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Aerosol and Particle Transport in Biomass Furnaces

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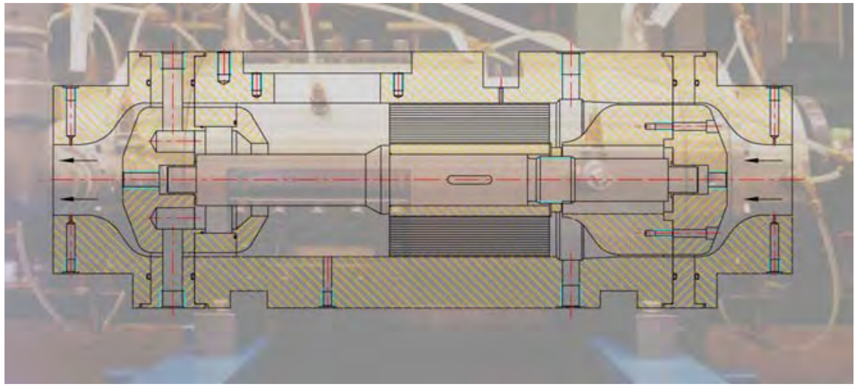
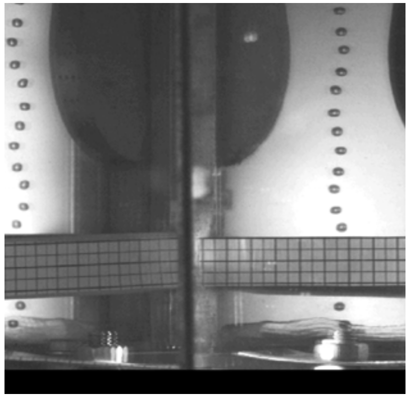
Background

Two Phase Flow
Turbulence modelling
Phase Separation
Heat Exchangers

BIOAEROSOLS

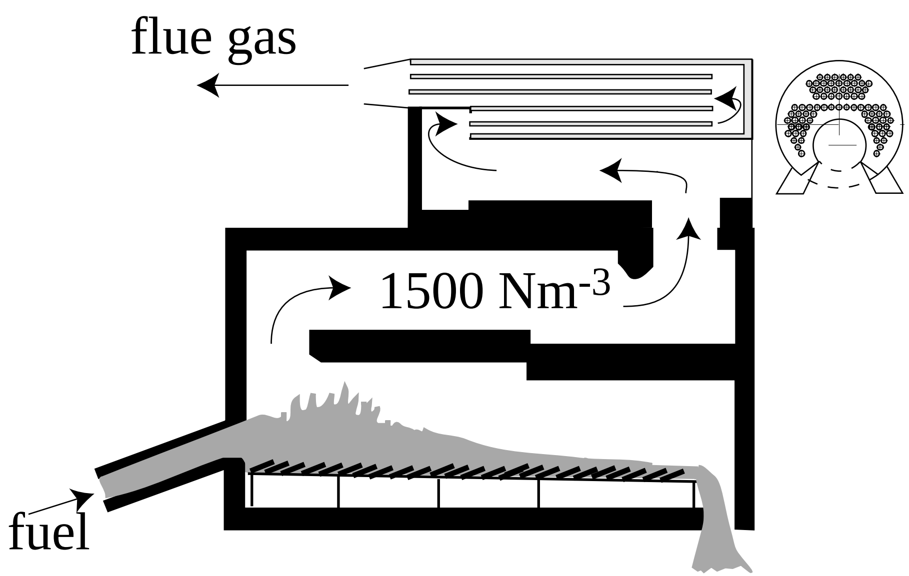
Graz University of Technology
Åbo Akademi University
Technical University of Denmark
ERC GmbH
MAWERA GmbH
StandardKessel GmbH





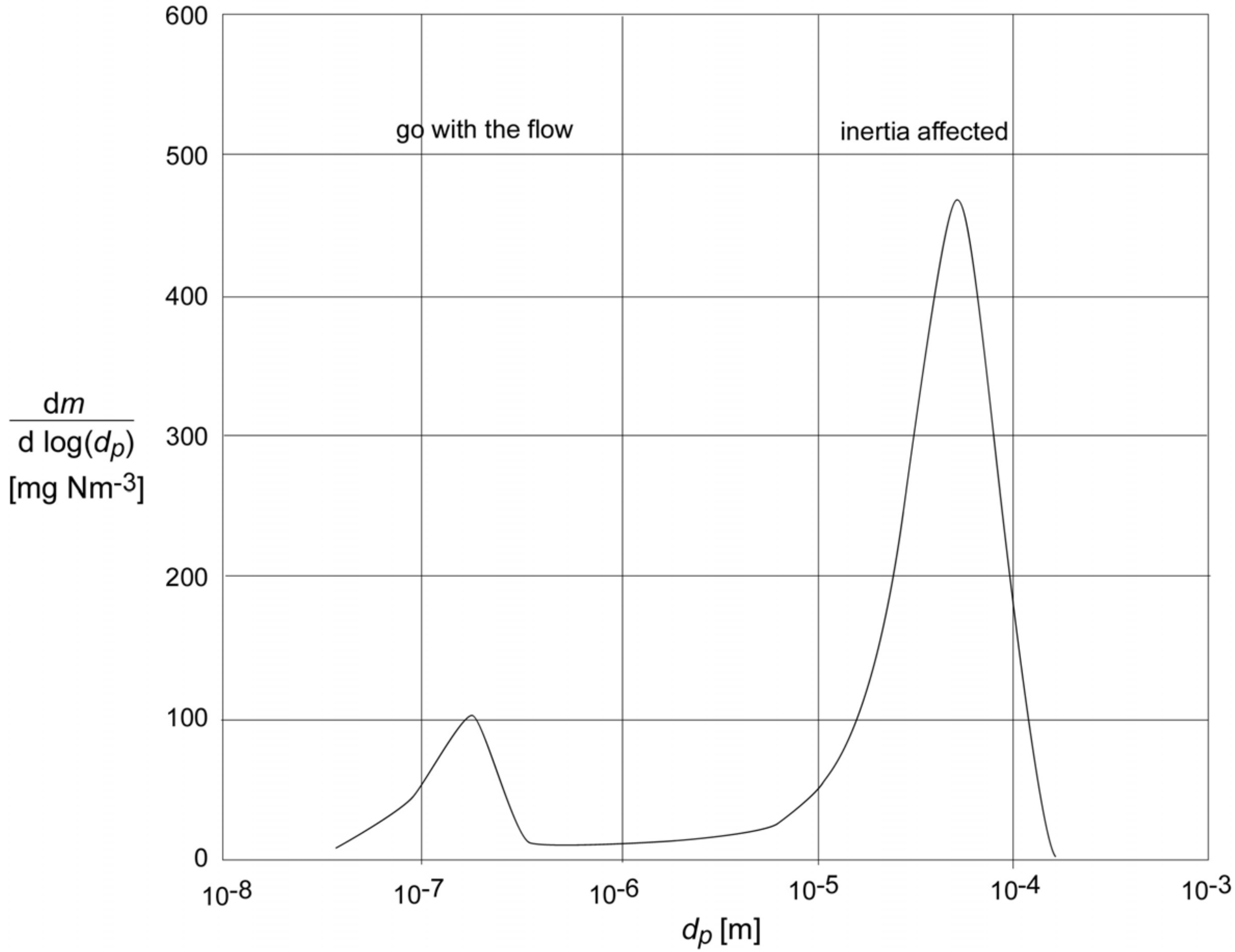
Contents

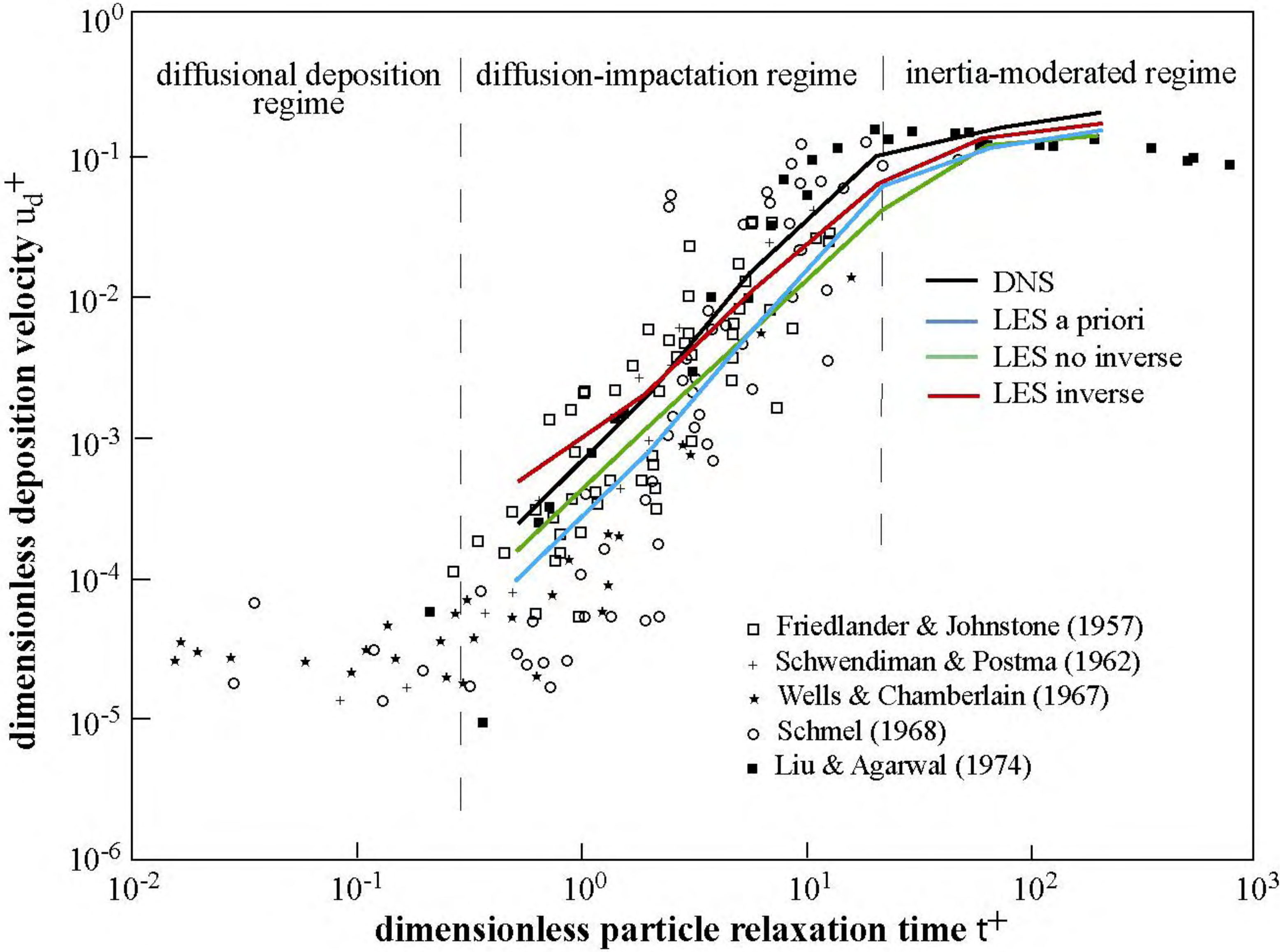
Applicability of CFD codes	K-ε LES DNS
Particle deposition	Mechanisms Diffusional deposition regime Inertia moderated regime

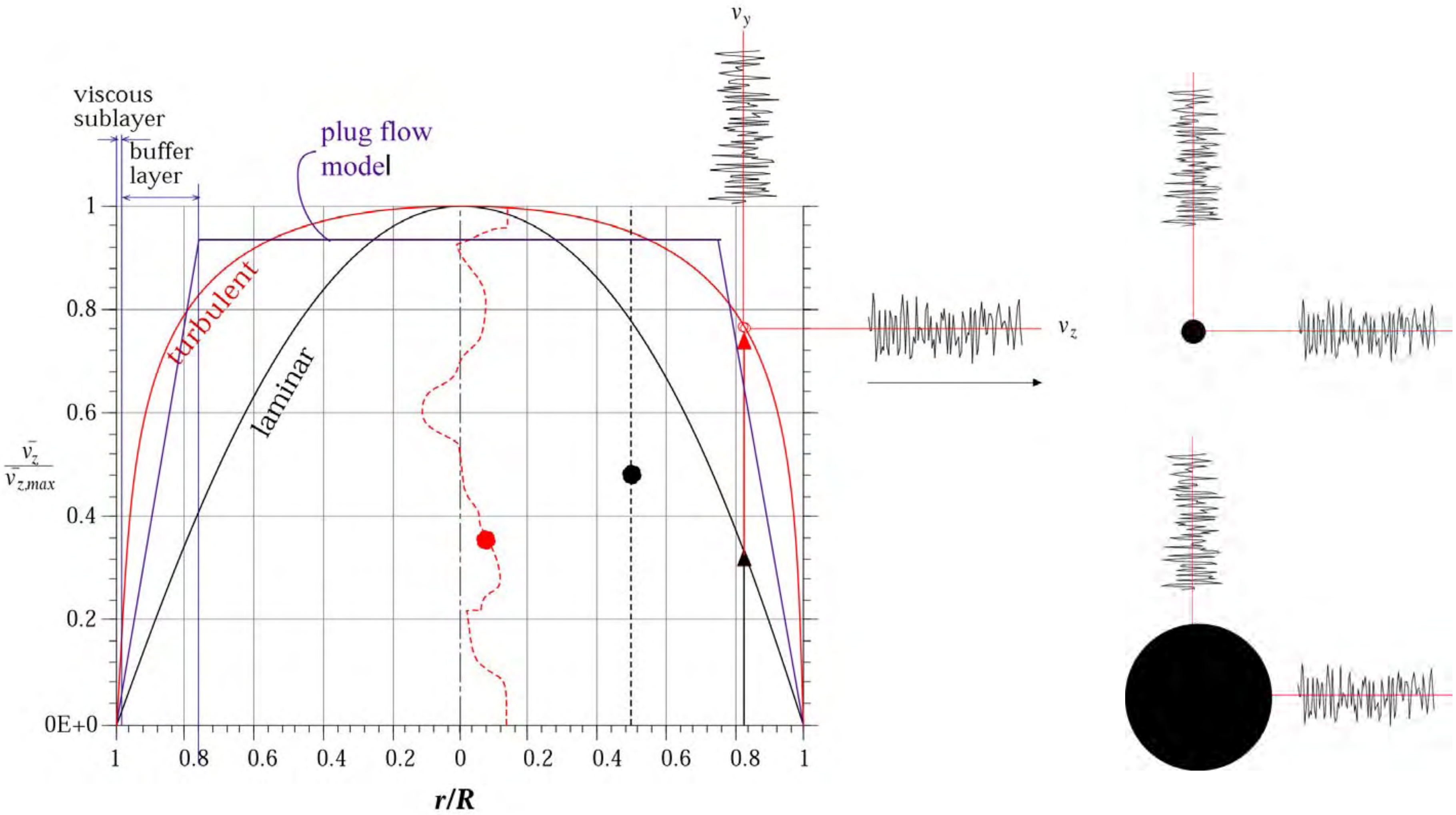


second boiler passage:
24 tubes Ø53 x 31600

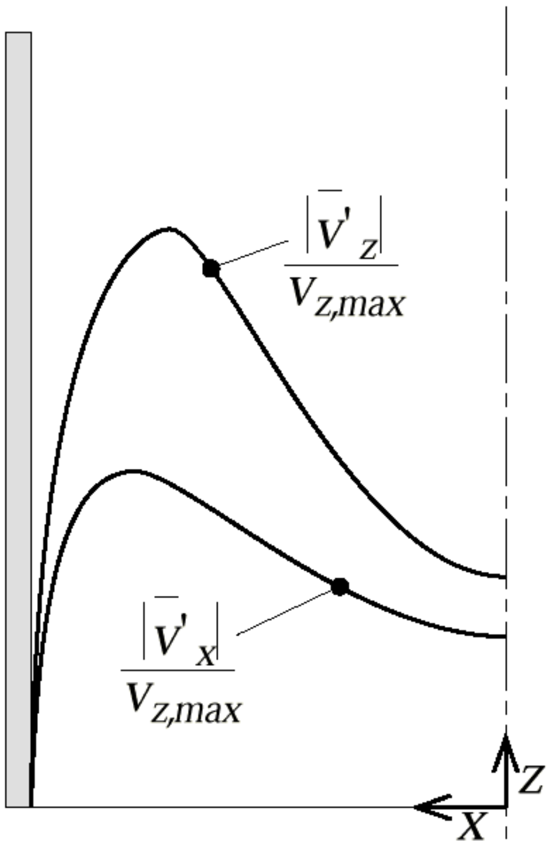
first boiler passage:
43 tubes Ø53 x 2400

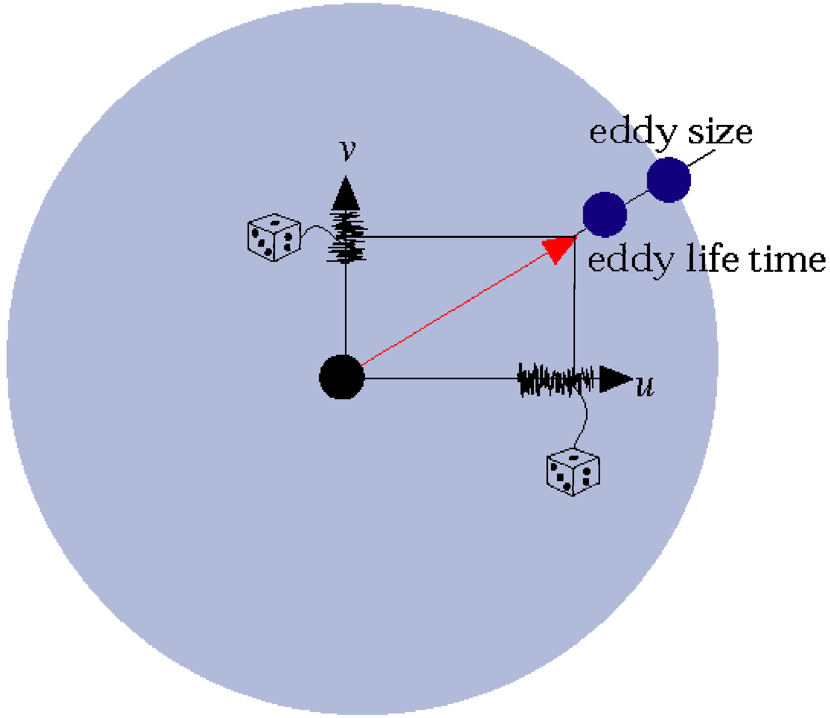

600
500
400
300
200
100
0
go with the flow
inertia affected
$\frac{dm}{d \log(d_p)}$
[mg Nm^{-3}]
10^{-8}
10^{-7}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
d_p [m]

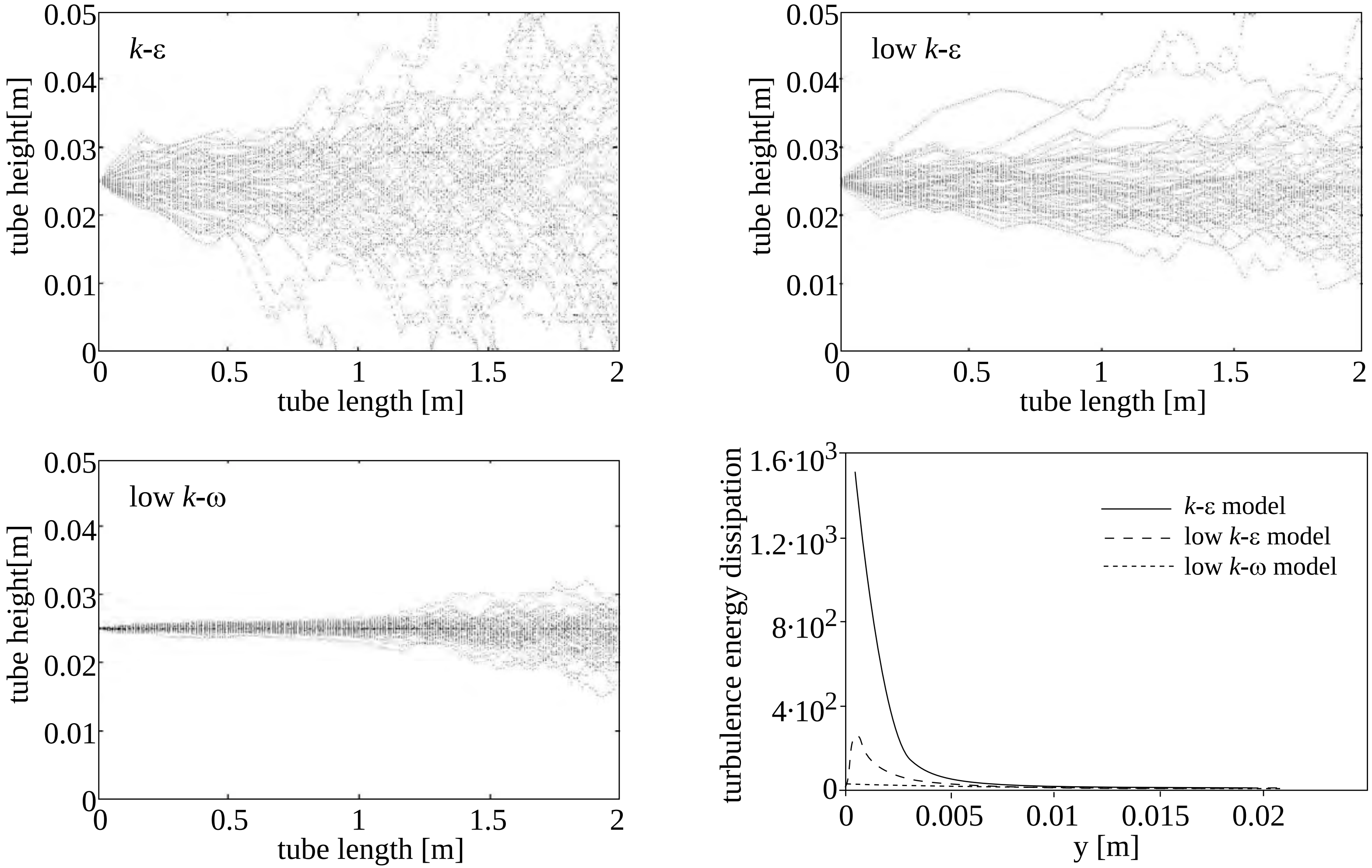

diffusional deposition regime
diffusion-impactation regime
inertia-moderated regime
dimensionless deposition velocity u_d^+
dimensionless particle relaxation time t^+
DNS
LES a priori
LES no inverse
LES inverse
Friedlander & Johnstone (1957)
Schwendiman & Postma (1962)
Wells & Chamberlain (1967)
Schmel (1968)
Liu & Agarwal (1974)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3



viscous sublayer
buffer layer
plug flow model
turbulent
laminar
v_y
v_z
$\frac{\bar{v}_z}{\bar{v}_{z,max}}$
1
0.8
0.6
0.4
0.2
0E+0
1 0.8 0.6 0.4 0.2 0 0.2 0.4 0.6 0.8 1
r/R


$\frac{|\overline{V'_z}|}{V_{z,max}}$
$\frac{|\overline{V'_x}|}{V_{z,max}}$
Z
X


eddy size
eddy life time
v
u


k-ε
low k-ε
low k-ω
tube height[m]
tube length [m]
0.05
0.04
0.03
0.02
0.01
0
0.5
1
1.5
2
turbulence energy dissipation
1.6·10^3
1.2·10^3
8·10^2
4·10^2
y [m]
0.005
0.01
0.015
0.02
k-ε model
low k-ε model
low k-ω model

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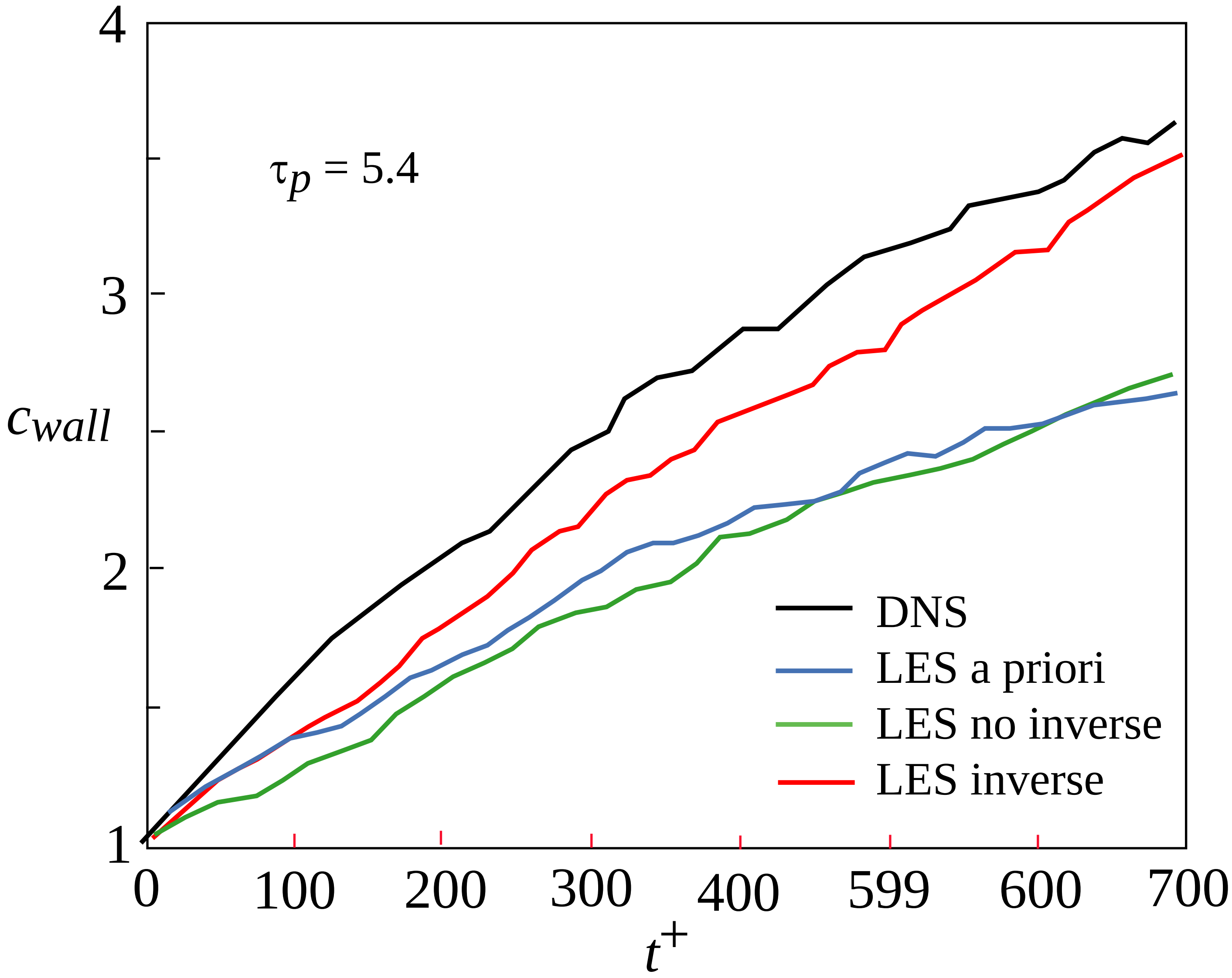
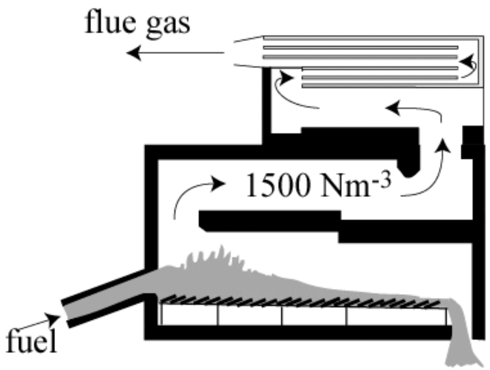


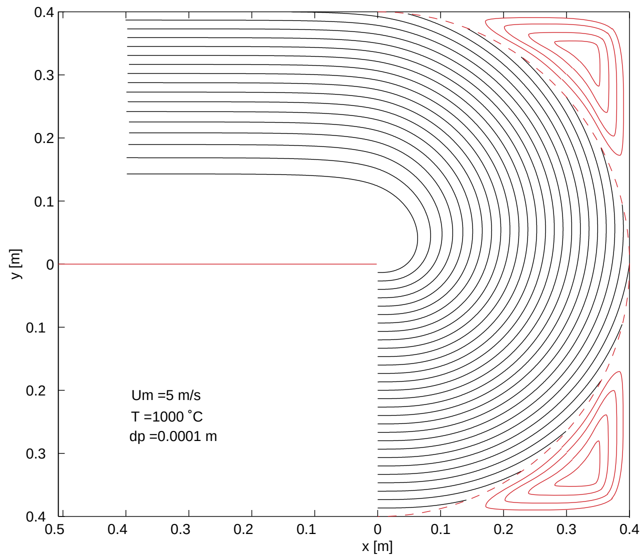
- commercial CFD models are less suitable for describing particle behaviour
  - inaccurate near wall
  - geometrically inflexible
  - computing time required

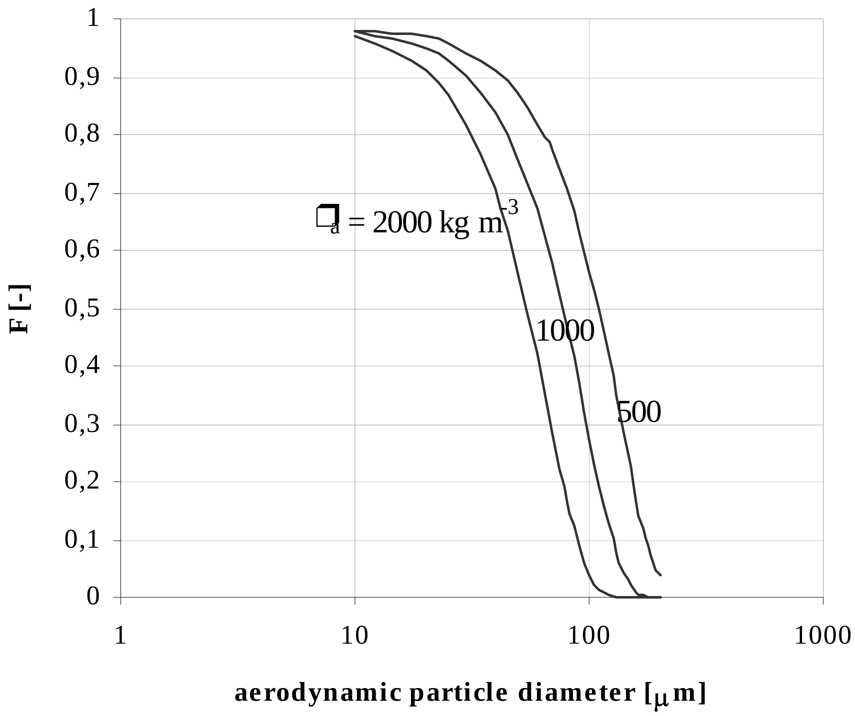
- use “global” methods to describe the main characteristics of the flow
  - commercial CFD code
  - Reynolds - Nusselt correlations (computerised)
  - potential flow models

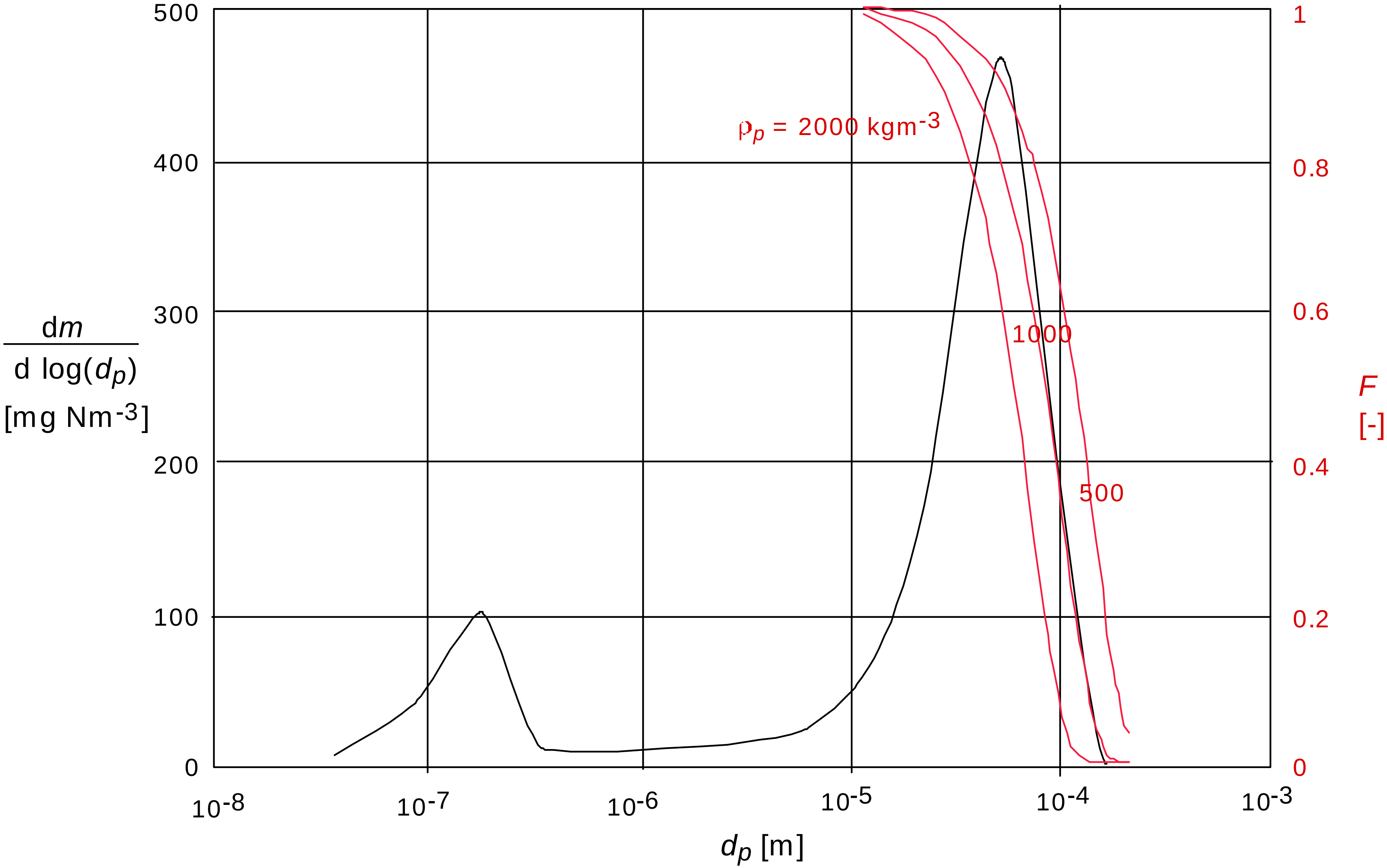
- add “blocks” for potential danger area’s
  - tube (bundle)
  - corners
  - entrainment

Coarse Particles








500
400
300
200
100
0
1
0.8
0.6
0.4
0.2
0
dm / d log(dp) [mg Nm-3]
F [-]
ρp = 2000 kgm-3
1000
500
10-8
10-7
10-6
10-5
10-4
10-3
dp [m]

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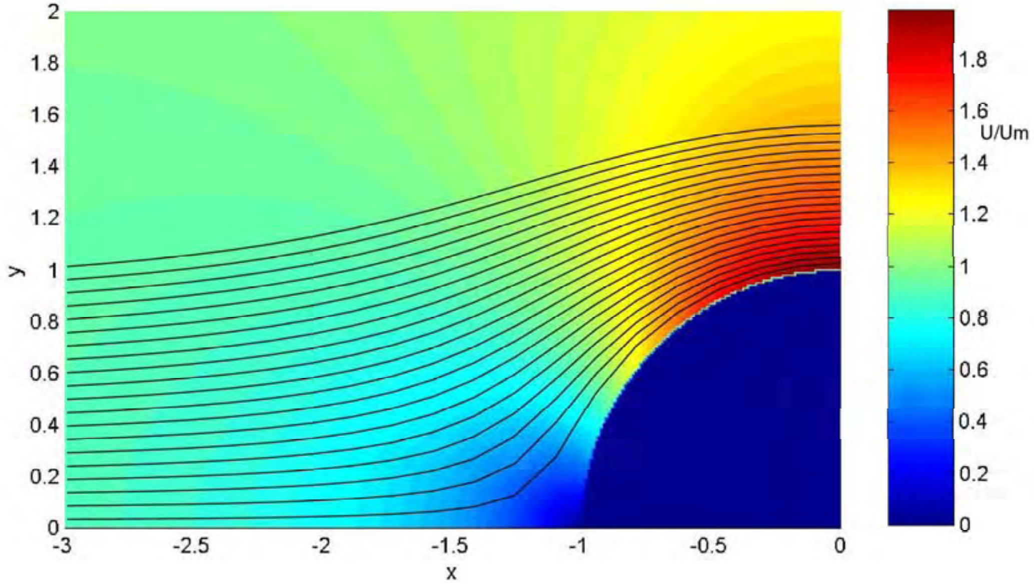

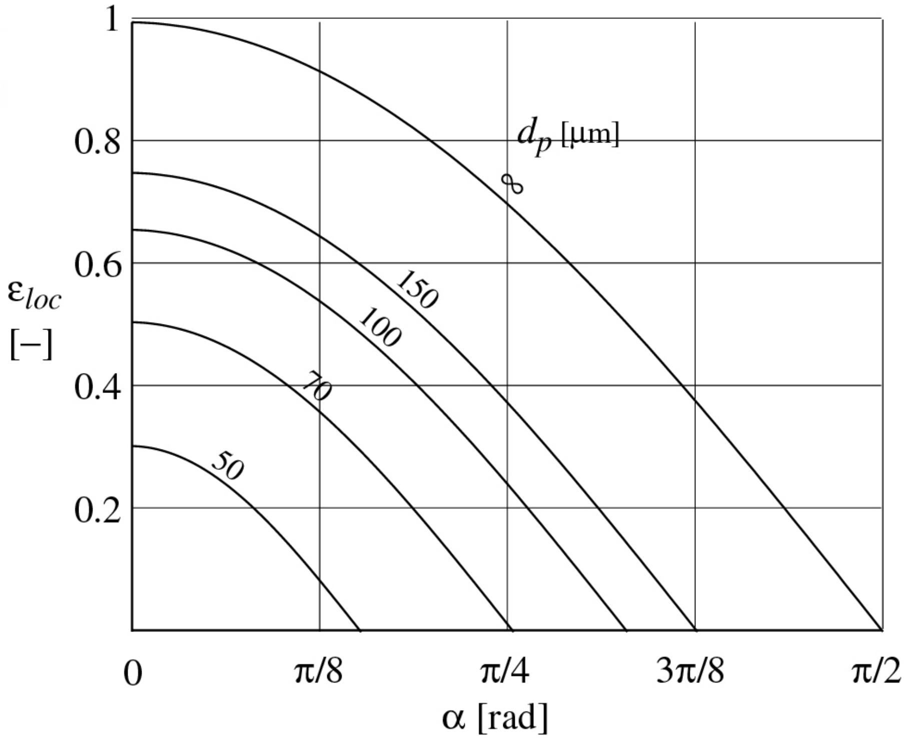

How do small particles reach the wall ?

Deposition velocity very close to the wall (viscous sublayer) :

Brownian motion / eddy diffusion

eddy impactation

thermophoresis

$$u_d^+ = \frac{u_d}{u^*} = 0.057\mathbf{Sc}^{-2/3} + 4.5 \cdot 10^{-4} \tau^{+2} + u_{th}^+$$

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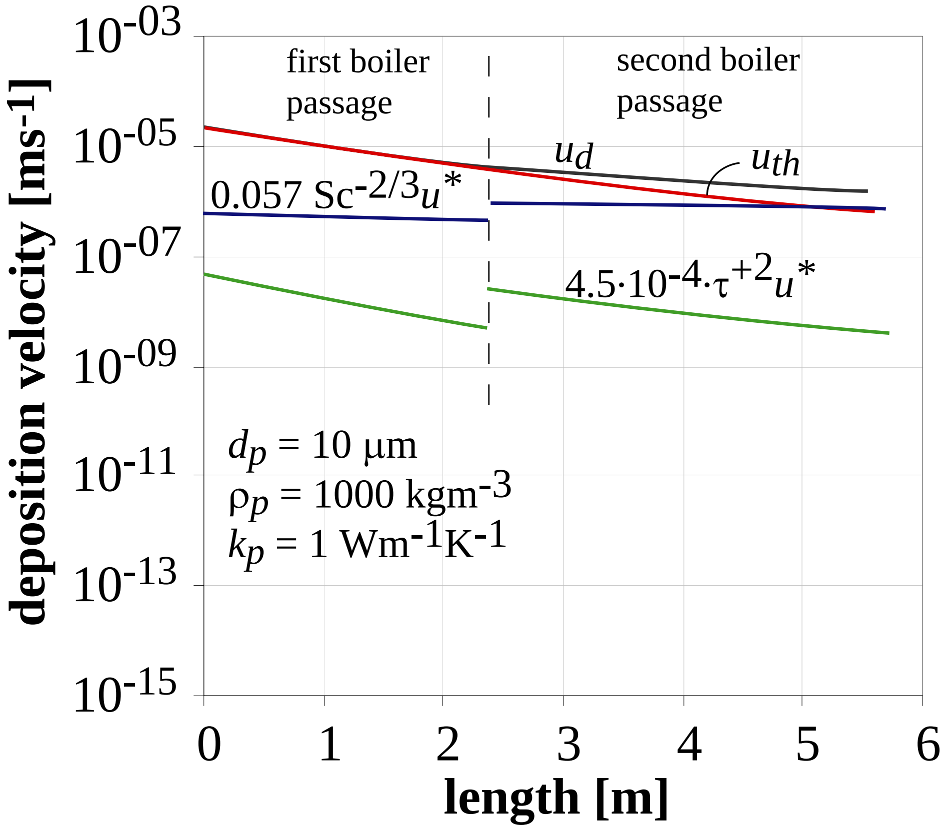
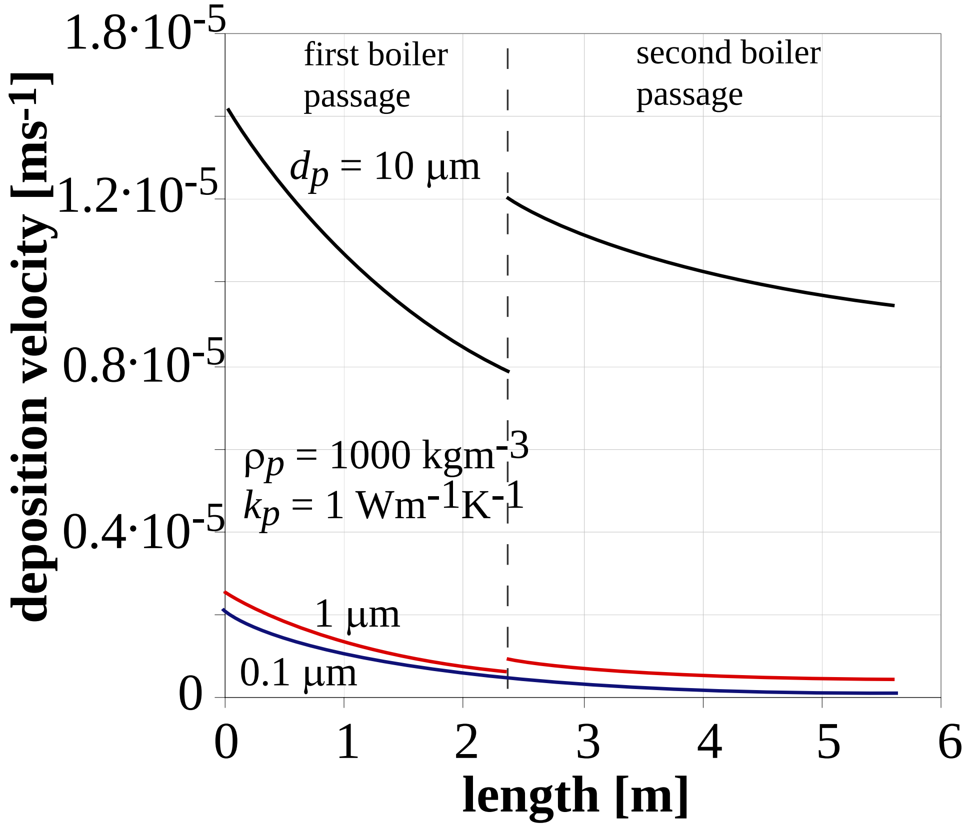
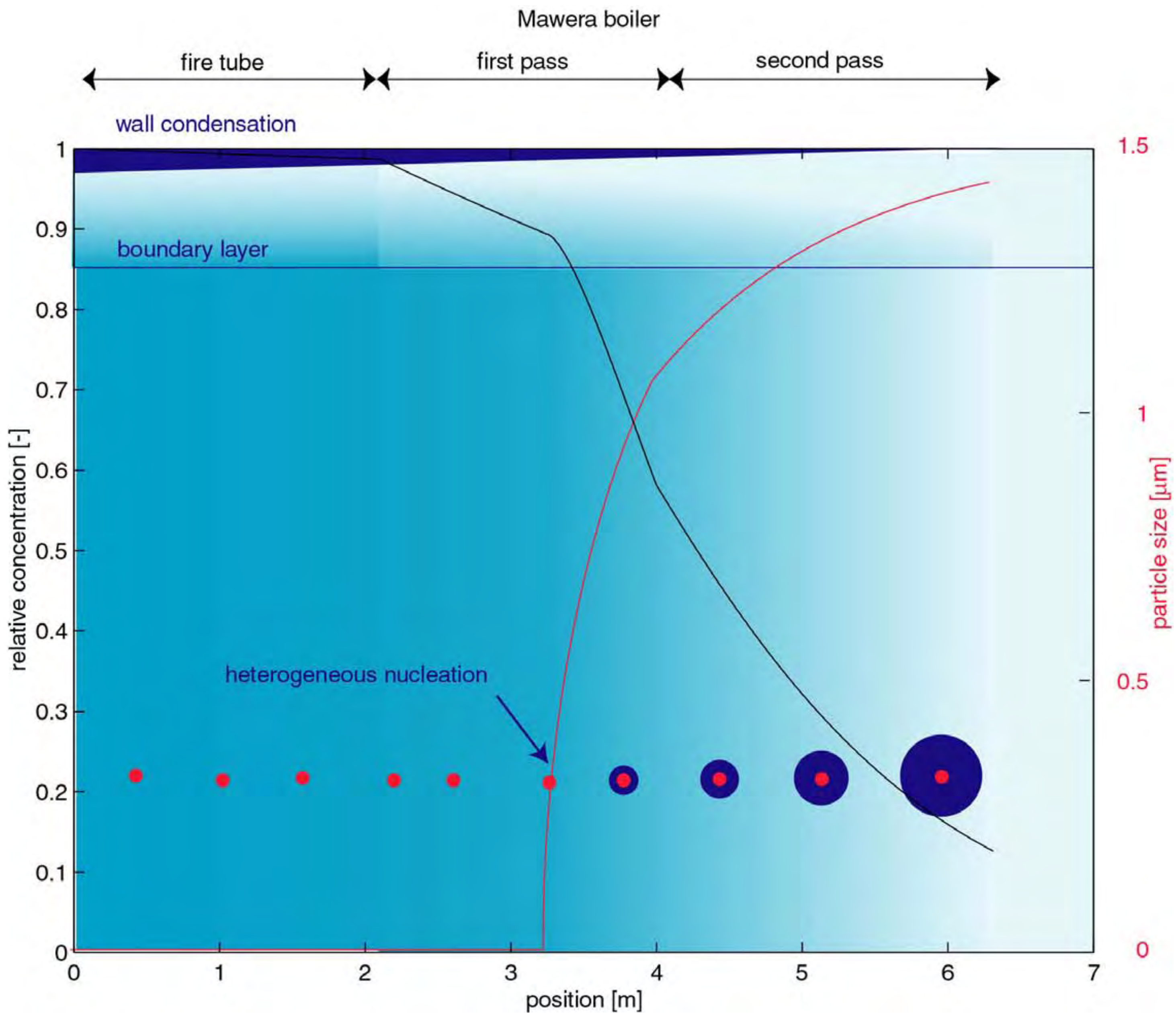
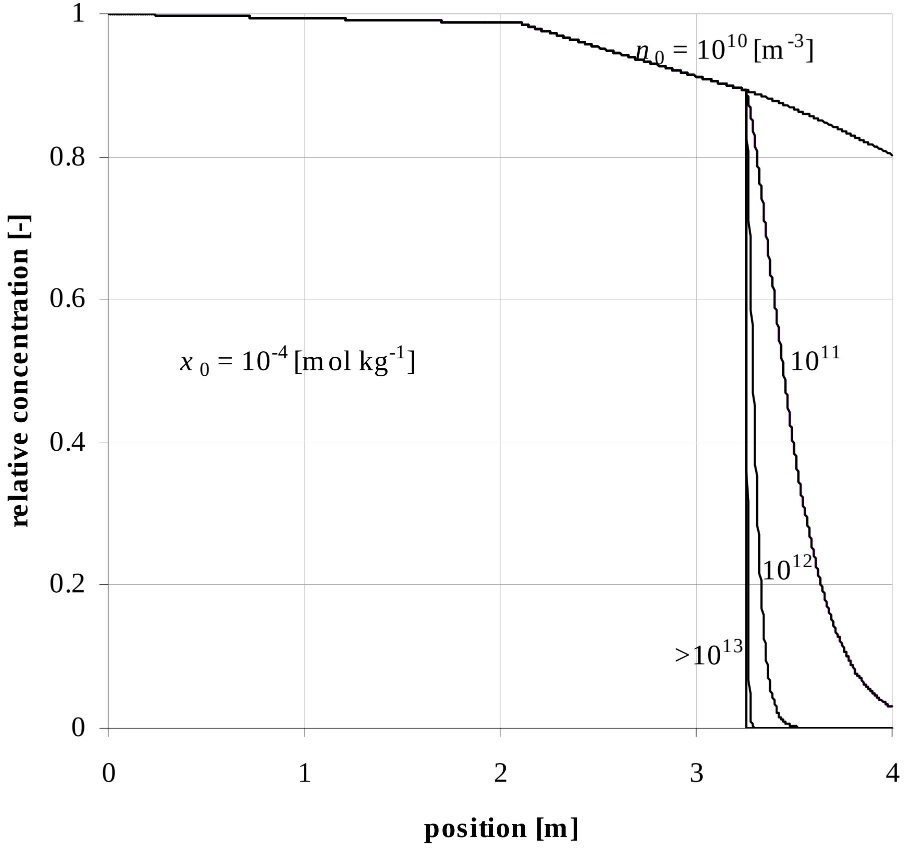
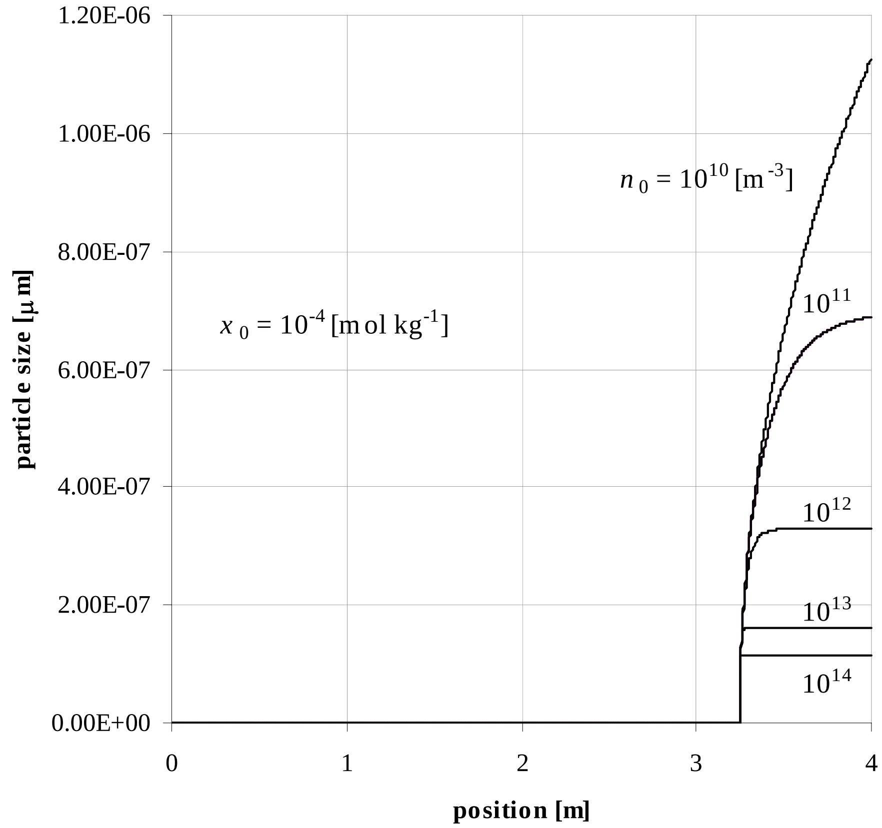





Mawera boiler
fire tube
first pass
second pass
wall condensation
boundary layer
heterogeneous nucleation
relative concentration [-]
particle size [µm]
position [m]
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.5
1
1.5
0
1
2
3
4
5
6
7


1
0.8
0.6
0.4
0.2
0
0
1
2
3
4
relative concentration [-]
position [m]
n 0 = 10^10 [m^-3]
x 0 = 10^-4 [mol kg^-1]
10^11
10^12
>10^13


1.20E-06
1.00E-06
8.00E-07
6.00E-07
4.00E-07
2.00E-07
0.00E+00
0
1
2
3
4
particle size [μm]
position [m]
n 0 = 10^10 [m^-3]
x 0 = 10^-4 [mol kg^-1]
10^11
10^12
10^13
10^14

Conclusions

- Description of the behaviour of large particles = OK
- The amount of small particles deposited is negligible
- Wall condensation can be of importance
- Integration of CFD and AFB models is essential regarding the boundary layer