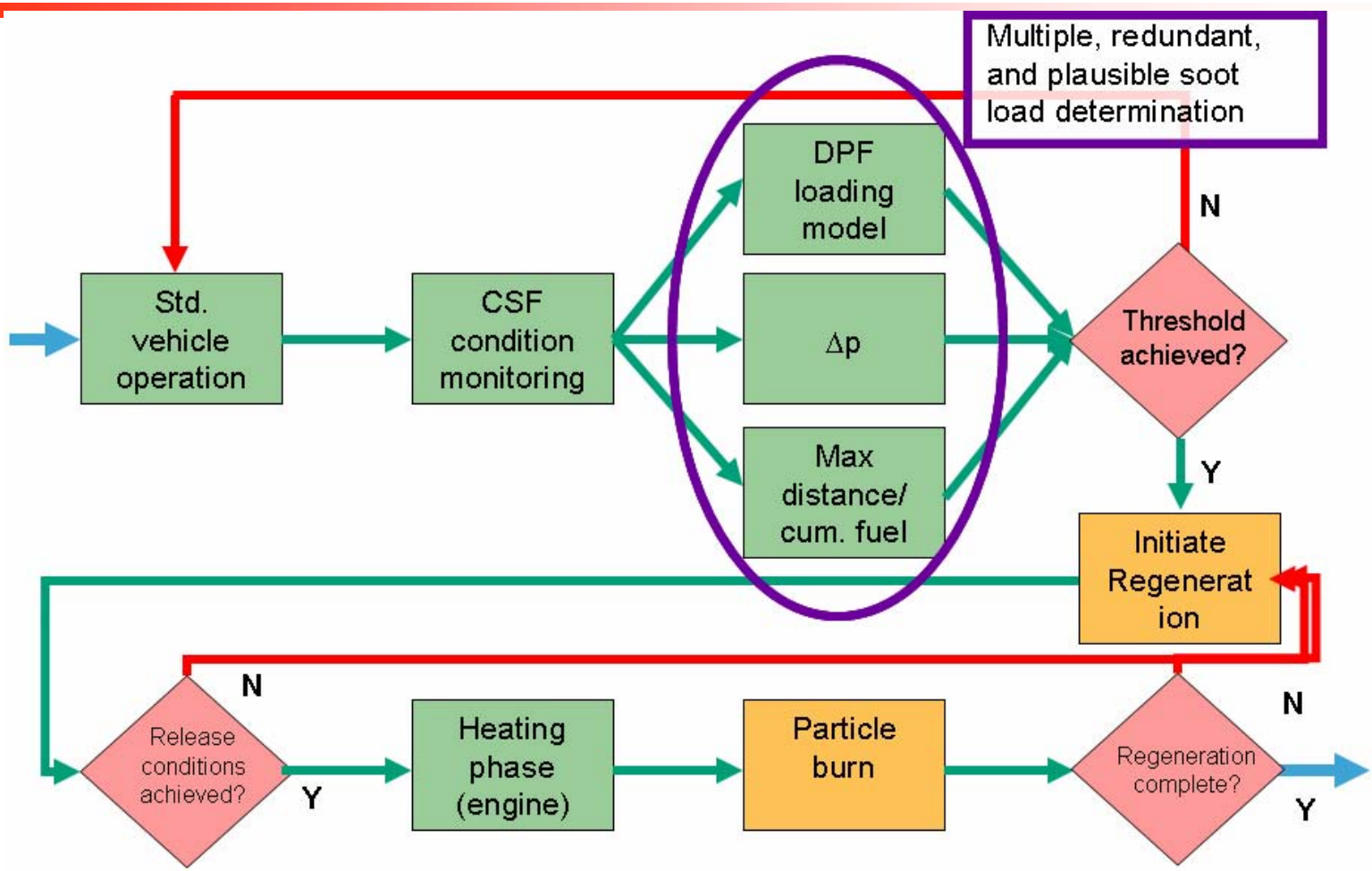
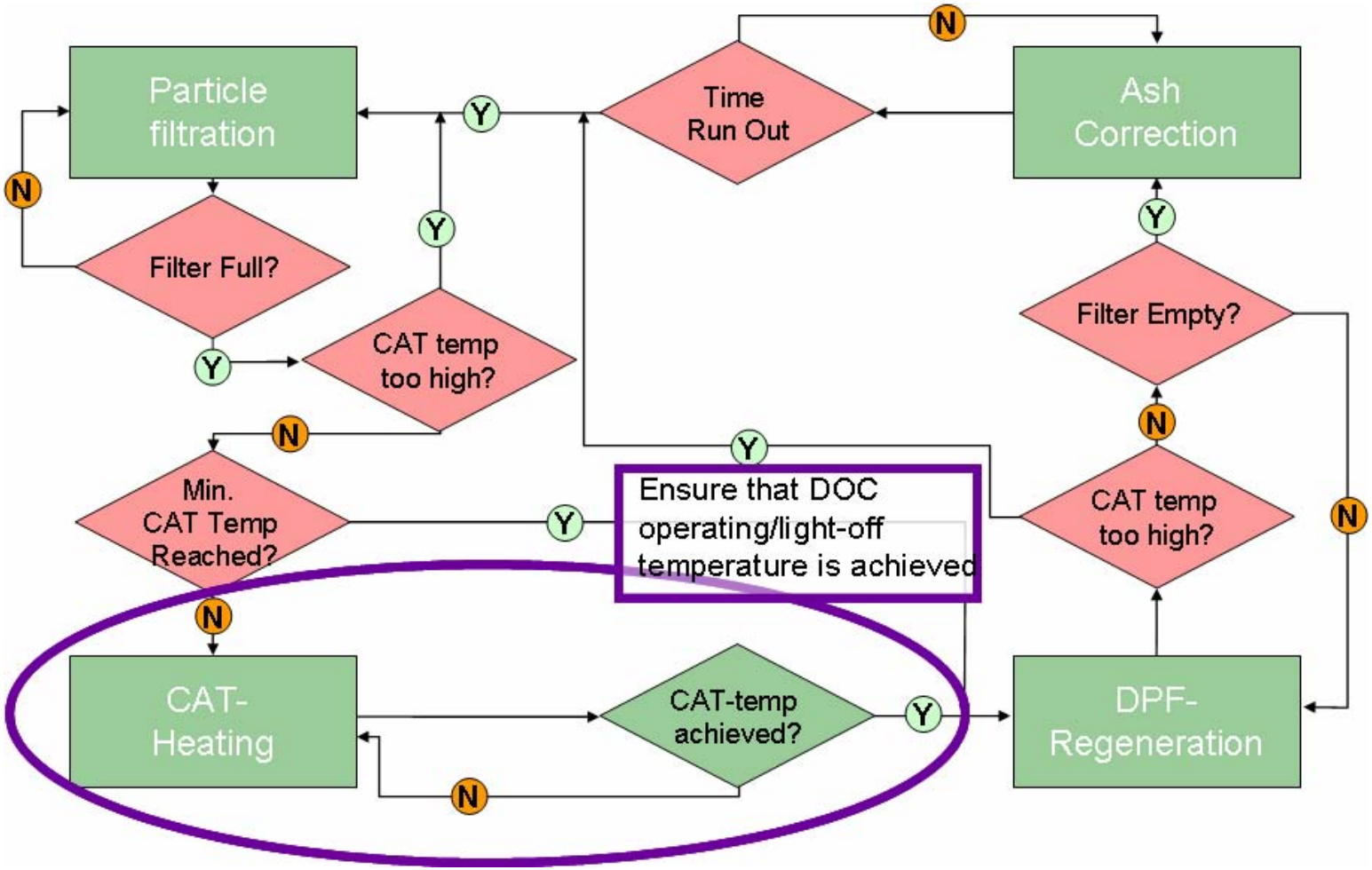
# Flow Diagram DPF Regeneration

Source: BMW (2)



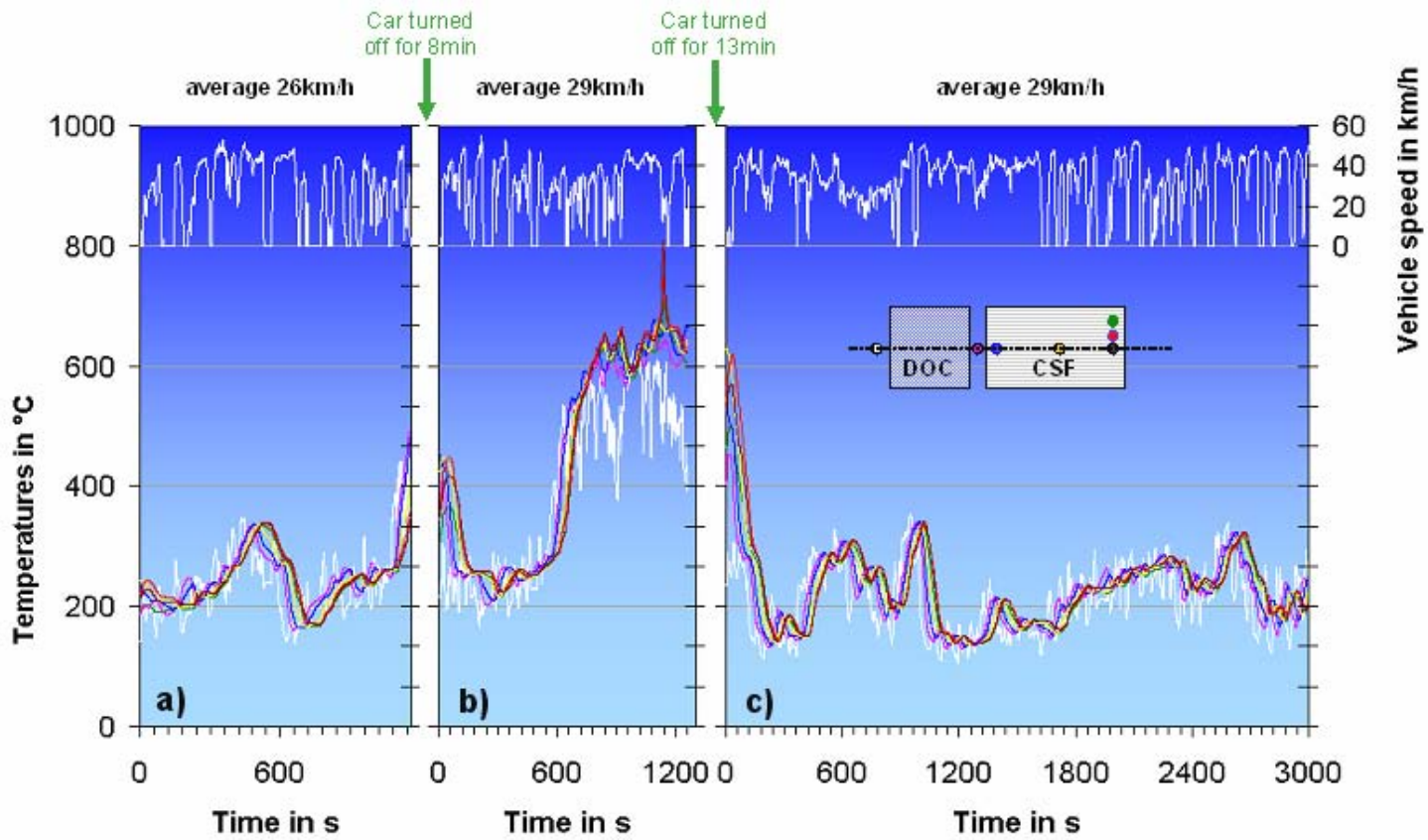
# Function of the DPF System
# Regeneration Control of the DPF

Source: DCX (2)



# Control systems enable tight thermal control during regeneration in city mode driving and key-off events

## *-as observed during Corning on-road vehicle test* Source: Corning (6)




Vehicle: 2.2l, EU IV calibrated passenger car, OEM calibration, OE-Filter replaced by Corning DuraTrap® AT Filter

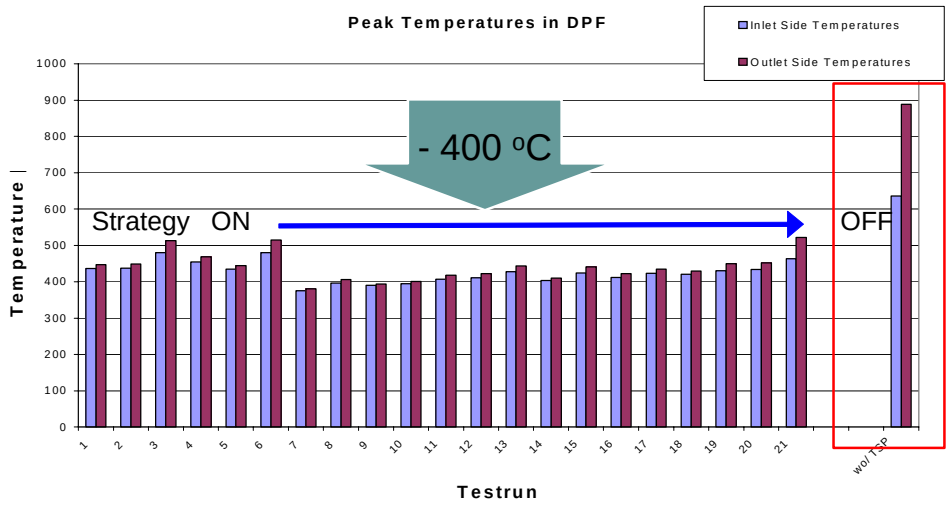
Example of the thermocouple readings during a city test in which the regeneration was terminated two times when the driver stopped the engine.

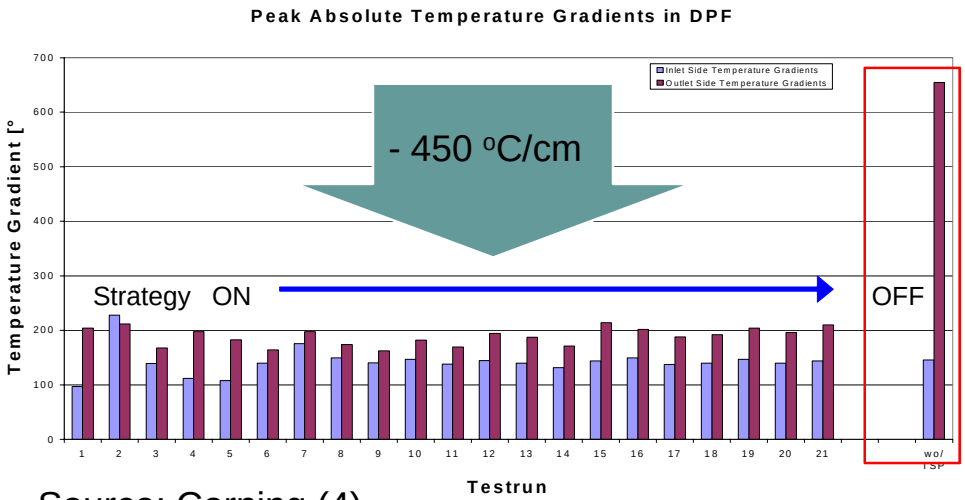
# Thermal Shock Protection Strategy Concept

Source: Corning (4)

- To reduce filter thermal shock during uncontrolled regenerations, two things are required:
  - Reduce temperature/ temperature gradients
  - Reduce oxygen content
- Approach
  - manage the exhaust oxygen content (or λ) as a function of DPF temperature and load
    - Intake throttling
    - EGR valve actuation
    - Post injection
- Strategy development conditions:
  - 1.9 l prototype engine with common rail injection
  - DuraTrap® CO 5.66 x 6 200/12

# DPF Thermal Shock Protection Strategy with *Intake throttling, EGR, Post Injection (on engine)*




Source: Corning (4)

## Thermal shock protection strategy ON:

- Significant reduction in both peak filter temperatures and maximum temperature gradients
- Uncontrolled regenerations eliminated
- Key enabler for lower filter system cost

# Summary

- Advanced DPF regeneration management strategies are implemented in LDV application
  - Filter loading monitoring and control
    - Multiple, redundant and thus plausible soot & ash control
  - Regeneration initiation & control
    - In-cylinder based
    - Post injection timing & quantity
    - Insurance that system is at required operating temperature
- Thermal Shock Protection Strategy demonstrated as concept
- It is conceivable that similar strategies need to be applied to HDV as well
- The control logics would apply even if non-in-cylinder DPF heating concepts are being used
  - Possible application of in-cylinder late injections, “mild” post-injections, throttling, etc. for system warm-up phase prior to regeneration initiation

# References


1. G. Boretto, et al.; 2004V068, Fisita Barcelona May 2004

2. W. Mattes, et al.; MTZ 7-8/2004 Vol 65

3. “Das neue Mercedes Benz Dieselpartikelfilterkonzept fuer PKW in Verbindung mit der Abgasstufe EU4”; J. Schommers, et al.; 25. Wiener Motorensymposium, April 2004

4. “Regeneration Control – Key to successful application of new DPF systems”, Zink et al., Proceedings of 13. Aachen Kolloquium Fahrzeug- und Motorentechnik, October 2004.

5. “Application of Catalyzed Diesel Particulate Filter System (CPF) To Small SUVs for Euro IV”, Wonkun Kim, et al., 4th HMC Diesel Symposium, October 21, 2004

6. “Performance and Durability Evaluation of the new Corning DuraTrap® AT Diesel Particulate Filter – Results from Engine Bench and Vehicle Tests“, (in Engl.) Heibel et al., To be published: Proceedings of 14. Aachen Kolloquium Fahrzeug- und Motorentechnik, October 2005.