International Solvent Extraction Conference (ISEC 2022)
Göteborg, Sweden, Sept. 26 to 30, 2022

Detailed Drop-Based Simulation of Settling Behavior

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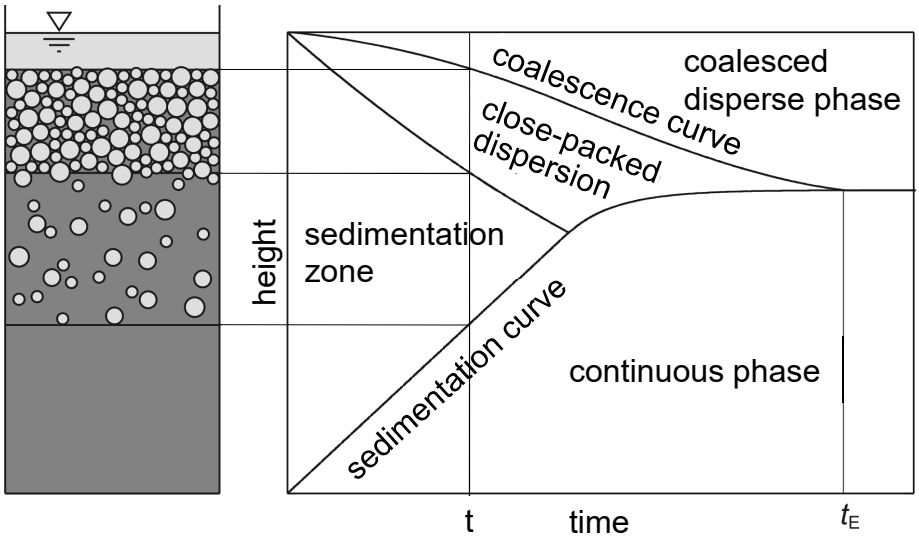
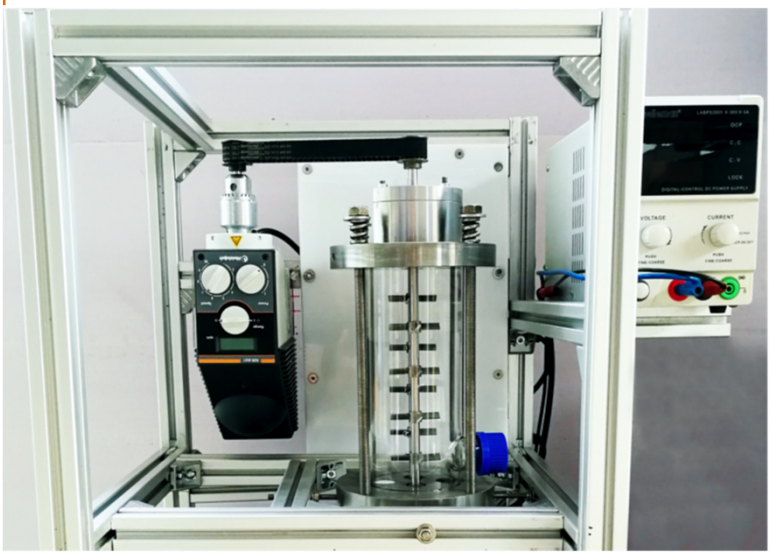
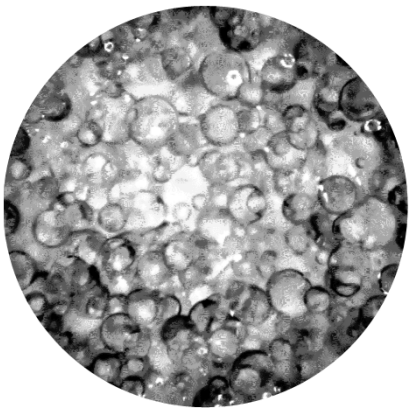
general settler concept



e.g.: Henschke, Schlieper, Pfennig, 2002: Determination of a coalescence parameter from batch-settling experiments. Chem. Eng. J. 85, 369-378.

settling cell with SOPAT probe





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Leleu, Pfennig, 2017: Standardized Settling Cell to Characterize Liquid-Liquid Dispersion. ISEC 2017 Book of Abstracts

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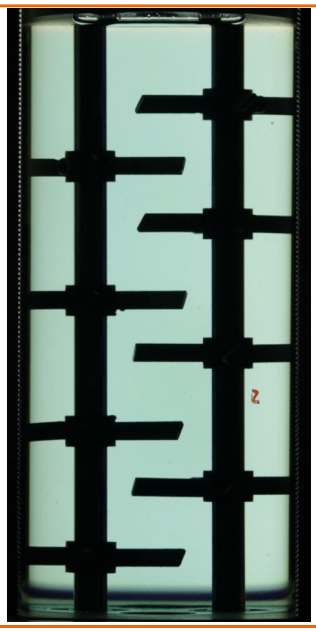
iso-optical system

water + ethylene glycol + hexane

- identical refractive index of phases
- no refraction at interface
- transparent dispersion



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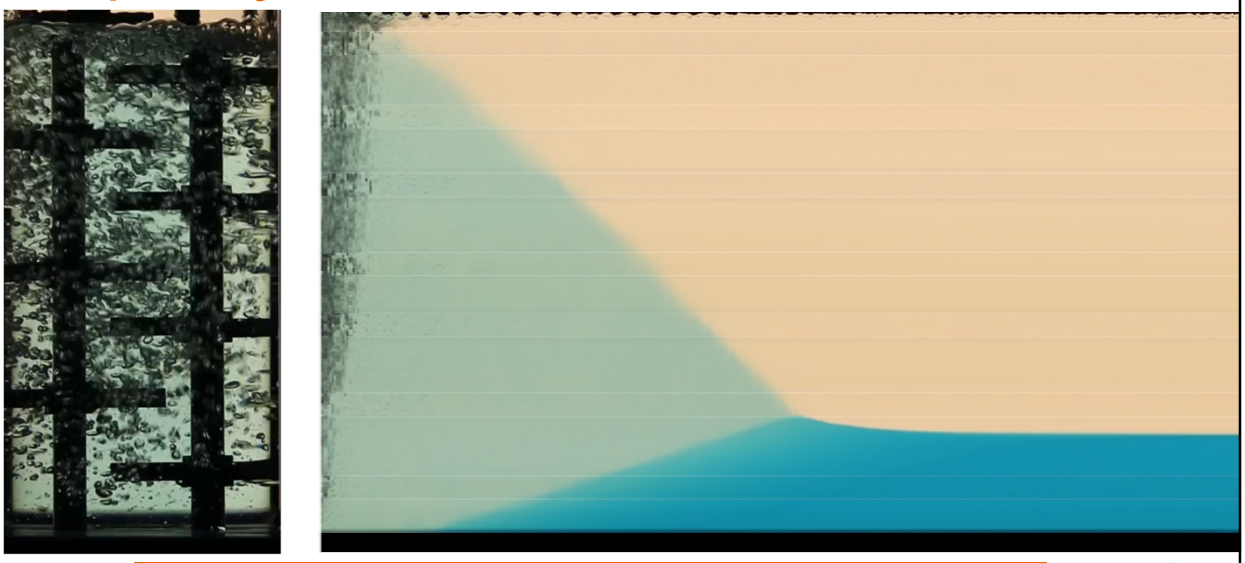

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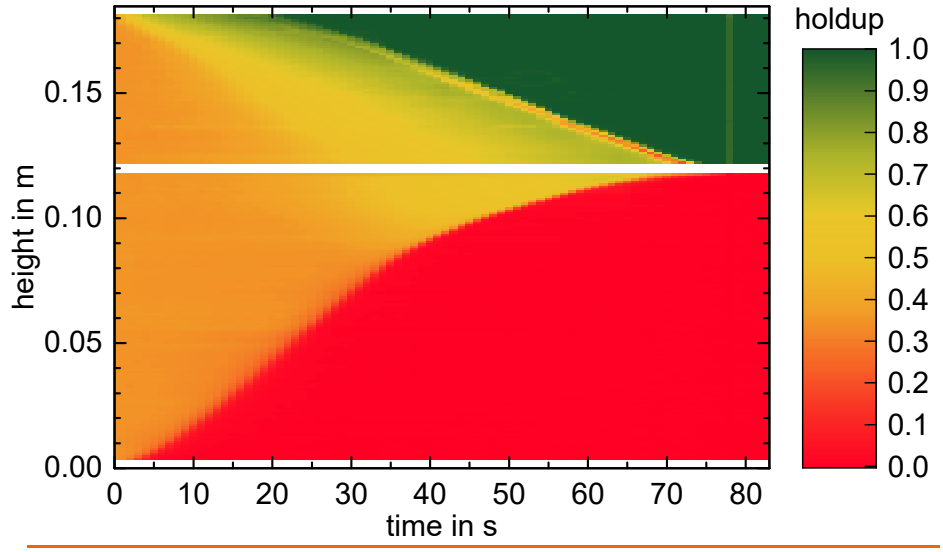
experimental holdup, initial holdup: 35 % organic



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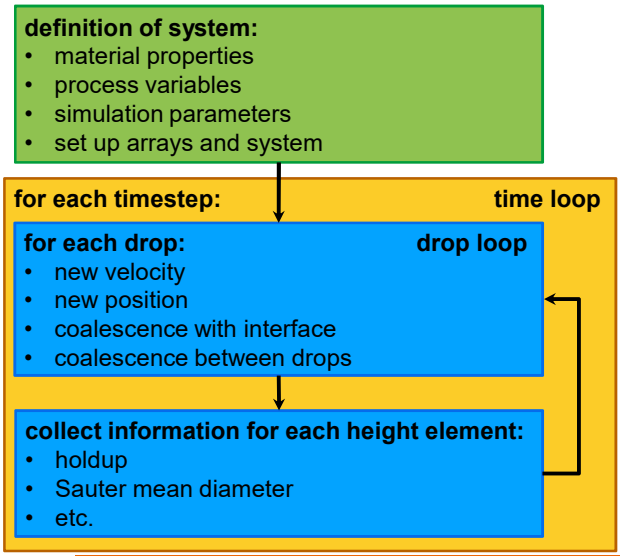
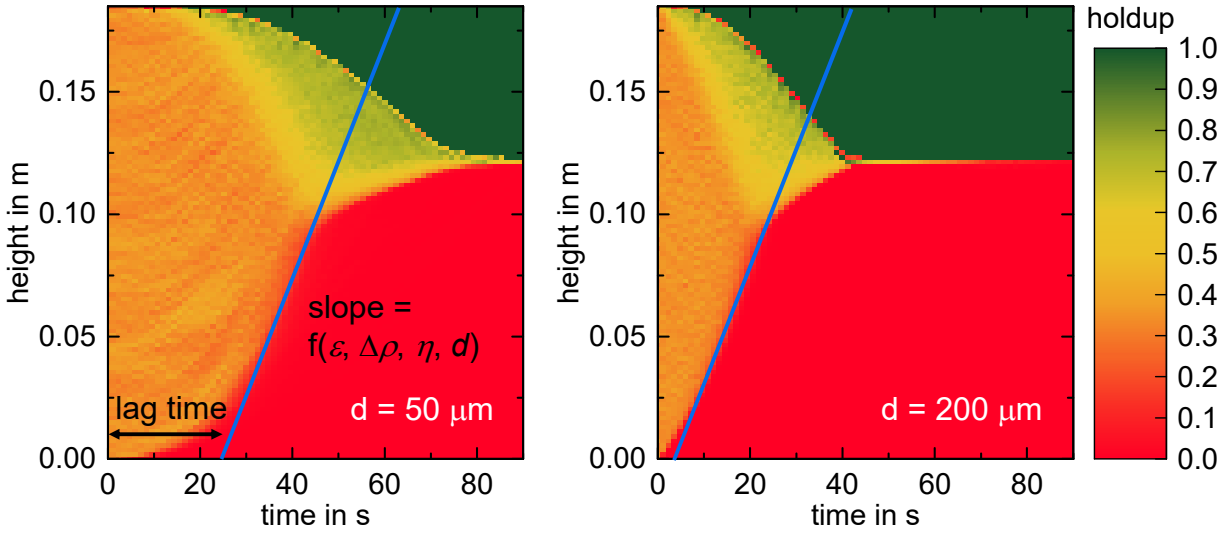
ReDrop: drop-based modeling

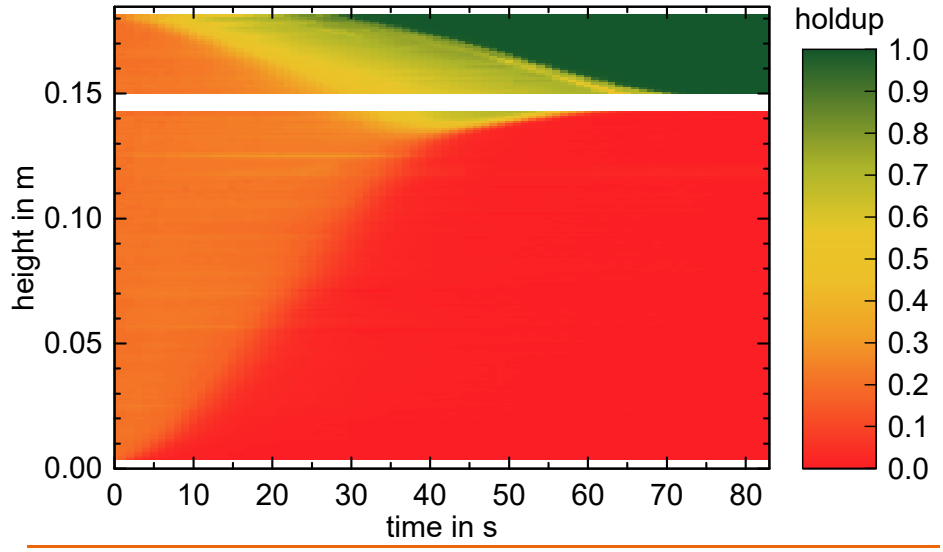


lag time & characteristic drop diameter



Leleu, Pfennig, 2019: Drop-Based Modelling of Extraction Equipment. Ion Exchange and Solvent Extraction **23**, 253-285.

experimental holdup, initial holdup: 20.5 % organic



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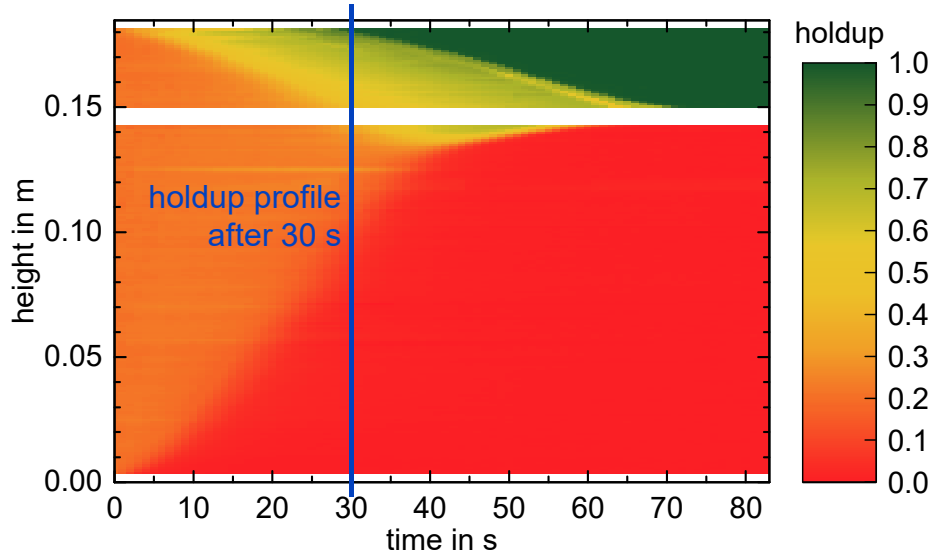

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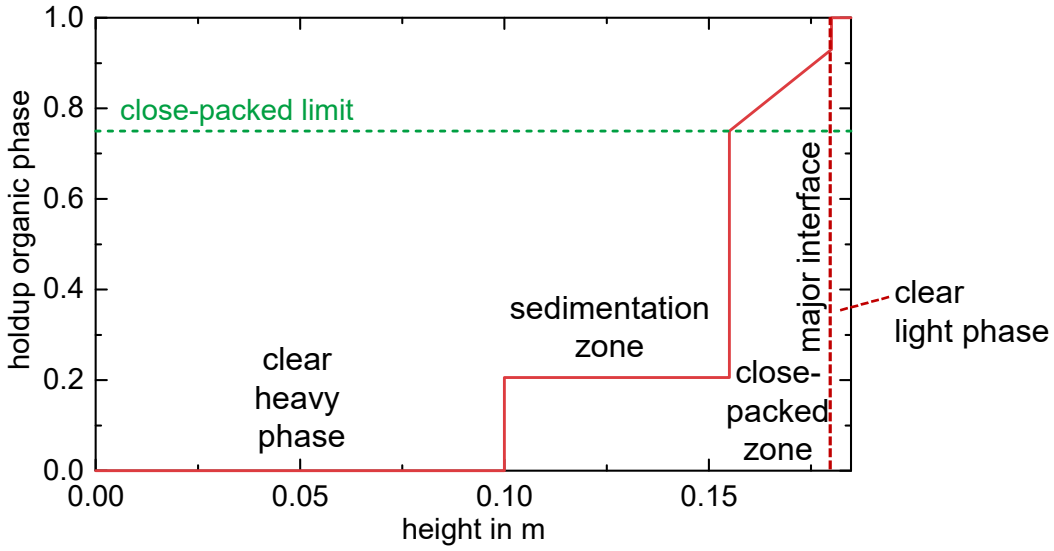
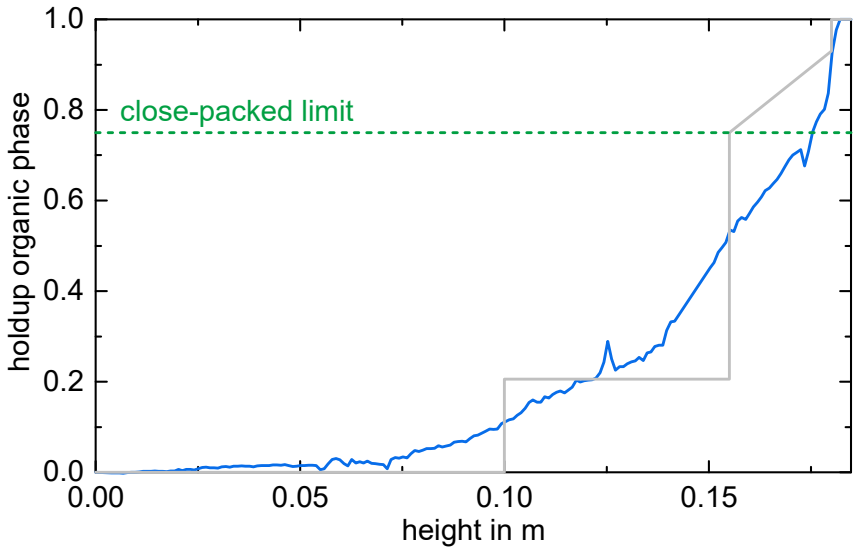
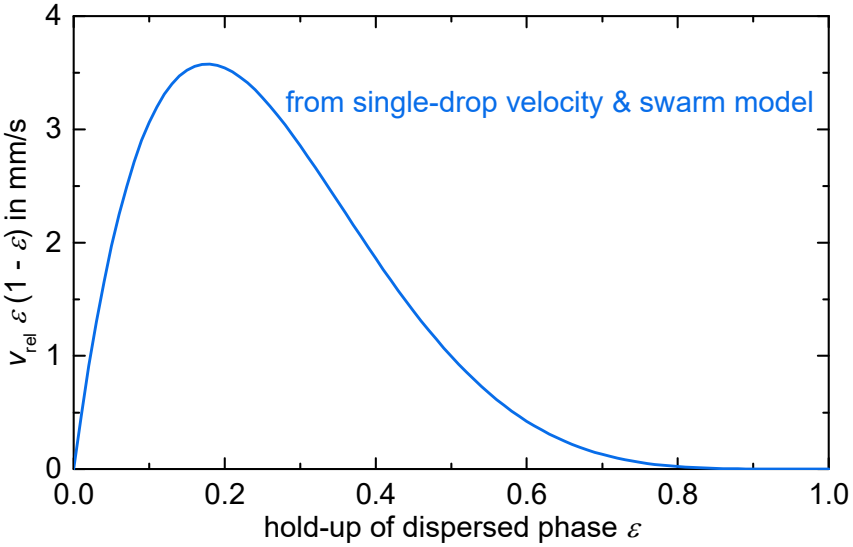
what we expect



what we find

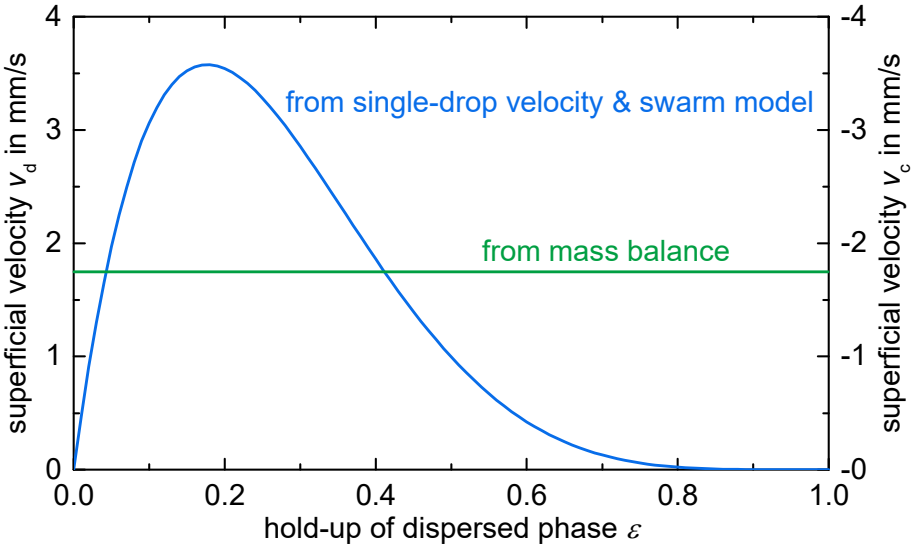


Wallis plot



G.W. Wallis: One dimensional two-phase flow. McGraw Hill, 1969

Wallis plot



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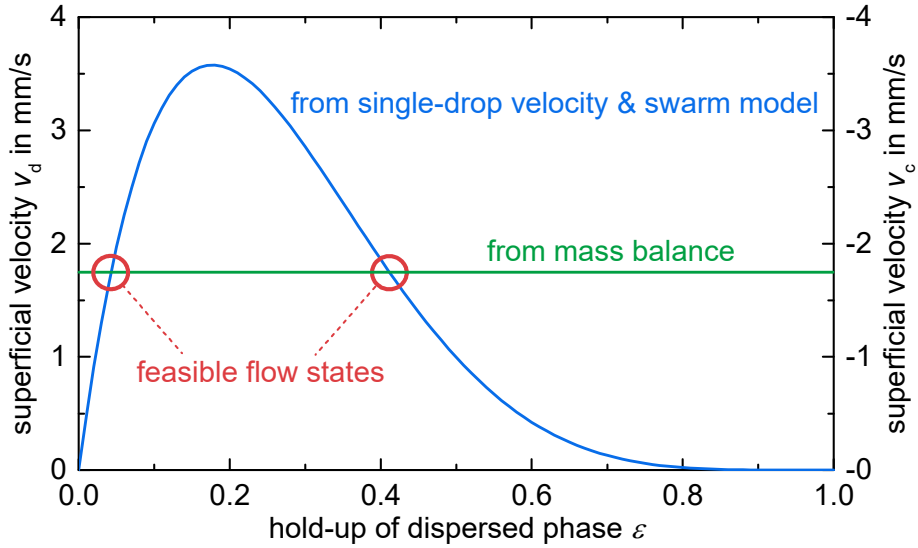

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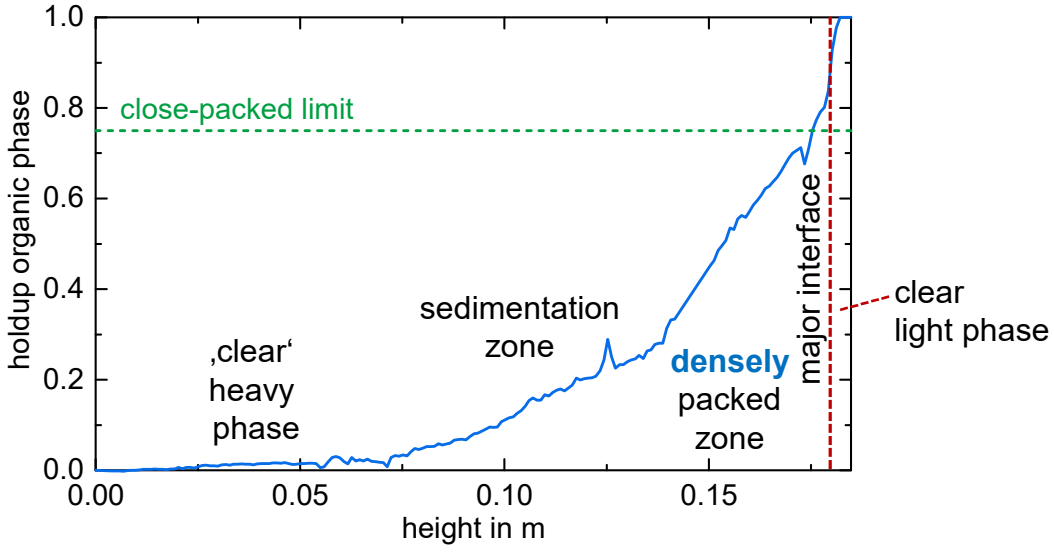
what we find



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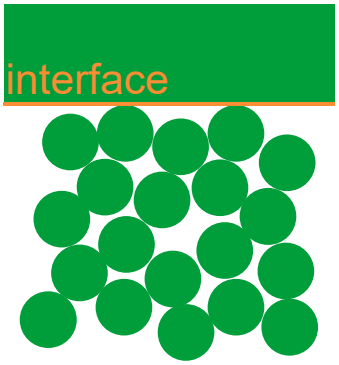
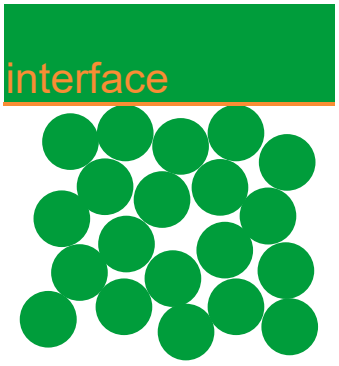
at the interface



before coalescence

at the interface



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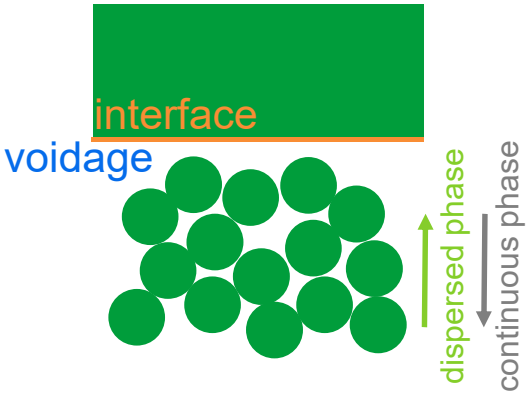
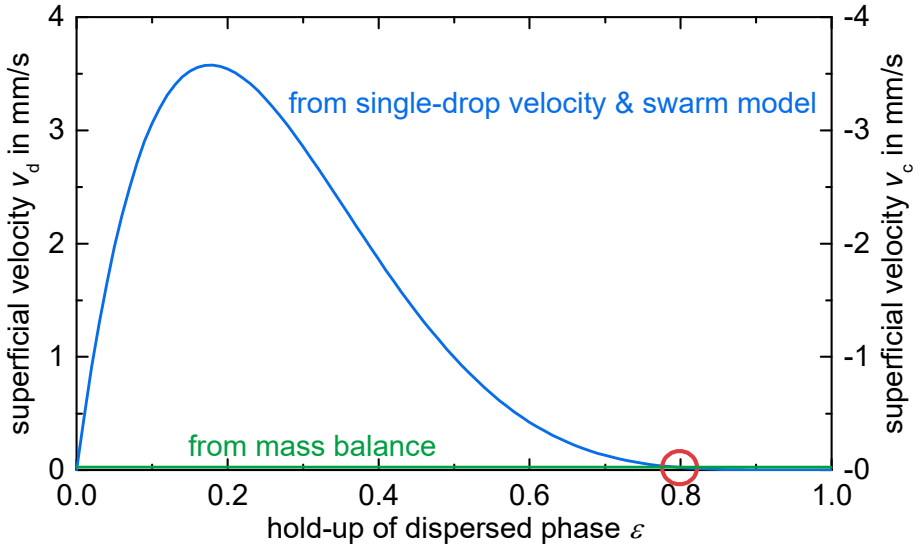


after coalescence

flowrate close to interface



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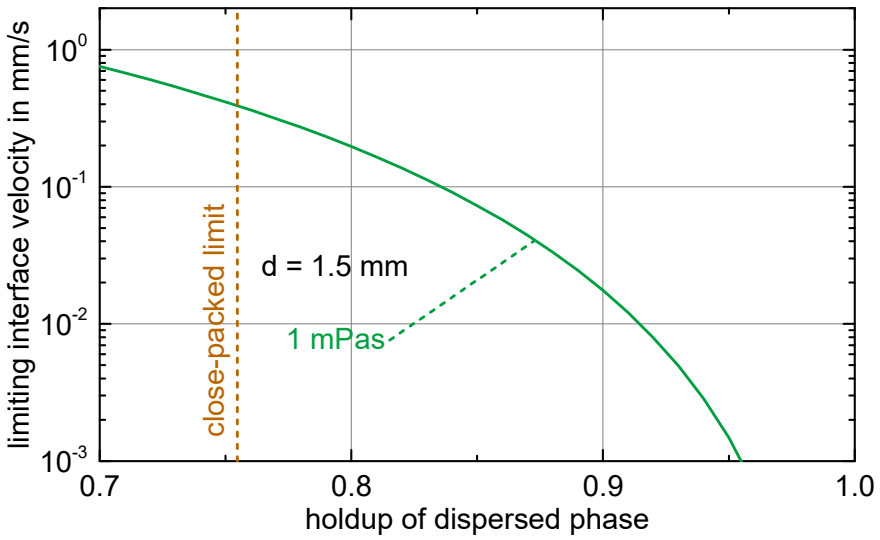
is this a general effect?



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$\Delta\rho$ = 400 kg/m^3
model: Henschke, Waheed, Pfennig, 2000 & Richardson, Zaki, 1954

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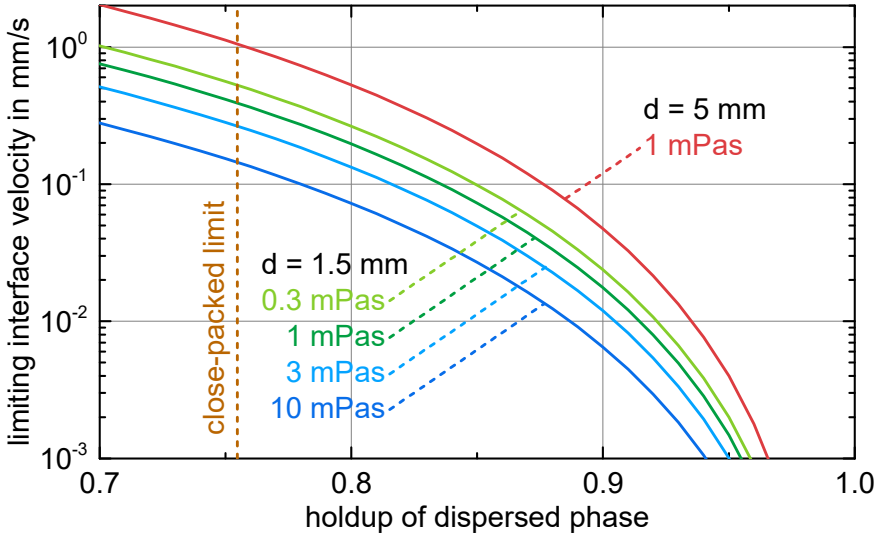

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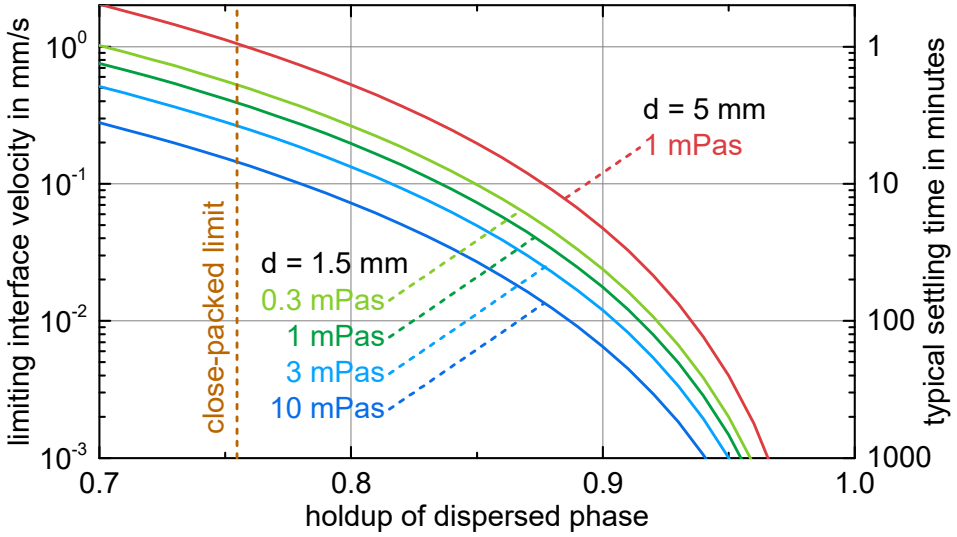

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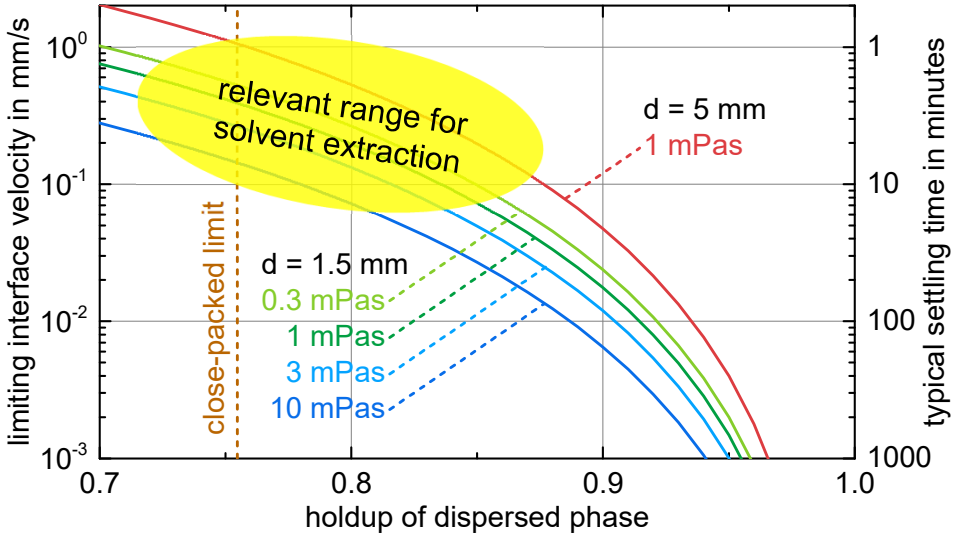

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coalescence probability

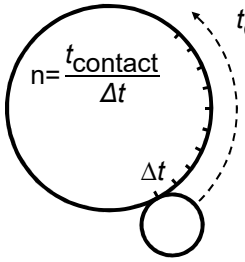
Coulaloglou & Tavlarides: $p_c = \exp\left(-\frac{t_{coalescence}}{t_{contact}}\right)$

Coulaloglou & Tavlarides, Chem. Eng. Sci., 1977

coalescence probability

Coulaloglou & Tavlarides: $p_c = \exp\left(-\frac{t_{coalescence}}{t_{contact}}\right)$

but:



$$p_{non-c,n\Delta t} = p_{non-c,\Delta t}{}^{n}$$

$$p_{non-c,\Delta t} = \exp\left(-\frac{\Delta t}{t_{coalescence}}\right)$$

$$p_{non-c,n\Delta t} = \exp\left(-\frac{n\Delta t}{t_{coalescence}}\right) = \exp\left(-\frac{t_{contact}}{t_{coalescence}}\right)$$

coalescence probability

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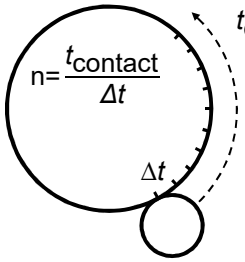

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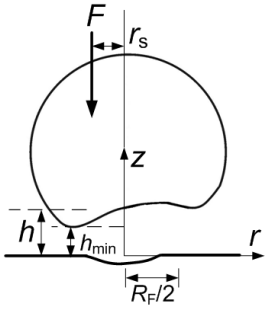
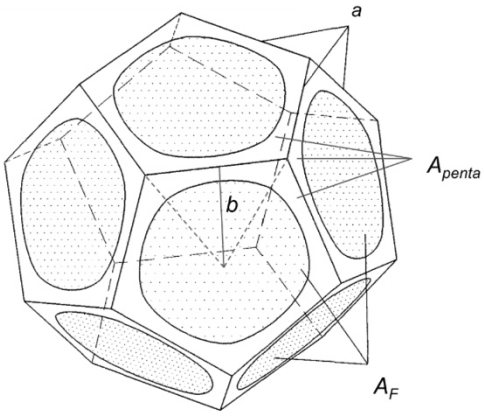
⇒ **correct:** $p_c = 1 - \exp\left(-\frac{t_{contact}}{t_{coalescence}}\right)$

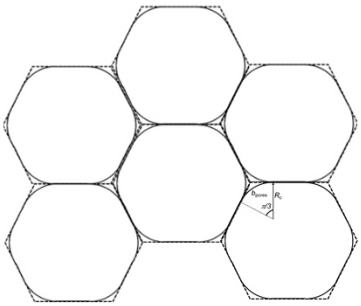
coalescence: polyhedron & asymmetric dimple model





$$t_{coalescence} \sim \frac{6\pi^2 \mu R_F R_a^{3/2}}{F_{driving} r_s^* \sqrt{h_{critical}}}$$

$$F_{driving} = F_{Young\text{-}Laplace} = \frac{2\pi R_F^2 \sigma}{R}$$



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e.g.: Henschke, Schlieper, Pfennig, 2002: Determination of a coalescence parameter from batch-settling experiments. Chem. Eng. J. 85, 369-378.

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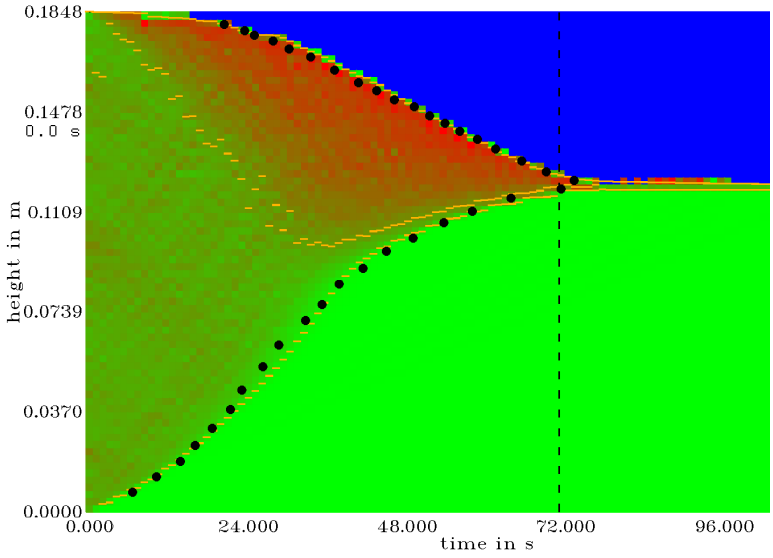
drop-based simulation results



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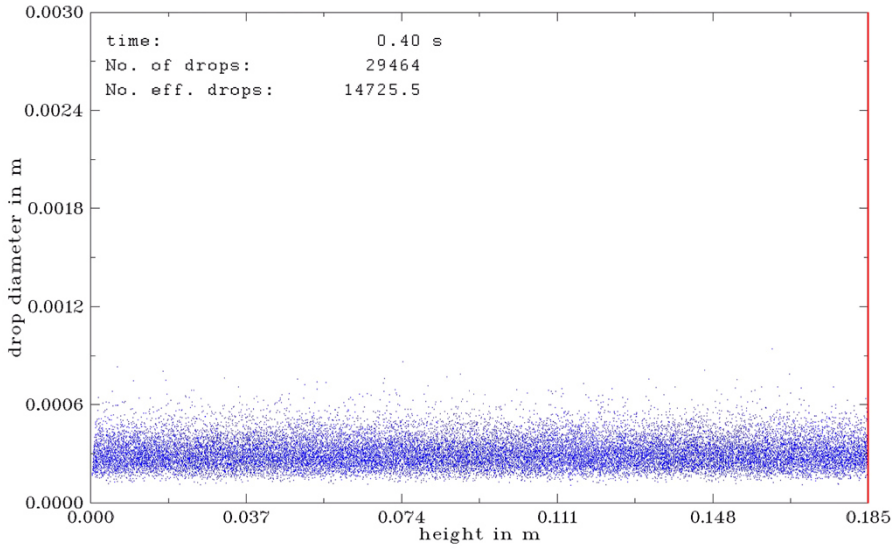

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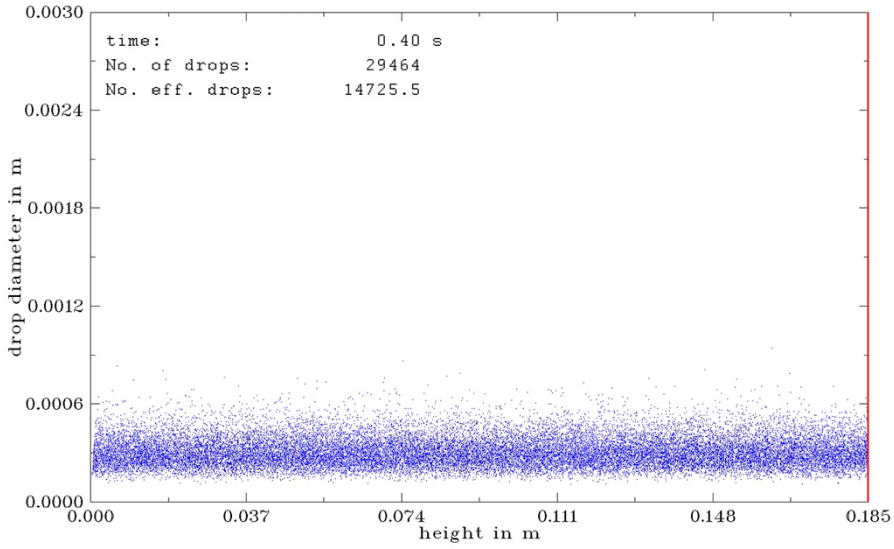

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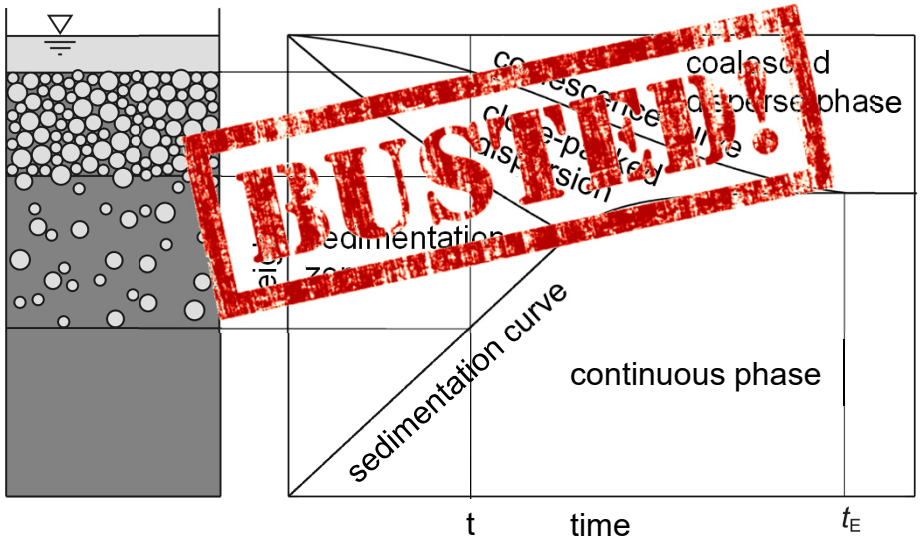
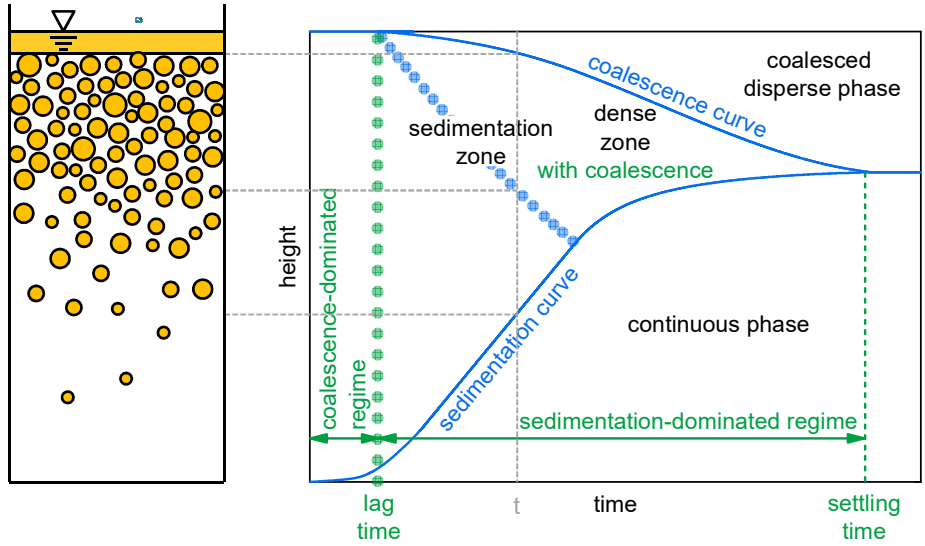
conclusions

- **lag time**: small drops, hardly sediment but coalesce ⇒ **polydispersity**
- **densely packed zone** ⇒ **velocity** of drop swarm **up to high holdup**
- close-packed zone:
  - occurs at most in small regions
  - drops don‘t press on each other and on interface
- modeling, simulation: ReDrop (representative drops)
  - drop sedimentation: polydisperse swarm up to high holdup
  - coalescence: Henschke polyhedron & asymmetric dimple model & correct coalescence probability

old general settler concept



new general settler concept



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