Modelling Particle Mass and Particle Number Emissions during the Active Regeneration of Diesel Particulate Filters

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CMCL Innovations

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Cambridge Particle Meeting

Background

Particulate emissions
- Particle Mass (PM)
- Particle Number (PN)

Real Driving Emissions

Heavy duty vehicles
- Compression Ignition
- Diesel Particulate Filters (DPFs)
- Active regeneration

Active regeneration releases particles

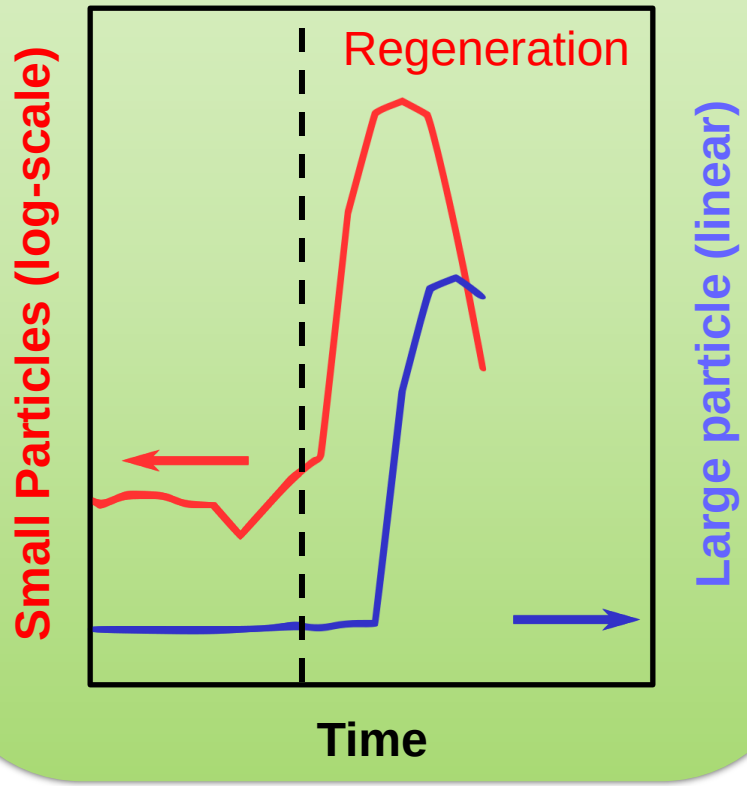

Image adapted from Cauda et al., Topics in Catalysis, Vol 42-43 (2007), p253-257

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Motivation

Studies on particulate emissions during regeneration are predominantly experimental

Particulate emissions measurements rarely compared with model predictions

Develop model to investigate particulate emissions during regeneration

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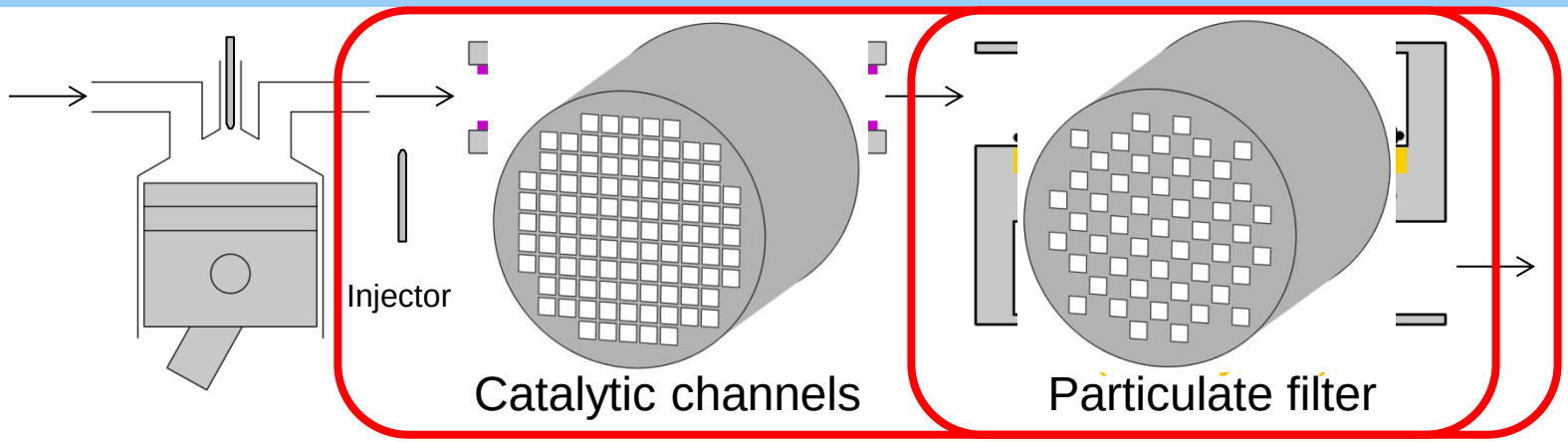
Exhaust after-treatment



Post-cylinder emission control

Filtration – Regeneration

Diesel Particulate Filter (DPF)

Could have catalytic coating

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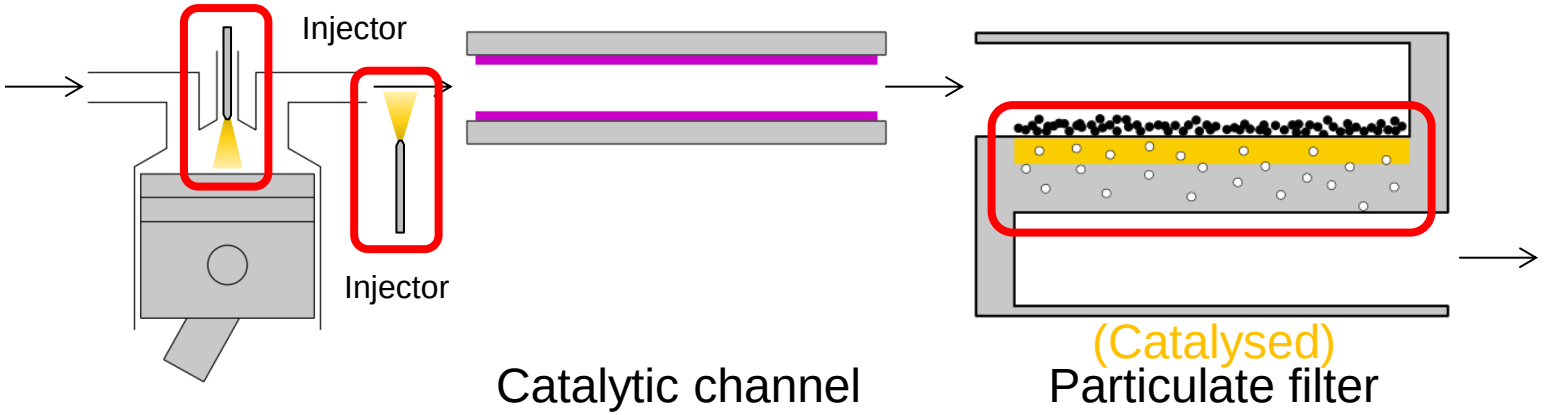
Sources of emission during regeneration



Reduced filtration efficiency
- Particle load
- High temperature

Different inlet conditions
- More particles from engine[1]
- Post-engine fuel injection[2]

Generated particles
- Semi-volatile (sulphuric acid)[3]
- Soot fragmentation[4]

1. Ko et al., Journal of Aerosol Science 91 (2016) 62–77.
2. Yoon et al., Atmospheric Environment 122 (2015) 58–64.
3. Guan et al., Journal of Environmental Management 154 (2015) 225–258.
4. Beatrice et al., Experimental Thermal and Fluid Science 39 (2012) 45–53.

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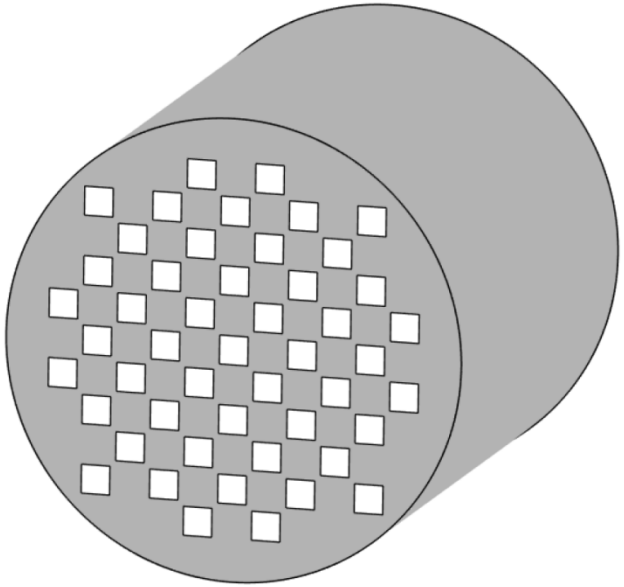
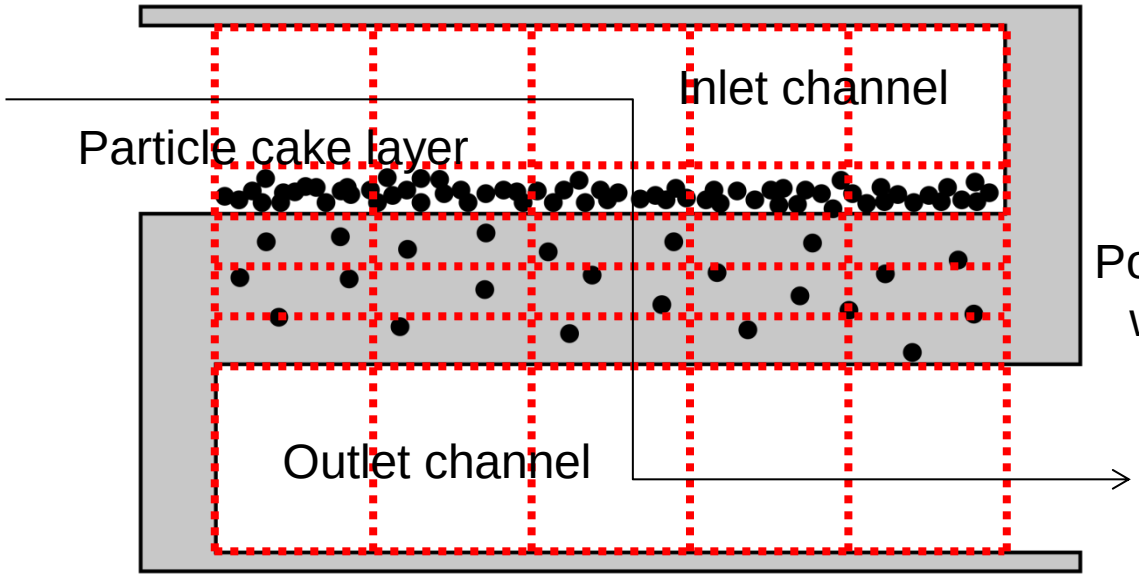
Modelling approach

Pair of representative channels

- Pressure drop
- Regeneration
- Phenomenological filtration





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Yang et al., Advances in Mechanical Engineering 8 (3) (2016) 1–14.

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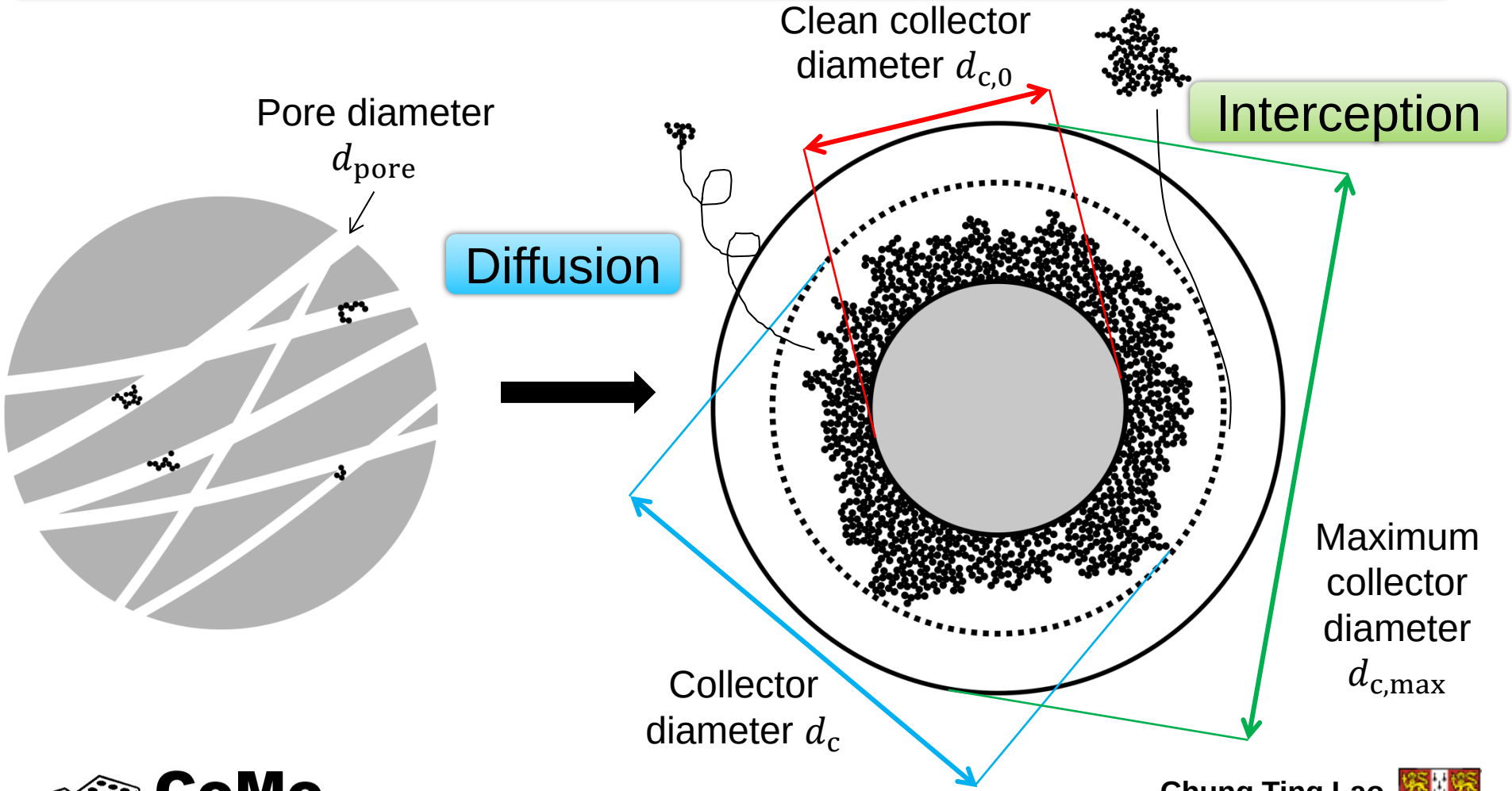
Phenomenological Filtration

Unit collector model describes filtration in porous wall



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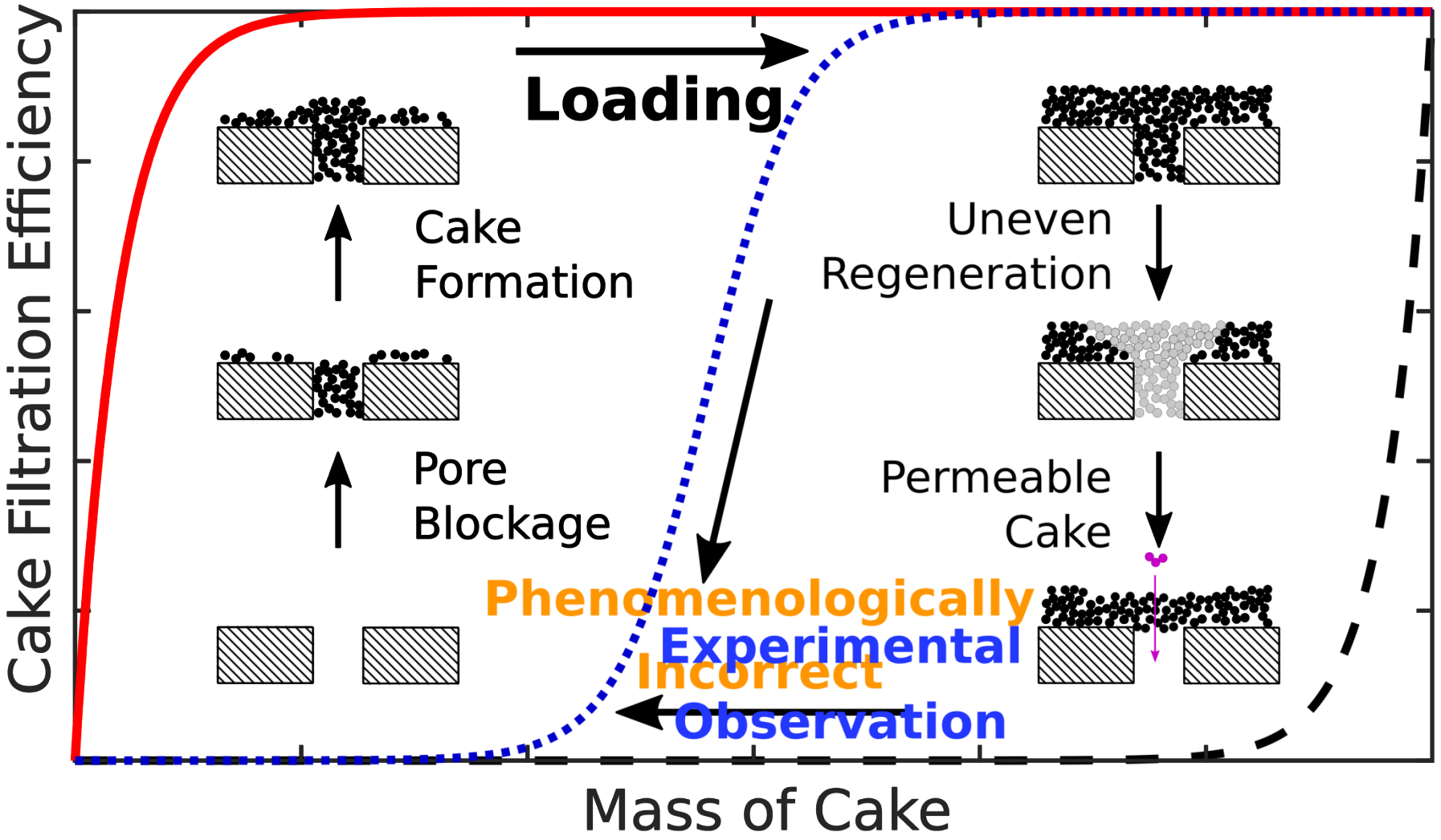
Model development: Filter unloading



Experiment of Choi et al., Energy 77 (2014) 327–337

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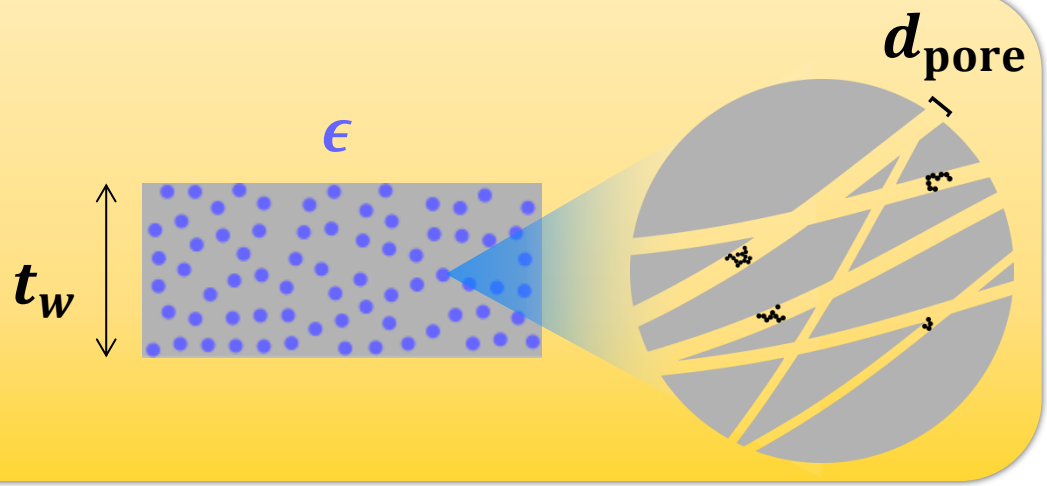
Model development: Temperature dependence

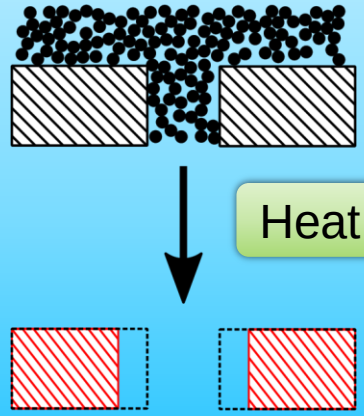
Filtration controlled by

- Porosity ϵ
- Wall thickness t_w
- Microstructure
  - Pore diameter d_{pore}



Unit collector model modified to capture temperature dependence

$$d_{pore} = \beta(T - T_{ref}) + d_{ref}$$



Heat up due to regeneration

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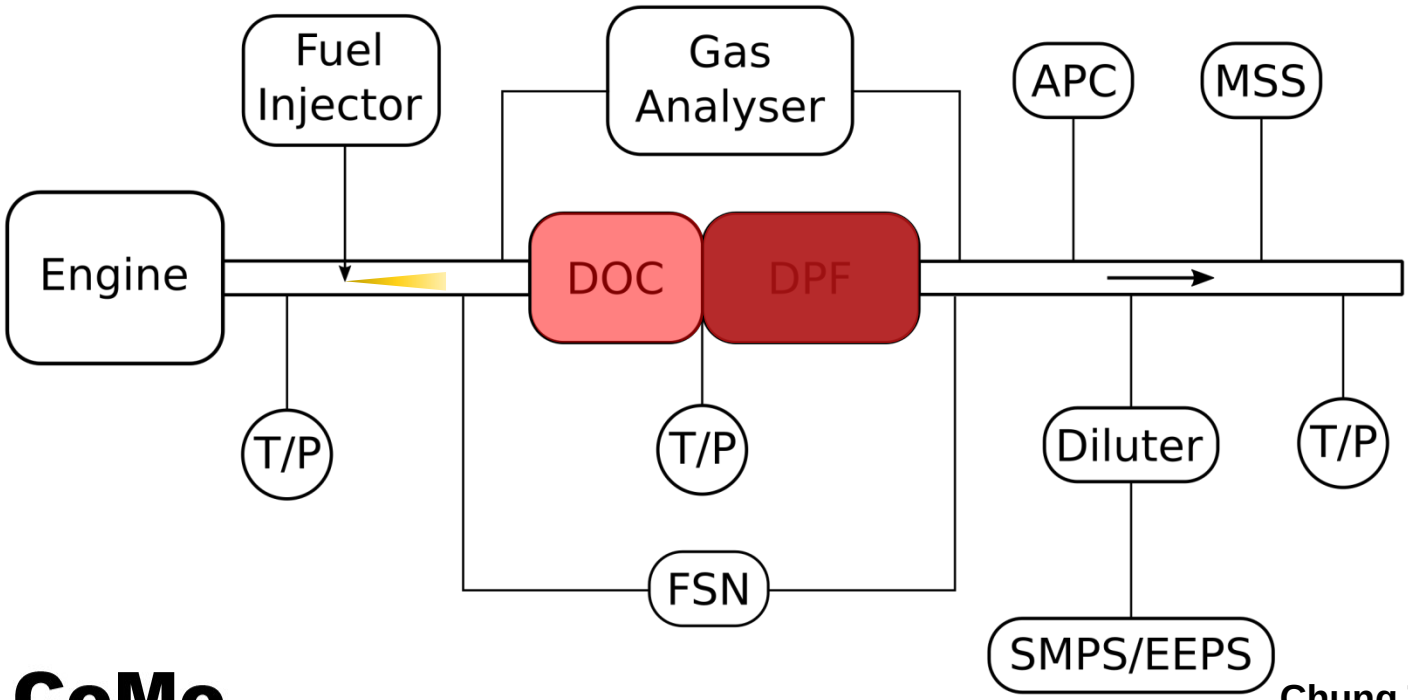
Experimental setup

10.5L Diesel engine
SiC DPF, no catalyst

Steady engine operation throughout
Inject fuel upstream of DOC to start regeneration



Experiment of Niessner et al., Journal of Aerosol Science 90 (2015) 14–25.

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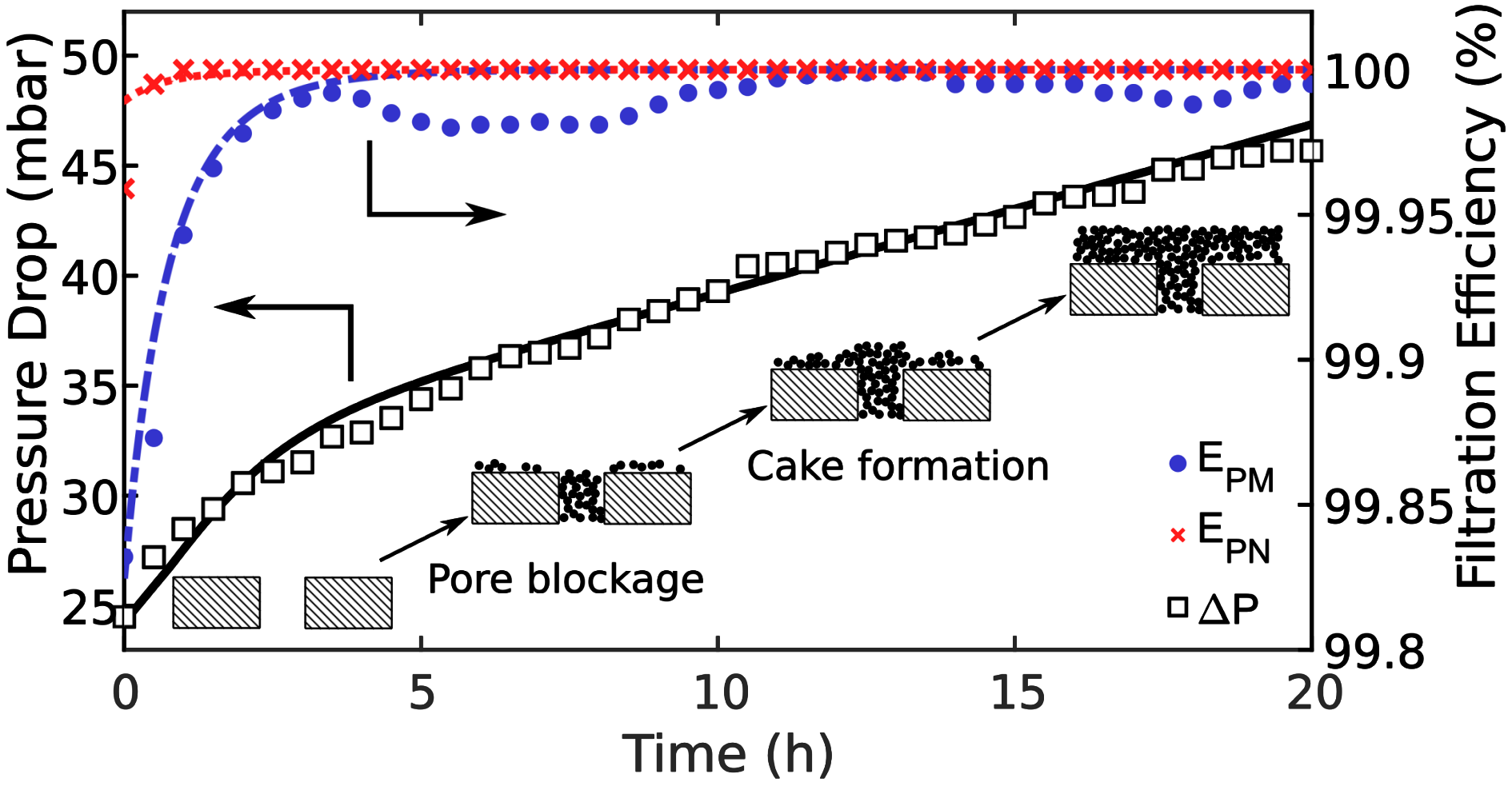
Particle loading



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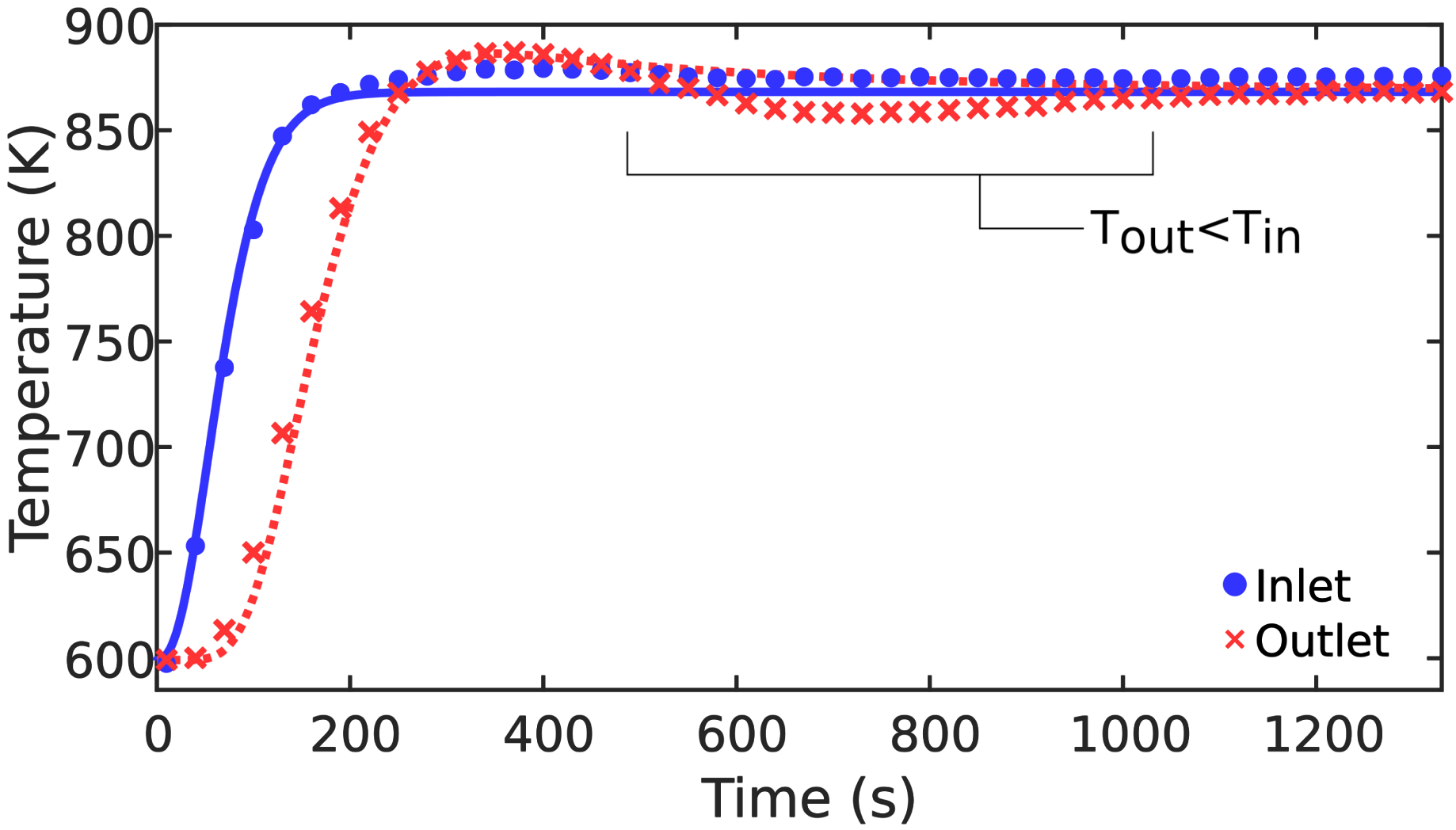
Regeneration temperature



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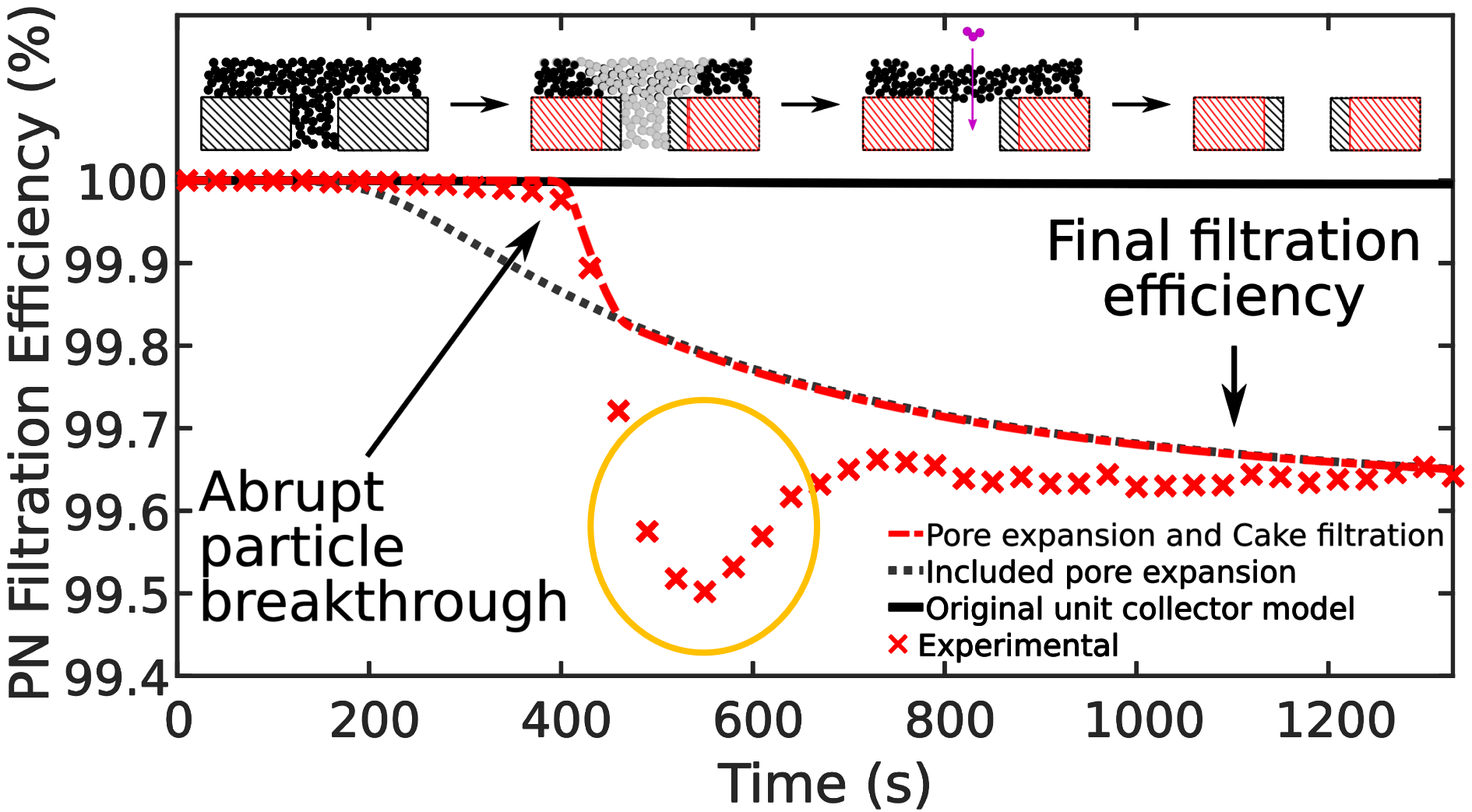
Regeneration filtration efficiency



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Summary

Compared model predicted filtration efficiencies with regeneration experiment

Additional filtration sub-models improved description of experiment

Continue to test other hypotheses on particle breakthrough and further develop model

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Acknowledgements

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