University of Brighton

Advanced Engineering Centre, University of Brighton

Research Seminar

Aerosols: environmental, technological and health science applications

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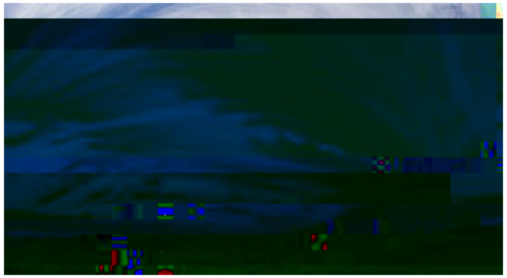
Definition

Aerosol is a suspension of solid or liquid particles in a gas.

Examples: dust, clouds
Bioaerosols: aerosols of biological nature (viruses, bacteria, fungi, spores, pollens)

Aerosol sources

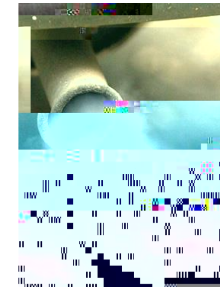
Nature aerosols



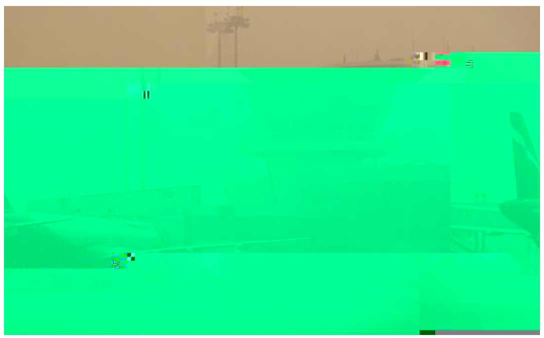
clouds

Sea aerosols

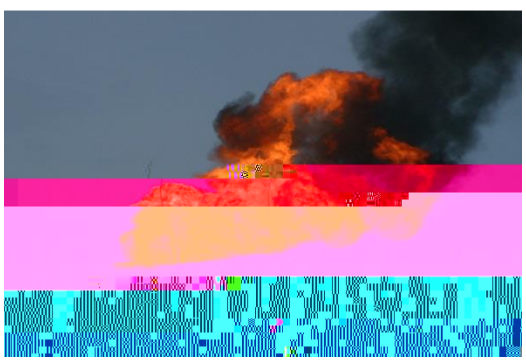
Dust-storm-Texas-1935



car emissions



Smoke from forest fires
Sheremetyevo 2010 08 07



industrial fire

tobacco smoke

sneeze particles

Aerosol particle sizes

The range of diameters of aerosol particles is **10^{-8} -10^{-4} m= Tf1 0 0 1 440.54 46.7 Tm**

Aerosol problems

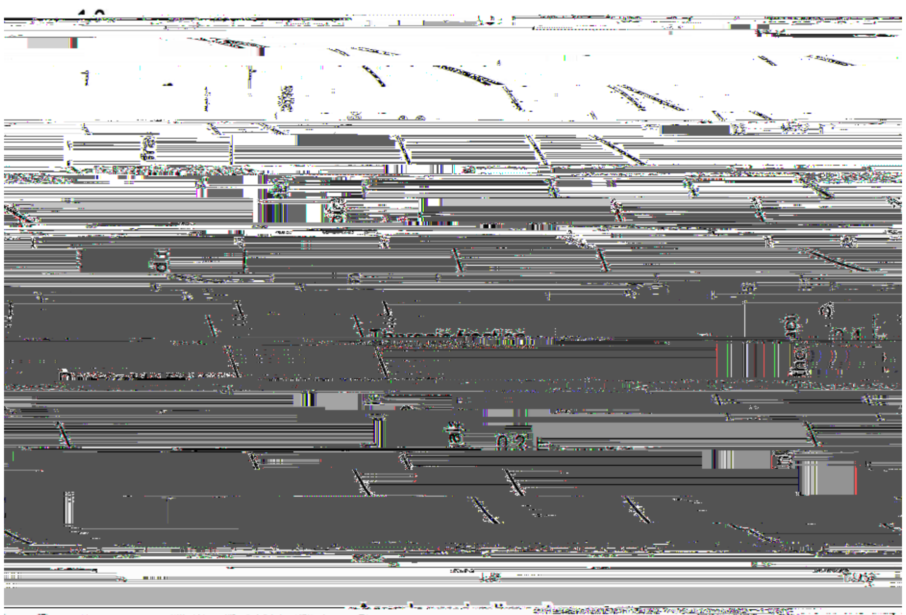
Monitoring
Health related problems
Air cleaning ς air flitration
Aerosol technology

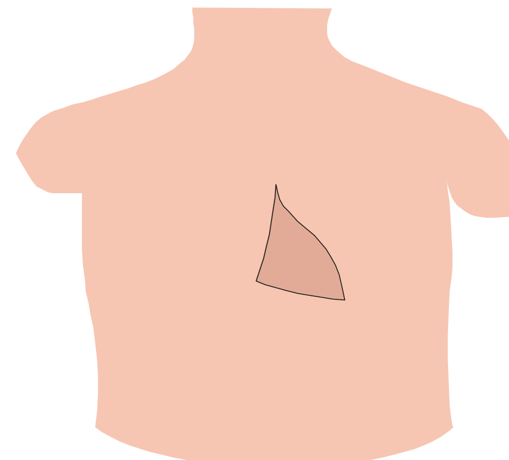
Course aerosols
Inertia
Gravity
Ultrafine particles
Diffusion
Phoretic forces (thermophoresis, diffusiophoresis, photophoreis)
Electrostatic forces

Terminology: particle size fractions

Human inhalability - aerosol influence

Environment	Workplace	
	inhalable	< 100 µm
PM10	thoracic	
		< 10 µm
	respirable	
PM2.5		
PM1		< 5 µm
PM0.1	Ultrafine	
Nanoparticles	Nanoparticles	

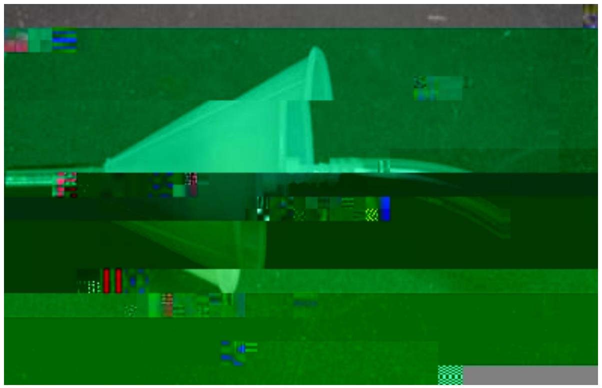


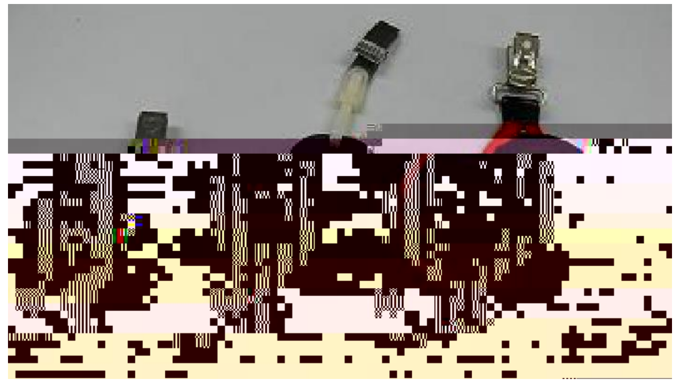


From the lecture of Prof. W.Koch, Fraunhover ITEM, June, 2014, Kazan

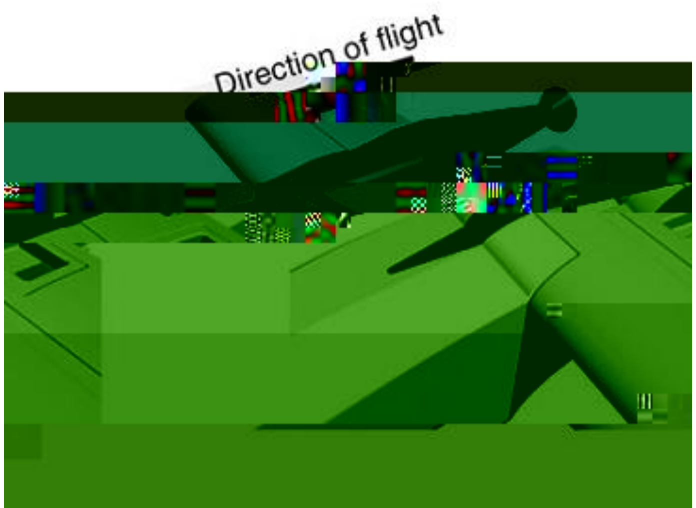
Curves of inhalable, thoracic and respirable dust fractions

Aerosol monitoring – aerosol sampling
Various sampler inlets





Darrah K. Schmees , Yi-Hsuan Wu and James H. Vincent



Respicon

[redacted]

Aspiration efficiency

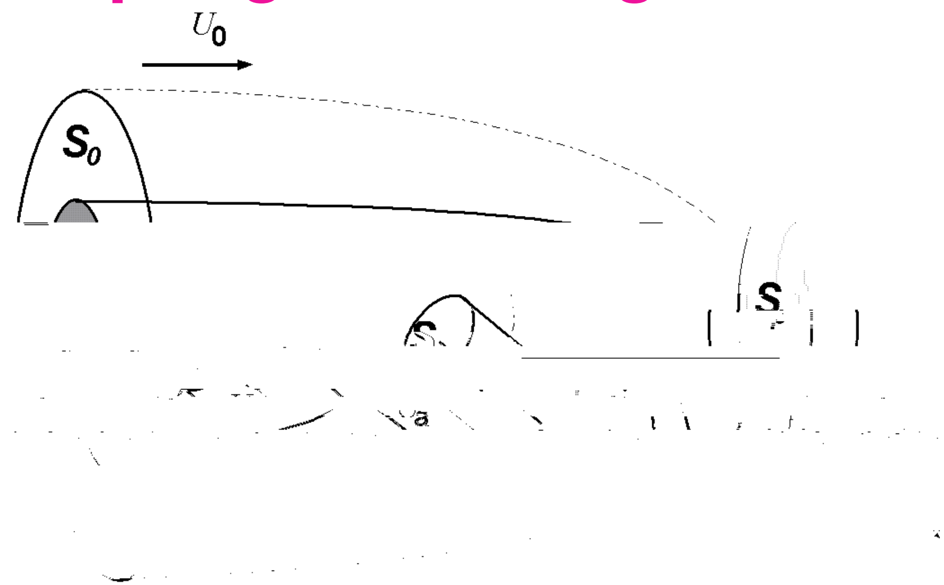
$$A \quad \frac{c_i}{c_0}$$

c_i

c_0

$$A \quad f(R_a, d_p, r_p, L_i, \mathrm{St}, v_s, \mathrm{Re}, B)$$

Sampling in moving air



$$A(t) \quad \frac{N_a(t \quad t)}{N_0(t)} \quad \frac{\iint_{S_a} c_a(x,y,t \;\text{à}\; t\text{ð}) v_{pa}(x,y,t \;\text{à}\; t\text{ð}) dydx}{\iint_{S_0} c_0(x,y,t) v_{p0}(x,y,t) dydx}$$

0

Lagrangian equations of particle motion

$$m\frac{d\bar{v}}{dt} \quad m \quad \bar{u} \quad \bar{v} \quad m\bar{A} \;\; t \quad m\bar{g} \quad \bar{F}_e$$

Aerodynamic drag **Brownian force** **gravity force** **electrostatic force**

$3 p\, m d \,/\, c_s\, m$

$\bar{v} \quad \bar{v}(x, y, z)$ **particle velocity**

$\bar{u} \quad \bar{u}(x, y, z)$ **air velocity**

m **viscosity**

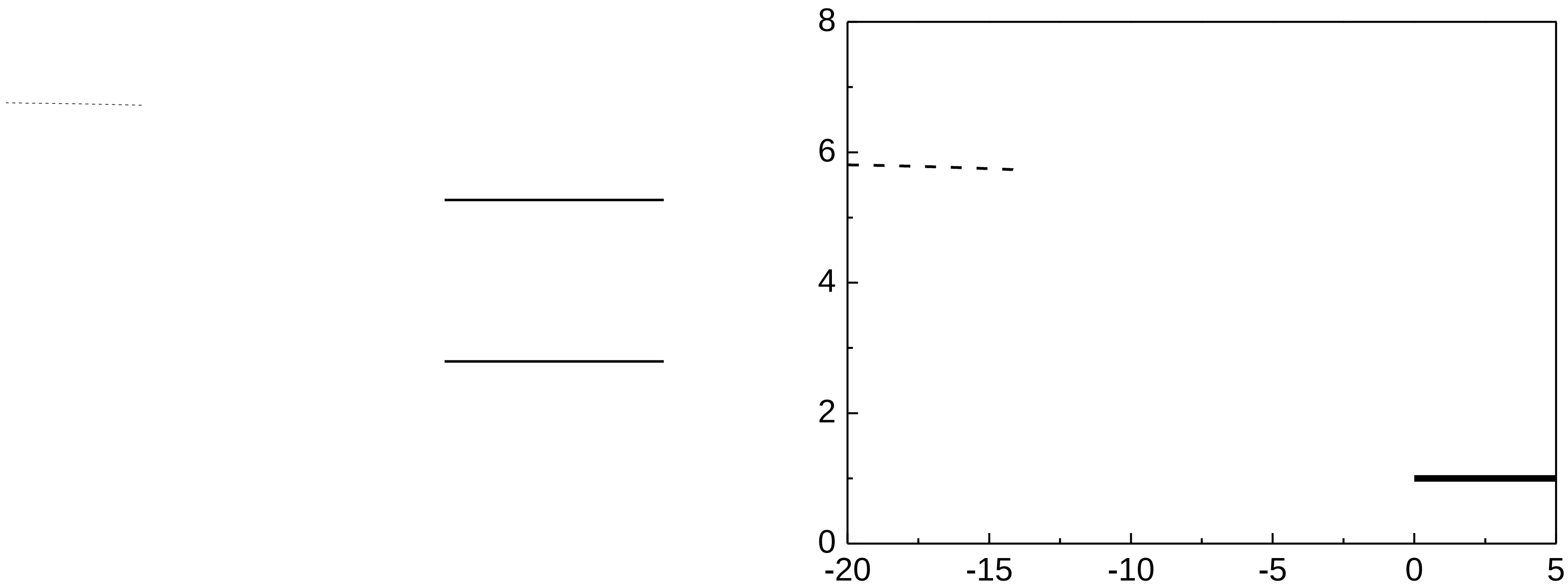
d **particle diameter**

m **particle mass**

c_s **Cunningham correction factor**

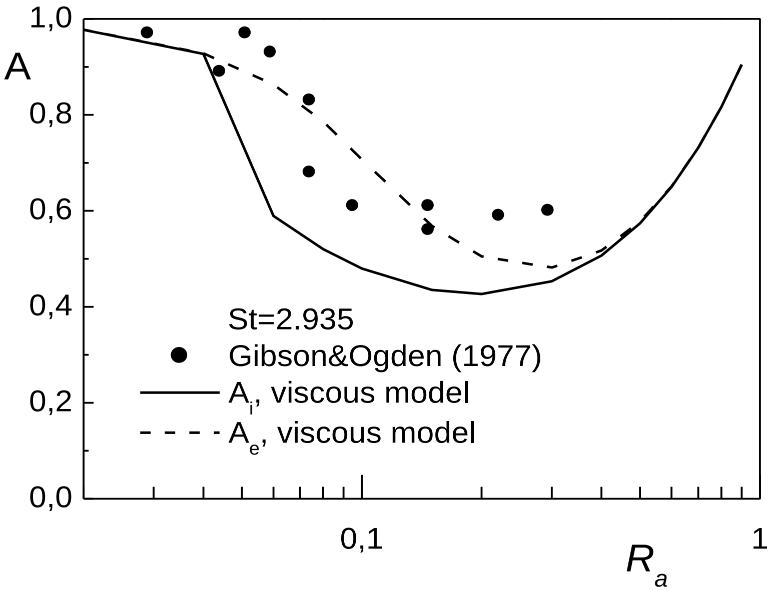
Thin walled sampler for very small velocities ratio

S.K. ZARIPOV, A.K. Gilfanov, D.V. Maklakov Numerical study of thin-walled sampler performance for aerosols in low windspeed environments. Aerosol Science and Technology, 2010.

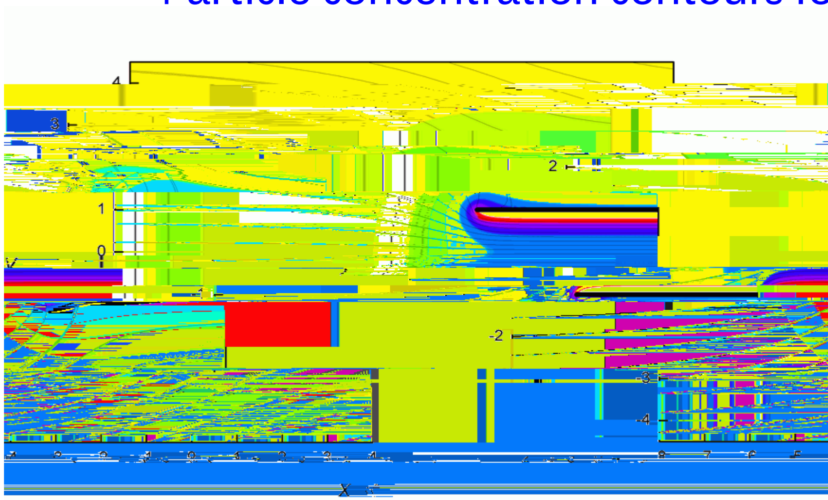


Comparison of Ai(Ra) и Ae(Ra) and experimental data Gibson&Ogden (1977) и Davies&Subari (1982)

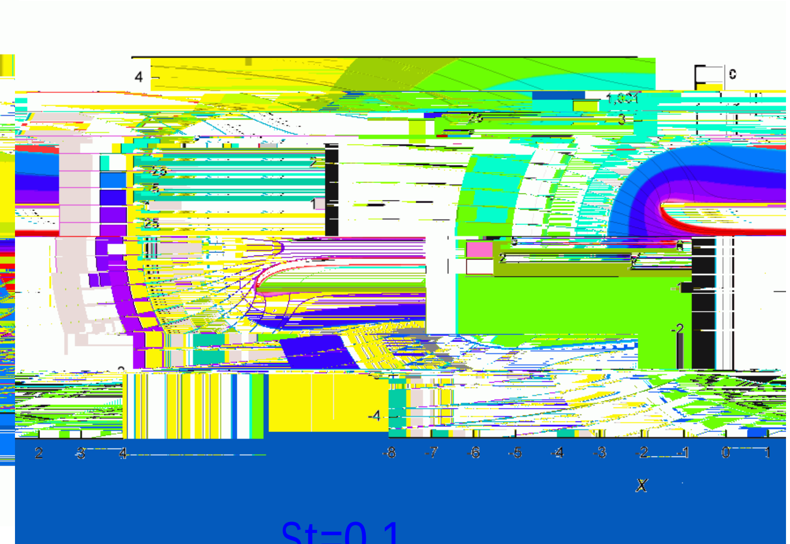
0,1



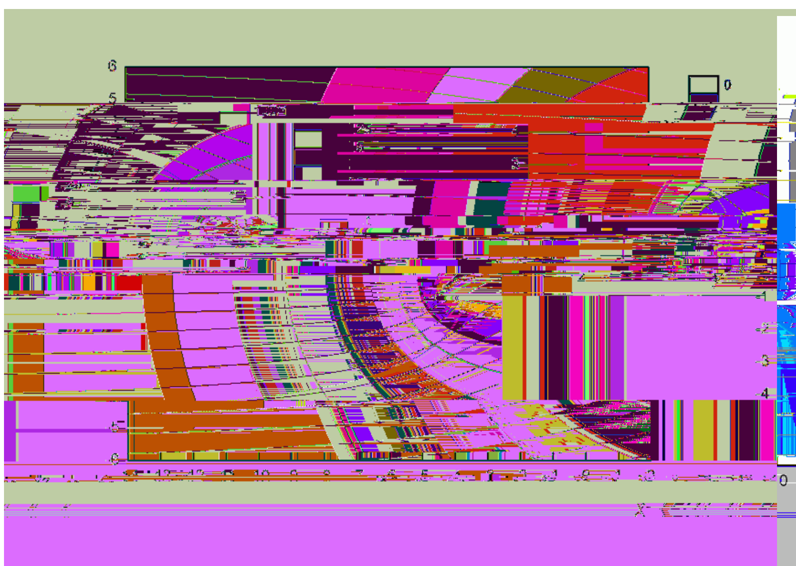
Particle concentration contours for a=0.2 (lines ς particle trajectories)



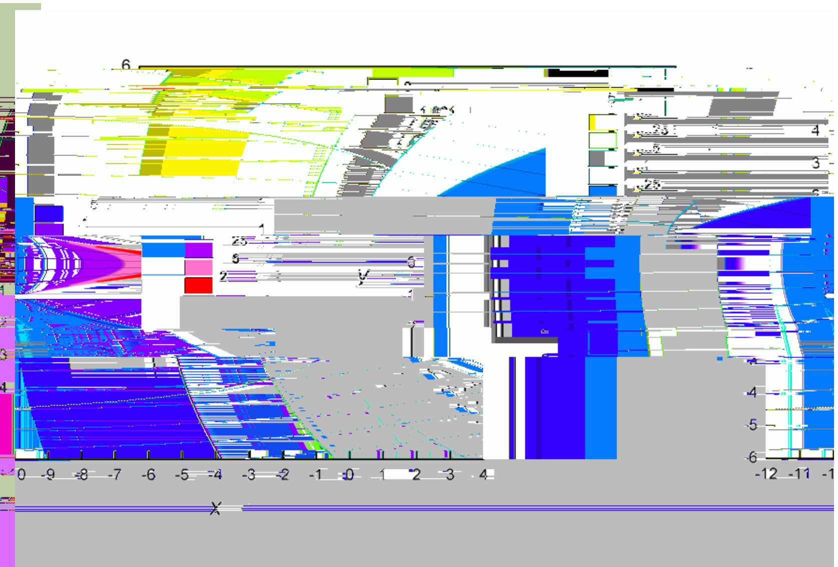
St=0.01



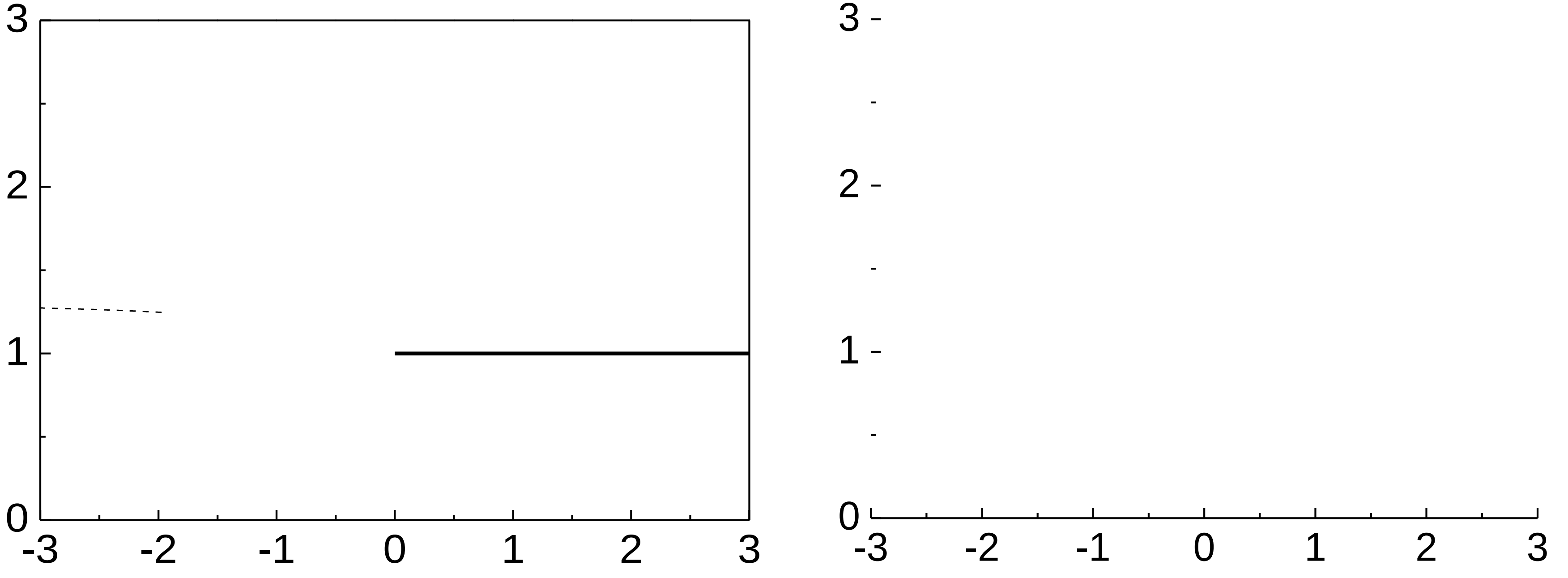
St=0.1



St=1



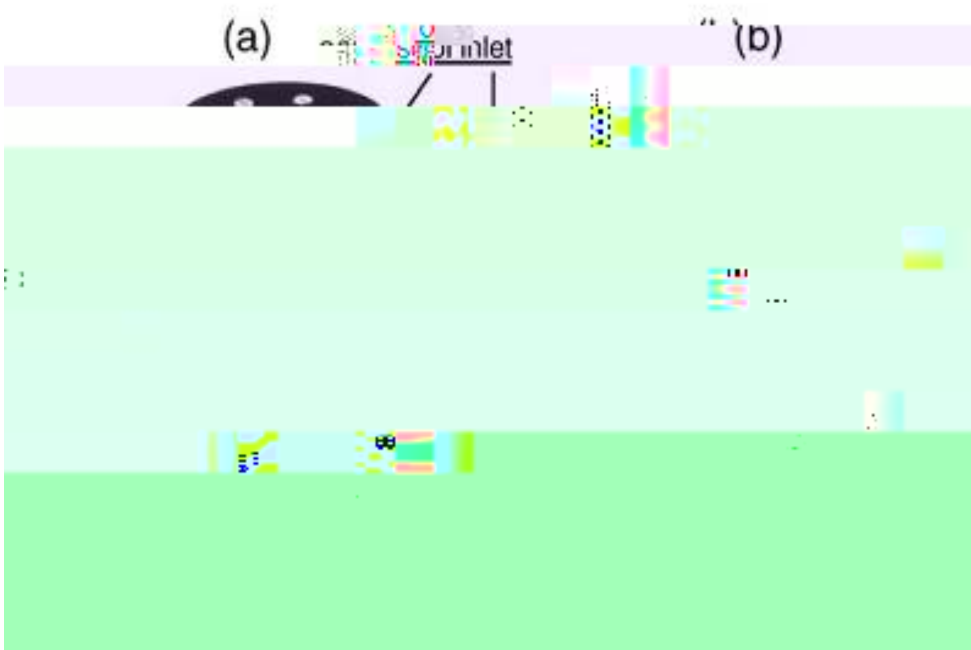
St=10



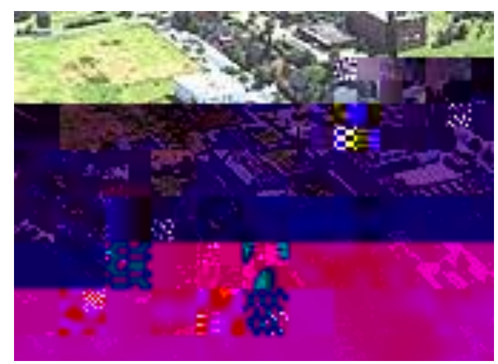
Particle trajectories and concentration isolines
R_a=0.2 and St= 1 for potential and viscous flows

Numerical study of performance of the RespiCon sampler in calm air

W. Koch et.al., 2009



FRAUNHOFER INSTITUTE TOXIKOLOGIE UND EXPERIMENTELLE MEDIZIN, HANNOVER



Numerical study of performance of the RespiCon sampler in calm air

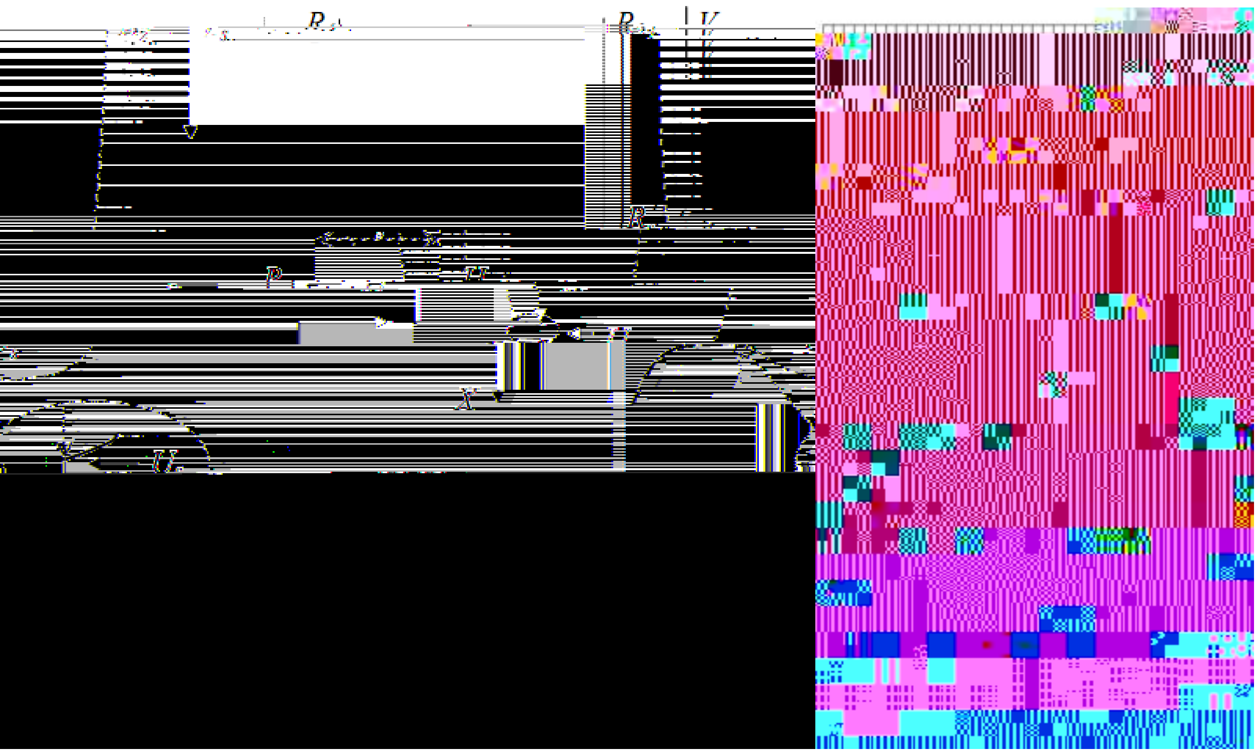


Fig. 2. RespiCon sampler scheme and mesh of calculation domain outsi198(1tsi37eu7 BDC p.9)-5

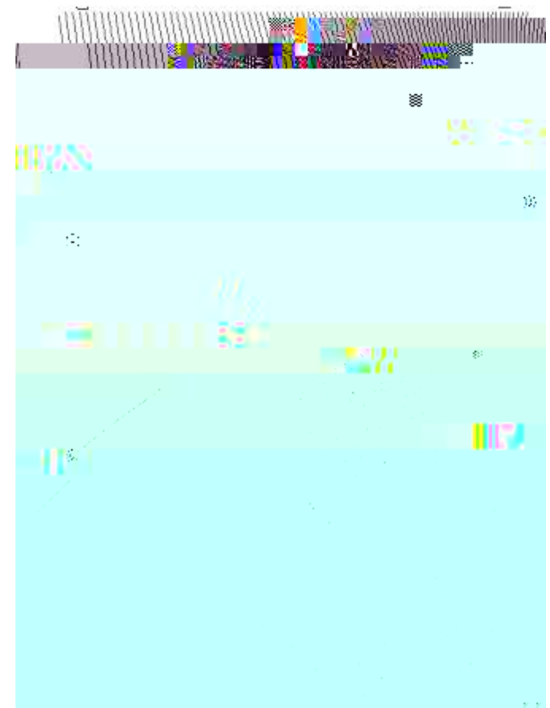
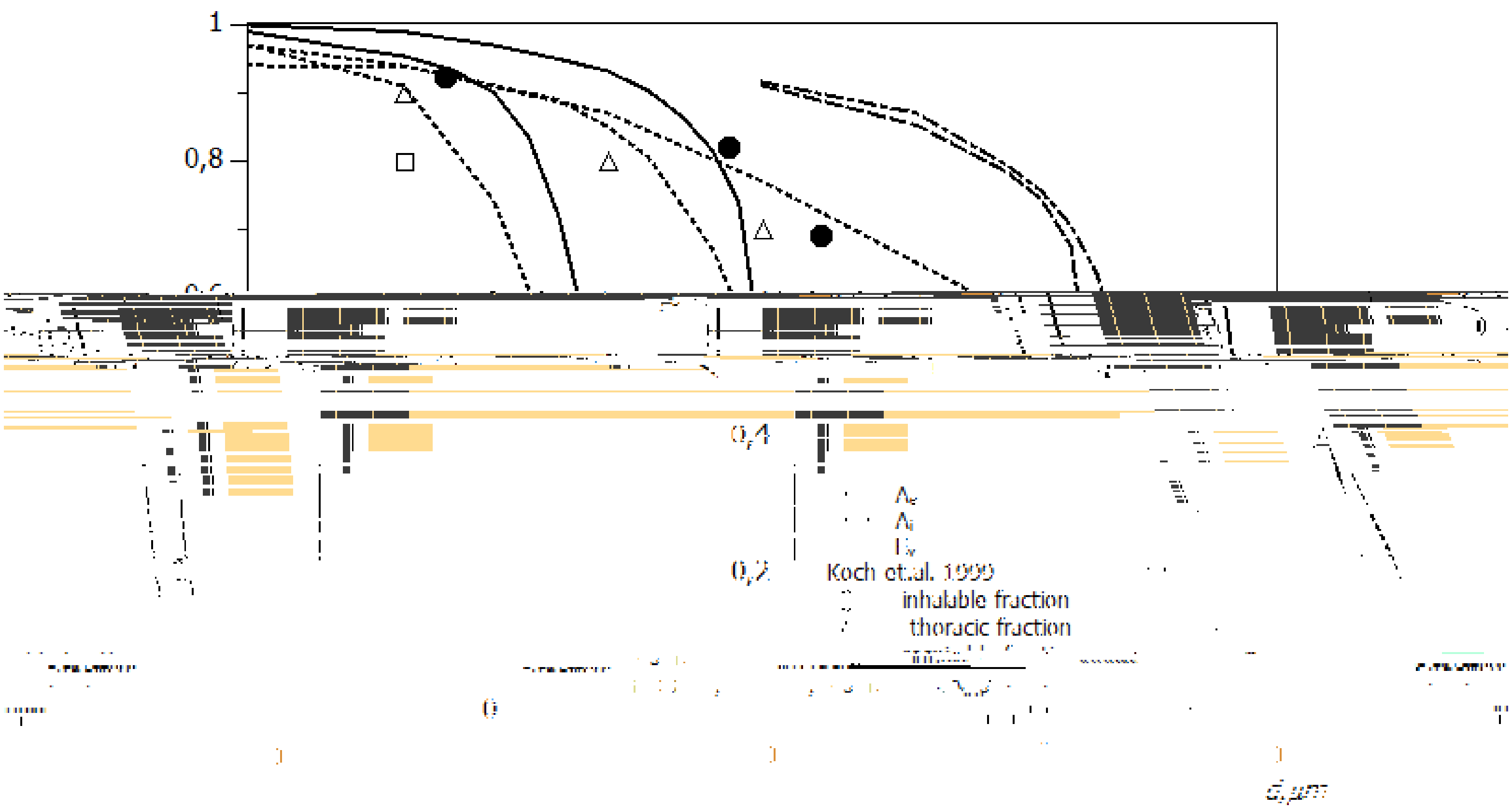


Fig. 4. Example of trajectories of particles impacting the slit wall

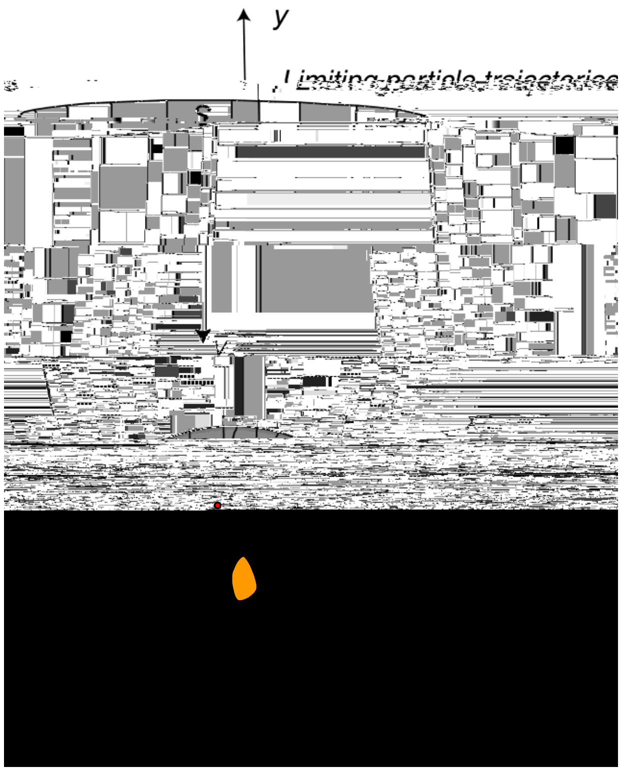
Collection efficiencies of RespiCon stages as a function of particle diameter



Sampling into spherical sampler in calm air

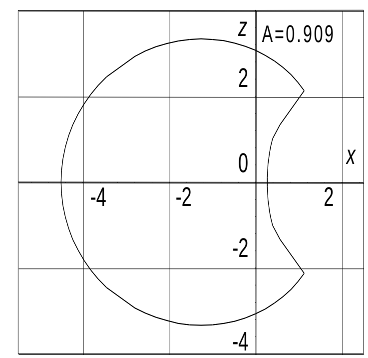
$\bar{U}_0 \quad 0$ R_a=0

α=π/2

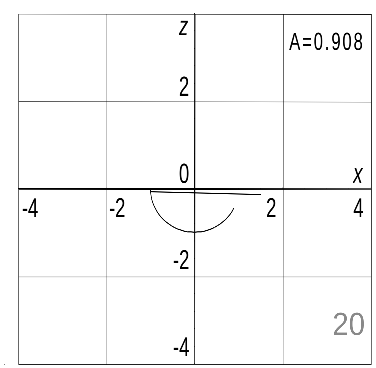


α=0

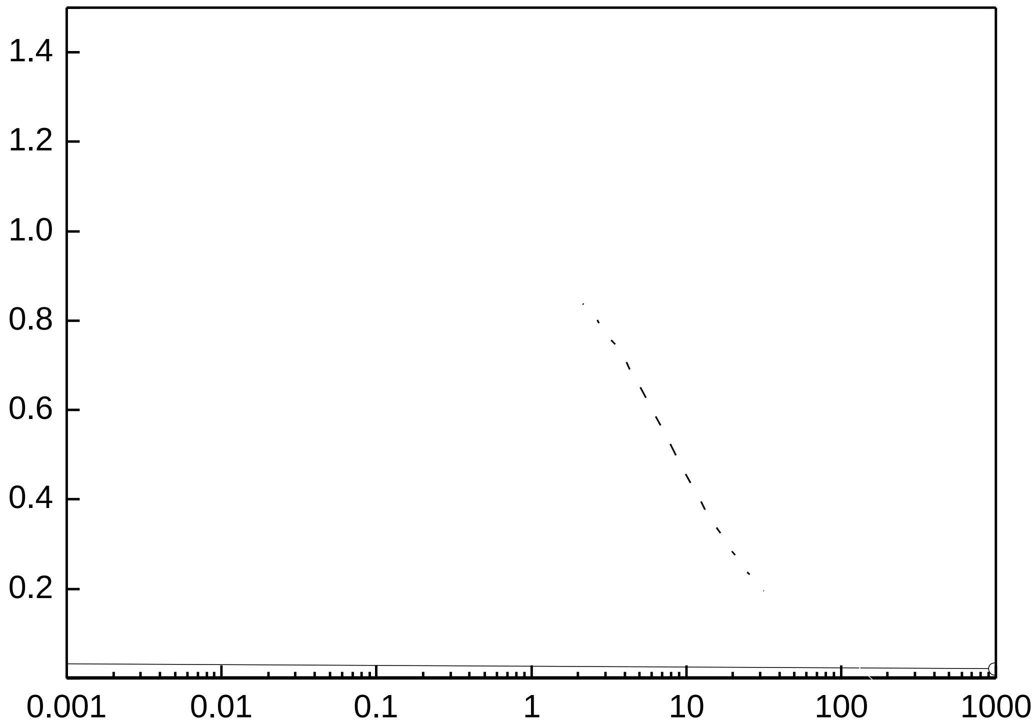
P



α=- π /2



=p



A(St$_C$ύ ̂ ⌒ϒ Vs=0.1 * 0.01

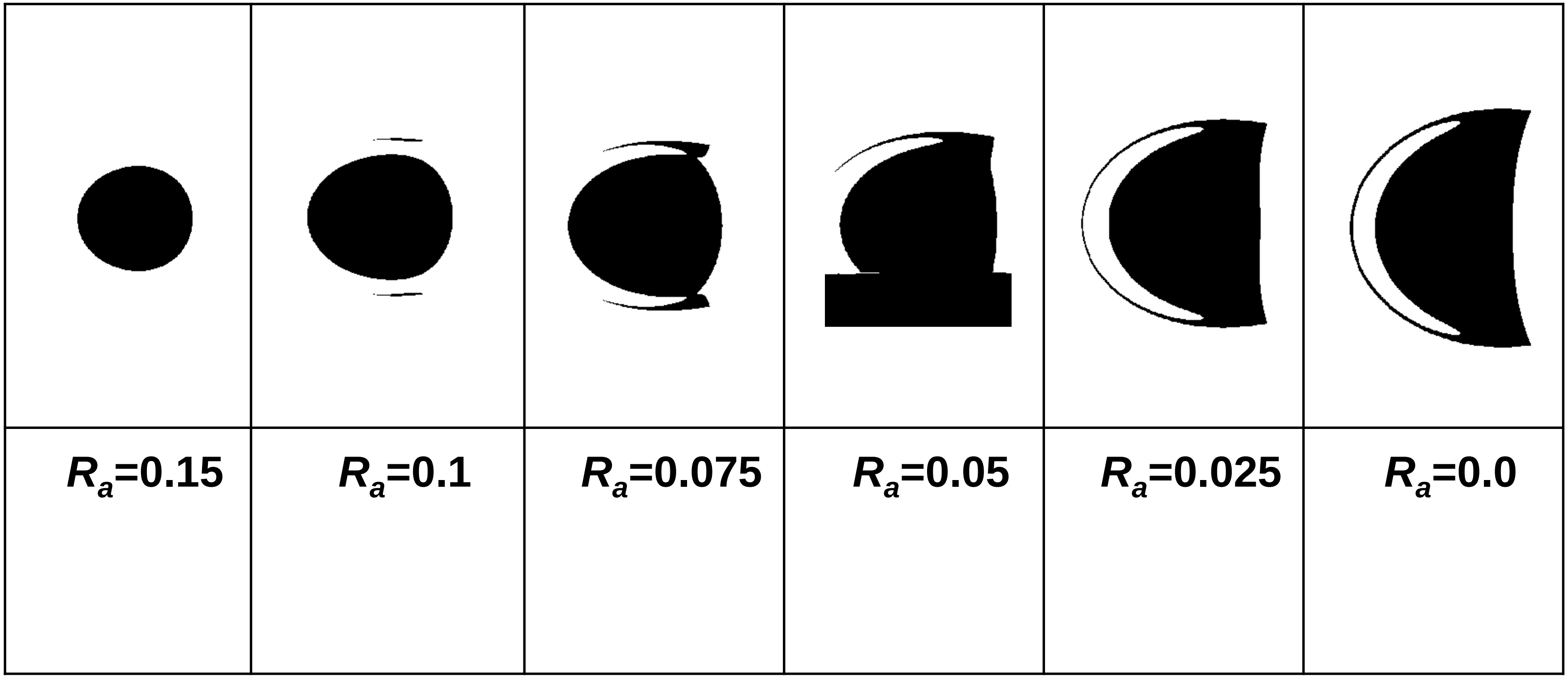


Fig.3.

$$A \quad 1 \qquad k \qquad k^2$$

$$k \quad \mathrm{St}(R_a^2 \quad R_c^2)^{3/4} \qquad 1$$

α=-15.19, β=

Aspiration efficiency - Inhalation fraction

$$IPM = 0.5(1 + \exp(-0.06 d_p))$$

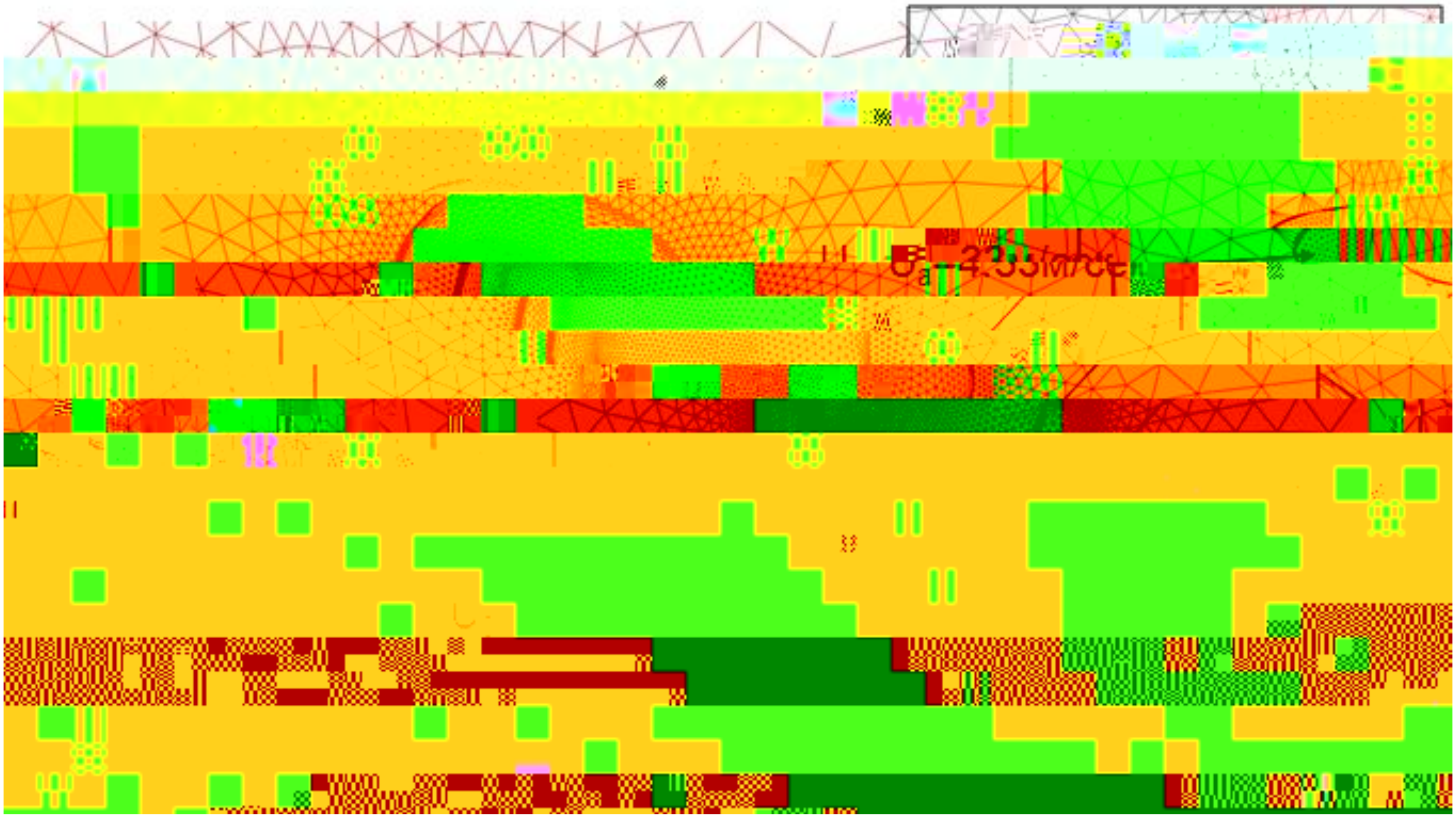
The criterion for inhalable particulate mass (IPM) from the American Conference of Governmental Industrial Hygienists (ACGIH)

Darrah K. Schmees , Yi-Hsuan Wu and James H. Vincent

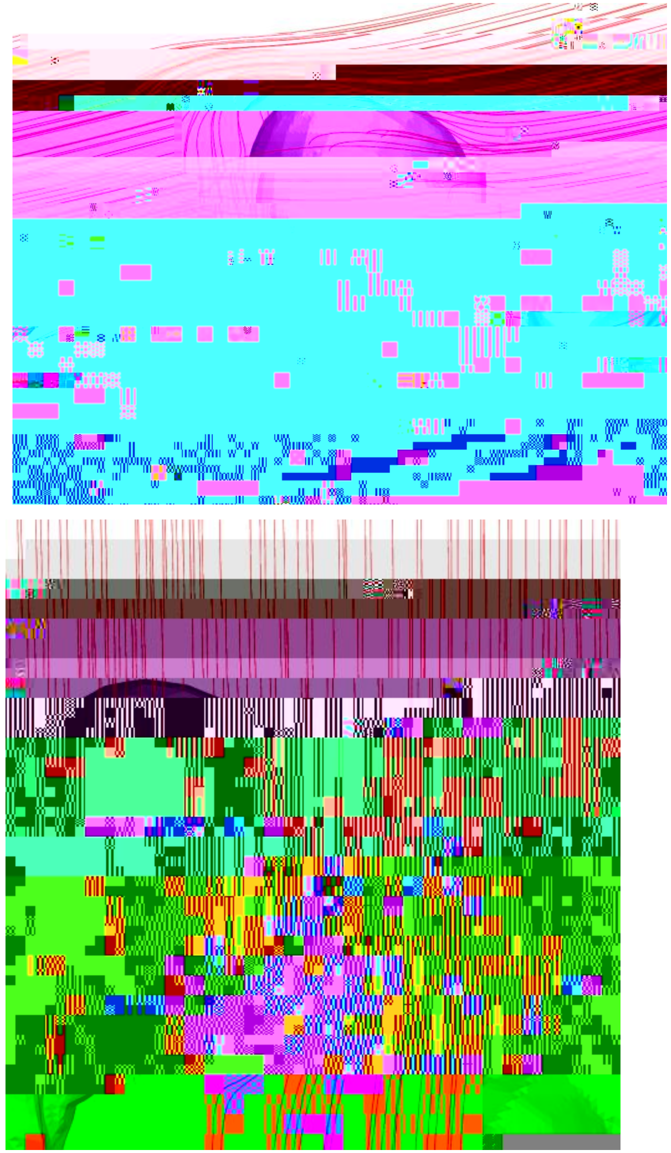
Experimental methods to determine inhalability and personal sampler performance for aerosols in ultra-low windspeed environments

J. Environ. Monit., 2008

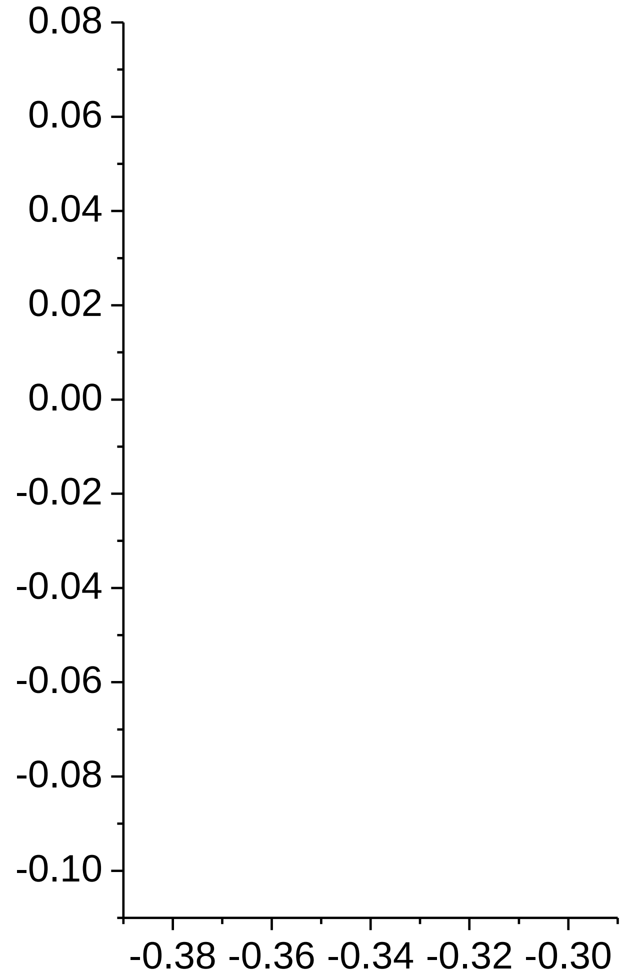
CFD model of aerosol flow in the vicinity of manikin head



Meshing in the vicinity of manikin head



The trajectories of particles at *d*=37μm for two wind velocities: a-U_0=0.2 m/s, b - U_0=0

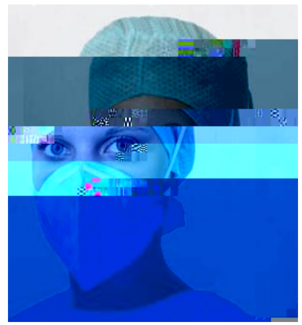


The area *Sp* of the aspirated particles

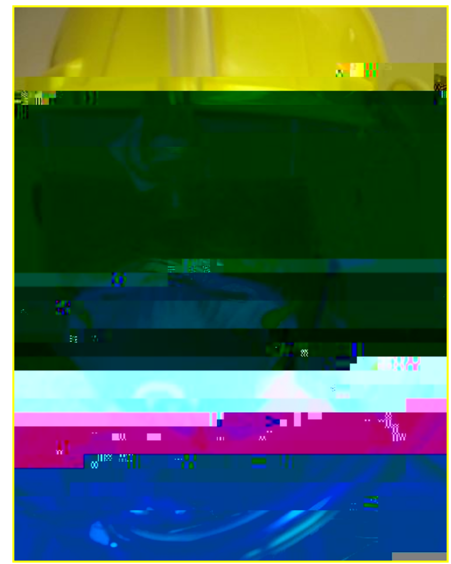
Inhalable fraction for breathing through mouth (1) and nose (2) in calm air

Facepiece filtering respirators (FFR) and surgical masks

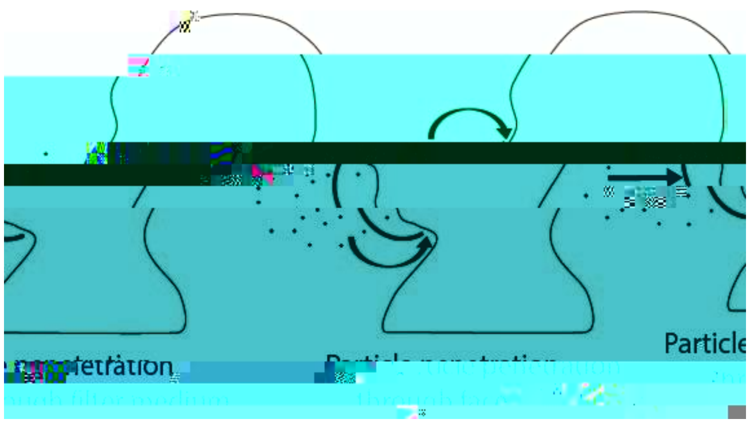
Variety of respirator facepieces



Performance evaluation on a manikin headform



Two pathways of particle penetration



Protection factor = C_{out}/C_{in}

Particle penetration = C_{in}/C_{out}

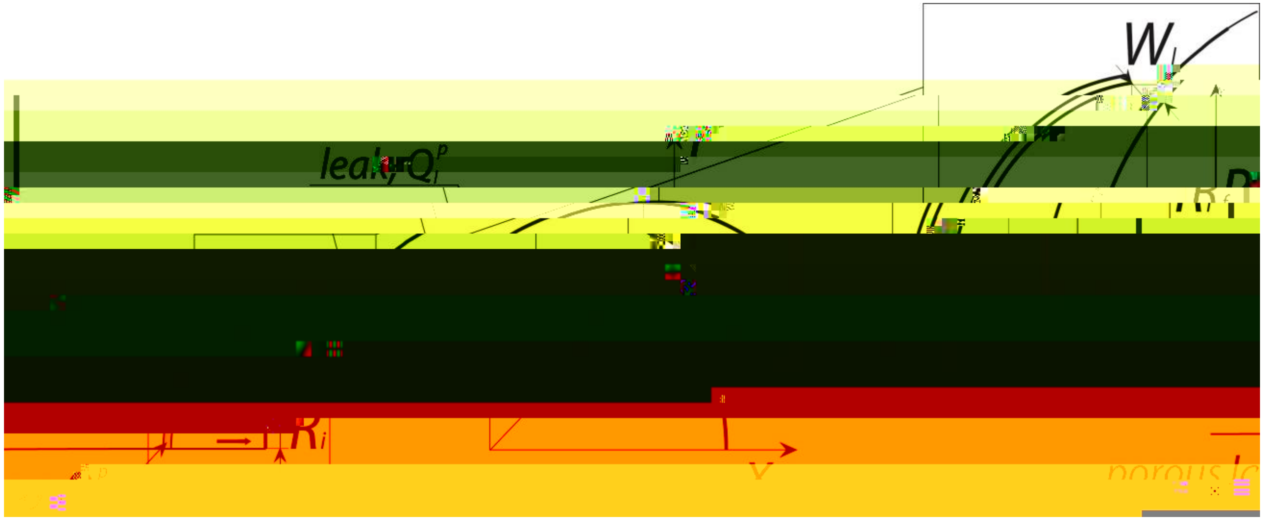
Experimental (combining manikin-based and human study protocols):

Grinshpun et al. (2009).

Leak flux / Filter flux

Particle diameter (>m)

An



Penetration of aerosol particles through filter layer

$$\eta_f = \exp\left(-\frac{4\alpha E_f L}{\pi d_f (1-\alpha)}\right)$$

α

Fitting the porous layer permeability to the experimental curves $\eta_f(d_p)$ from Rengasamy and Eimer (2012)

Kozeny-Carman formula:

$$k \quad \frac{e^3 d_{fiber}^2}{180(1 \quad e)^2}$$

Permeability used for calculations:

$$k = 9.55 \cdot 10^{-11} \text{ m}^2$$

The particle penetration through the filter $\eta_f(d_p)$ at $Q_i = 30$ l min^{-1}
1 ς approximated formulas d_{fiber} Г мл¢лт кҮΣ α=0.069, L=3 mm
2 ς experimental values from Rengasamy and Eimer (2012).

Parameters and conditions used in the modeling

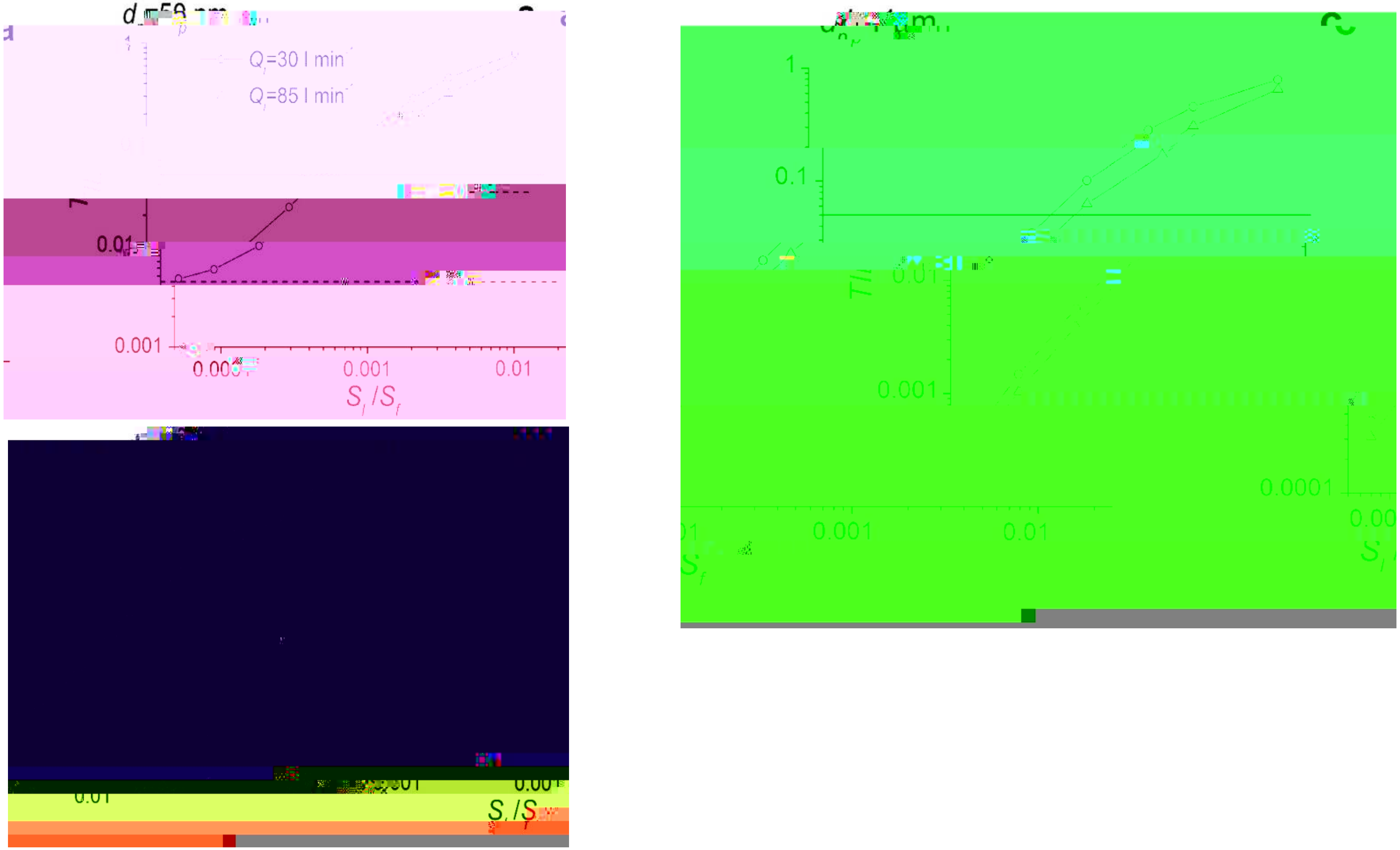
$R_i = 0.007$ m ($S_i = 0.000154$ m^2)
$R_h = 0.09$ m

spherical segment with
a height of *H*

Comparison to the experimental data of Rengasamy and Eimer (2012)

MODELING RESULTS:

$TIL = f\,(S_l/S_f)$ at d_p = 50 nm (a), 100 nm (b), and 1 µm (c) for different inhalation flow rates



Solid lines represent the target value for an N95 (*TIL*=0.05).

Dotted lines represent a “perfect fit” respirator (with no faceseal leakage).

NUMERICAL STUDY OF GROWING DROPLETS DYNAMICS IN UNSTEADY THERMAL CONVECTION FLOW

S.K. ZARIPOV , R.S.Galeev , W.Holländer. Numerical study of dynamics of growing droplets in Kelvin spectrometer. Abstracts of European Aerosol Conference-2007, Salzburg, T12A033.

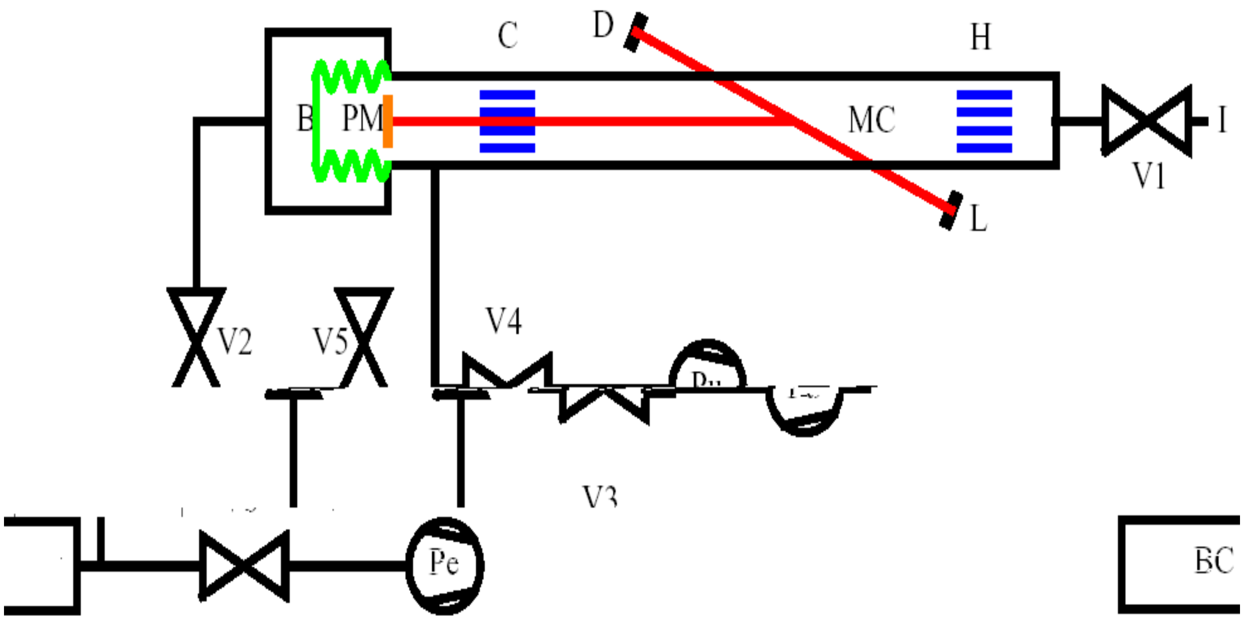
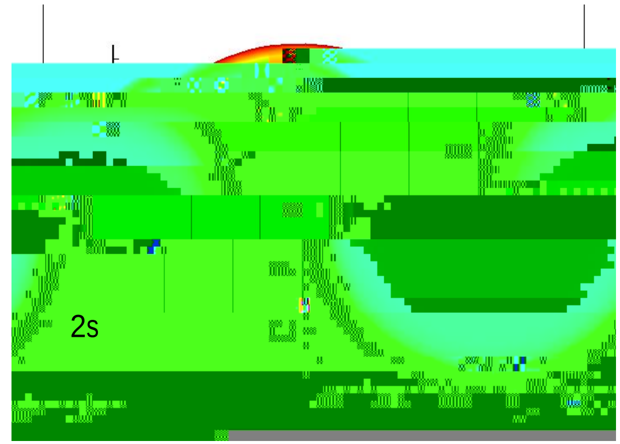


Fig.8. Time evolution of the temperature distribution in the cross section of the horizontal cylinder

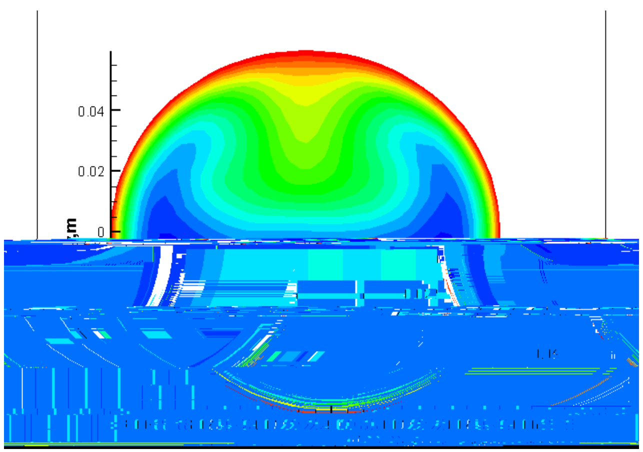
$$T_{¤}(\overline{r}_p, t)$$

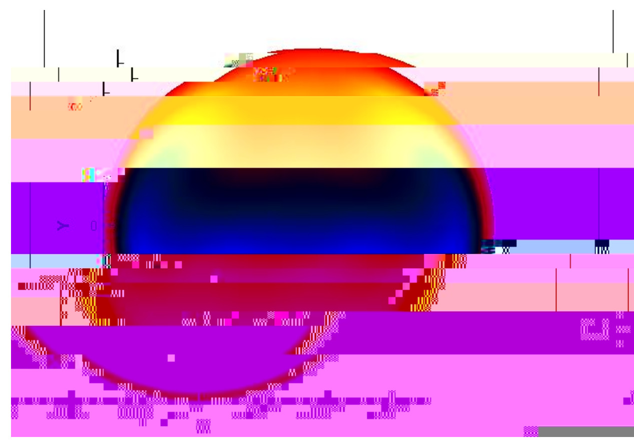
1s



2s

5s





10s

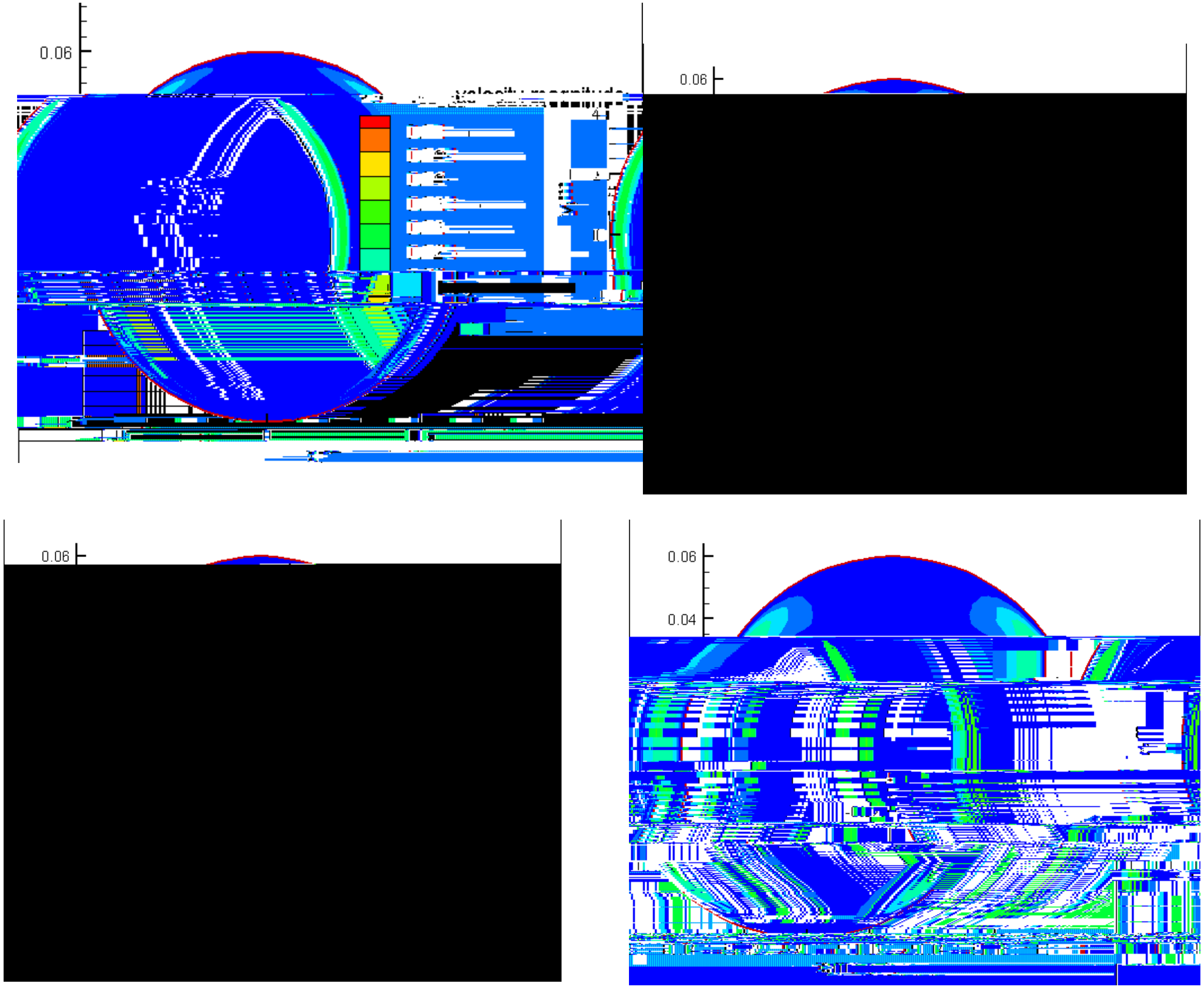
$$\bar{U}(\bar{r}_p, t)$$

1s

2s

5s

10s



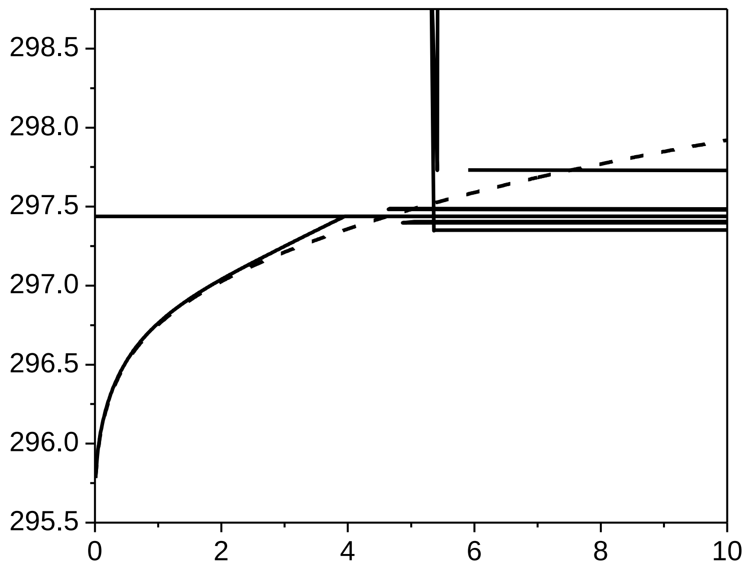


Fig.7. Average gas temperature with and without convection influence

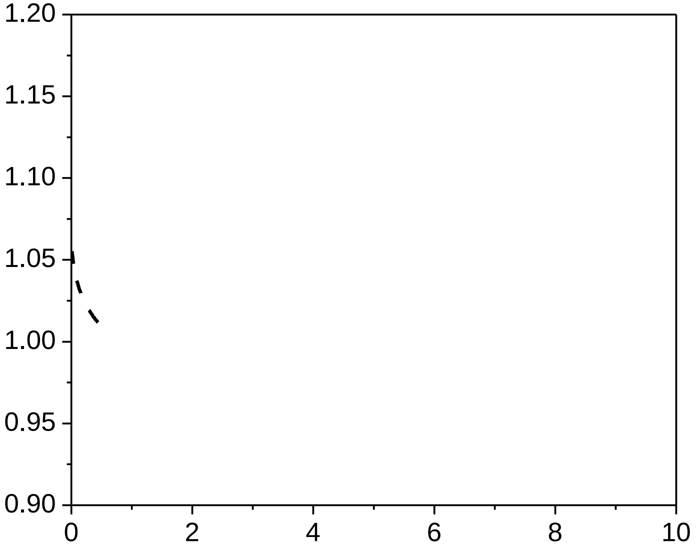
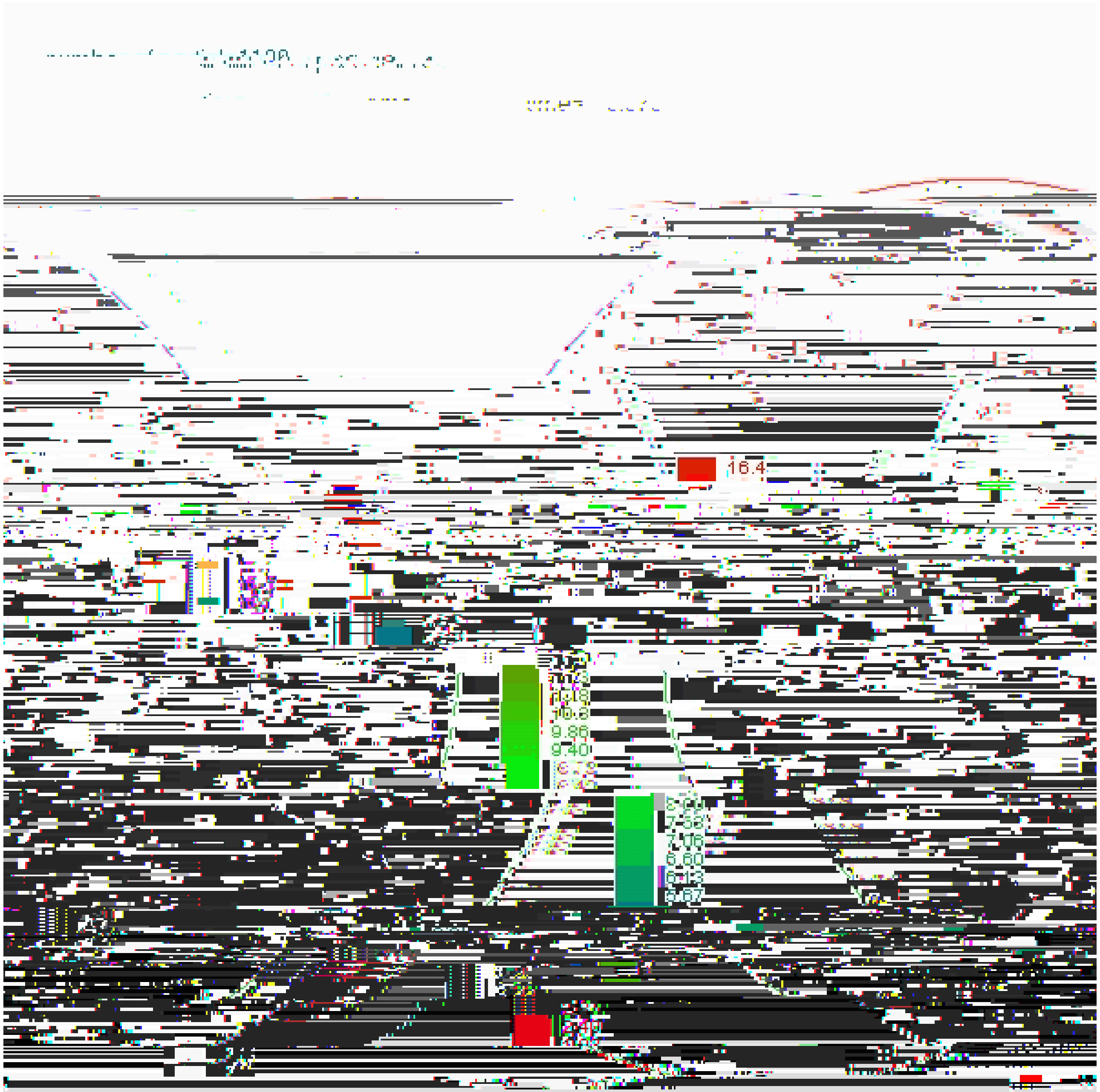


Fig.8. The saturation based on the average temperature gas temperature with and without convection influence


16.4
9.86
9.40
6.60

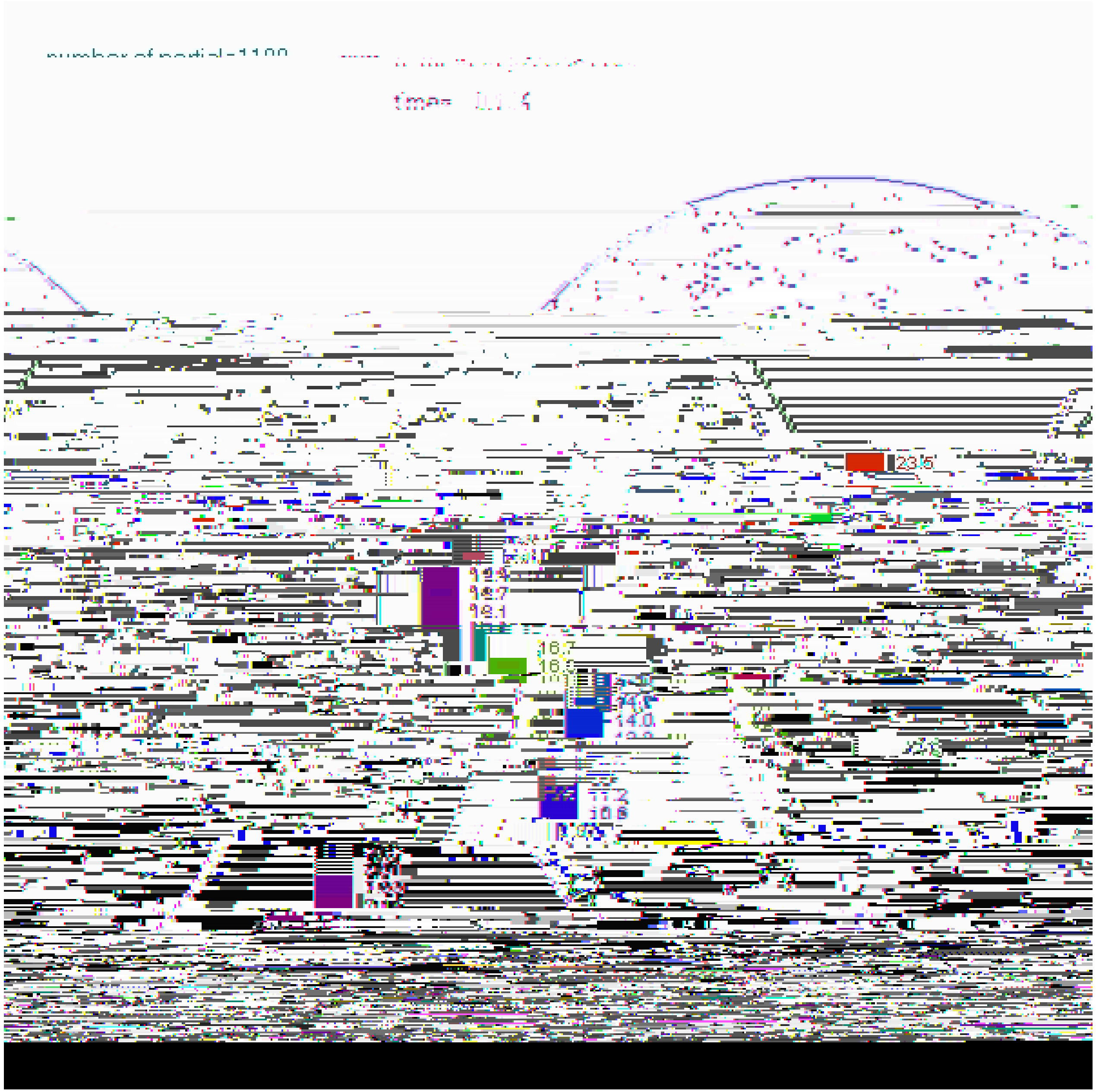
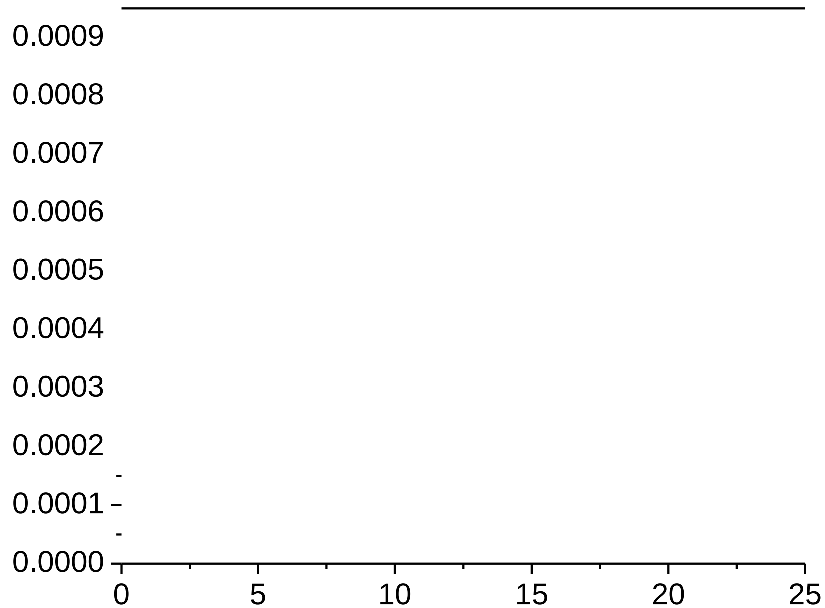


Fig.14. The mass density of condensing vapor on all droplets for N=1000 cm-3 and various initial saturations



g=9.81m/s

g=0

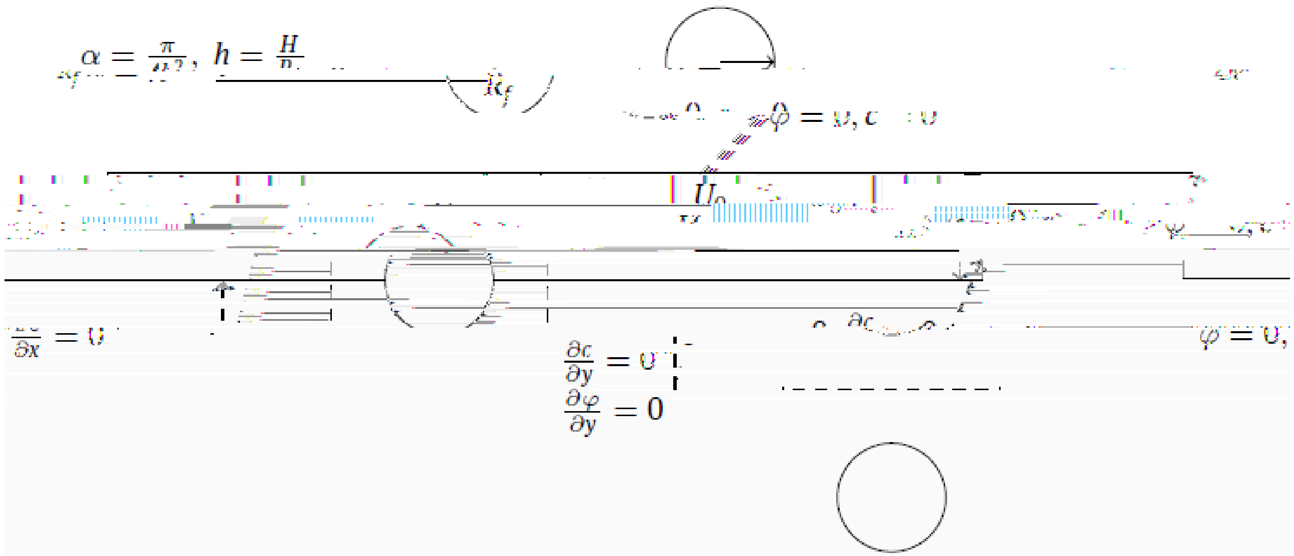
Transport equati(c)neDs GS5 gsq-0.000002123 0.000244149TfD

$C(\bar{r},t)$ - particle concentration

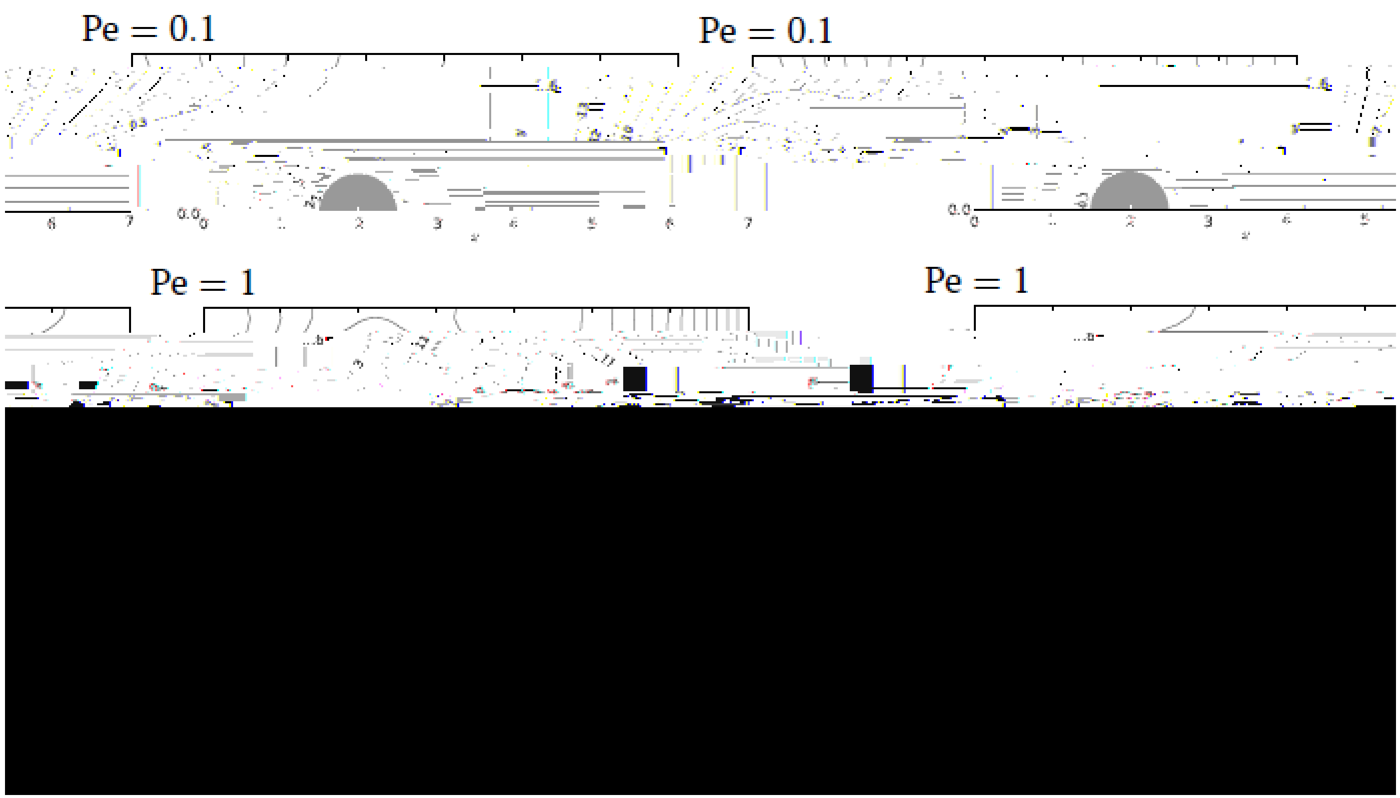
$J_D \quad D\nabla\cdot C$ Diffusion flux

$\bar{J}_u \quad C\bar{U}$ convective transport

$$\frac{\partial C}{\partial t} \quad D\nabla^2 C \quad \bar{U}\nabla C \quad qb\nabla\cdot(C\bar{E})$$

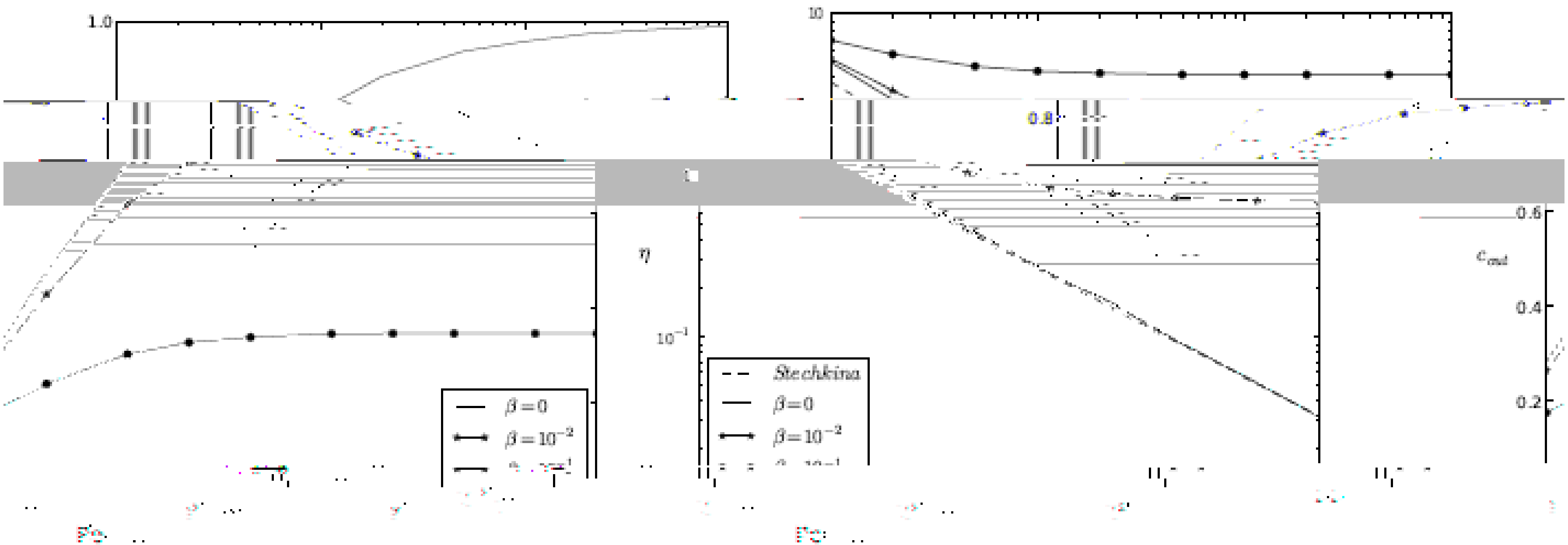


$\frac{\partial \varphi}{\partial y} = 0$



Pe = 0.1
Pe = 0.1
Pe = 1
Pe = 1

Deposition efficiency



Aerosol deposition on the porous cylinder

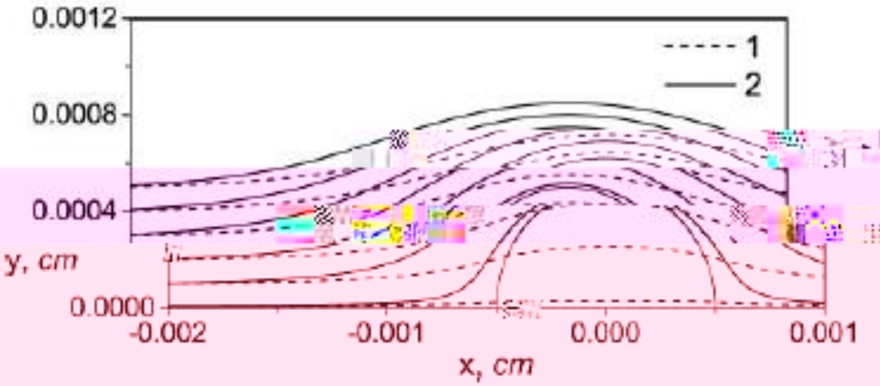
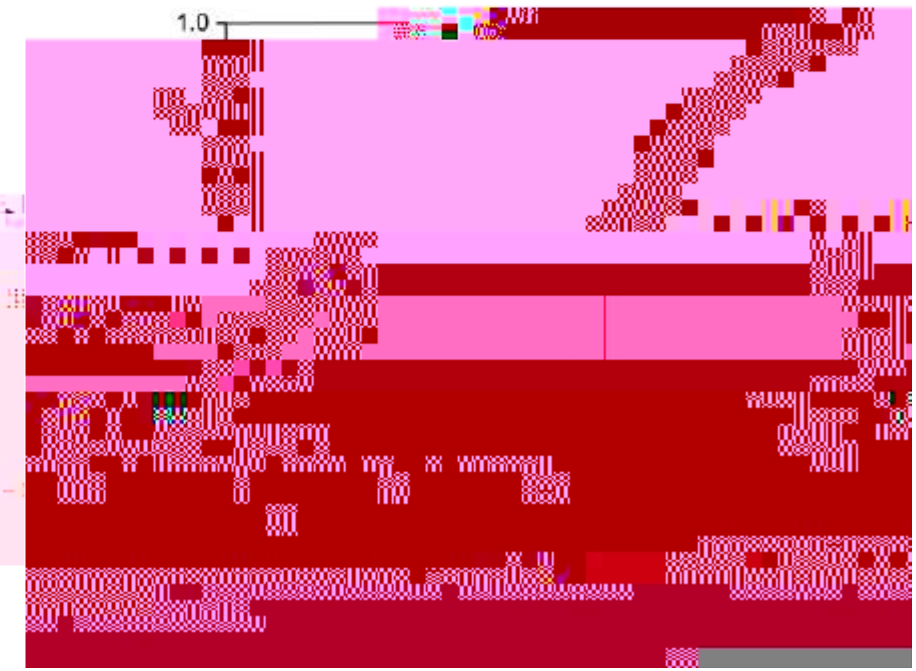
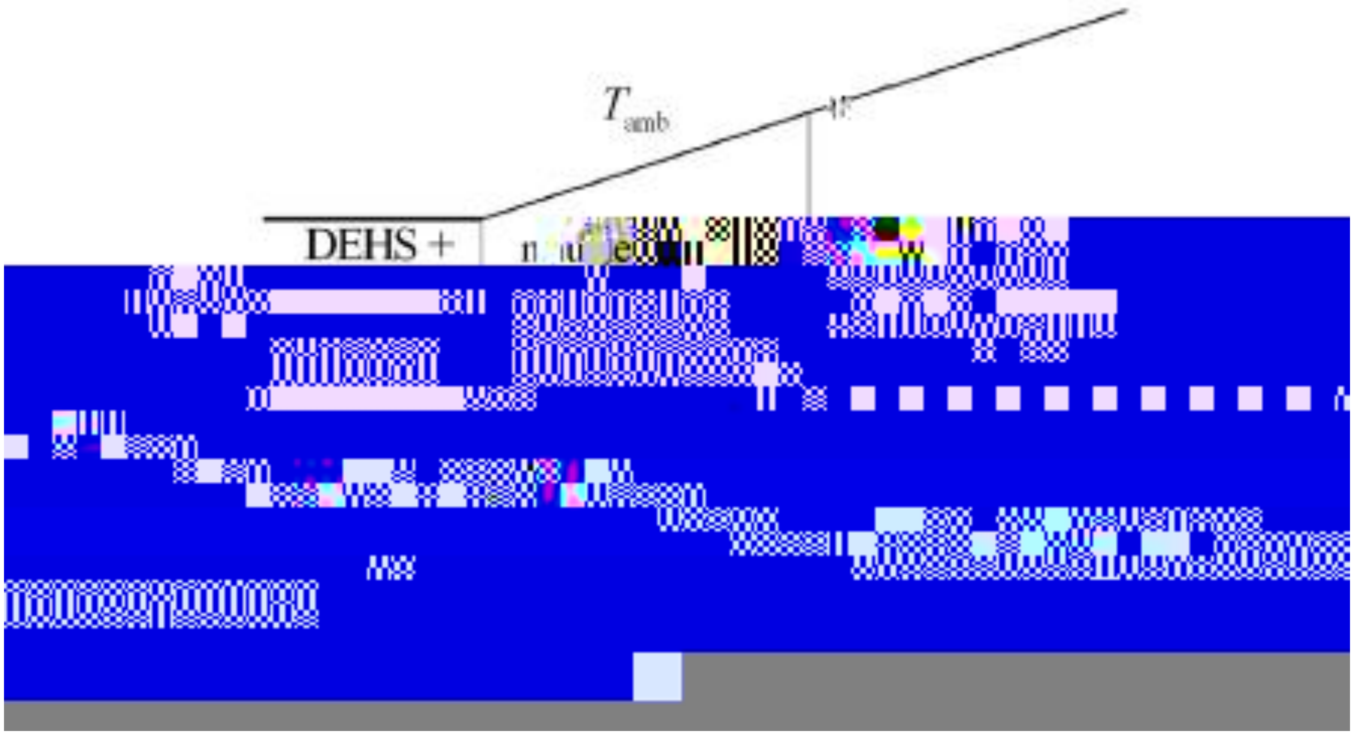


FIG. 4. Streamlines from numerical model $\alpha = 0.05$: (1) $Da = 10^{-4}$, (2) $Da = 10^{-3}$.



A.K. Gilfanov, W. Koch, S.K. Zaripov Mathematical modeling of di-ethyl-hexyl-sebacate nanoparticle formation in a free turbulent jet under high nucleation rate conditions. Journal of Aerosol Science. - 2016. - V.96. - P.124-139.



Collaboration
Brighton University - Kazan University
2016-2018

Joint project Royal Society (UK) RFBR (Russian Federation)

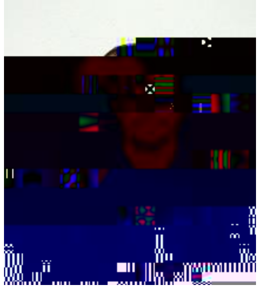
Modelling of aerosols/sprays for medical and automotive applications

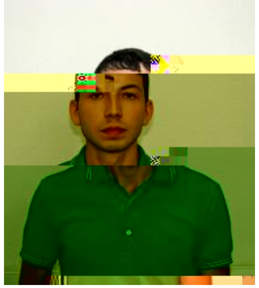
Aerosol laboratory

- Head Prof. Shamil Zaripov, GAeF member



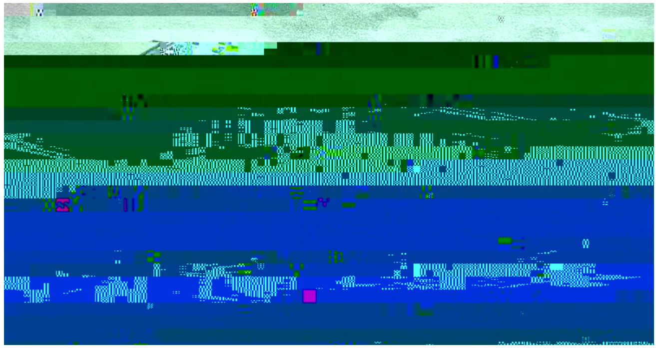


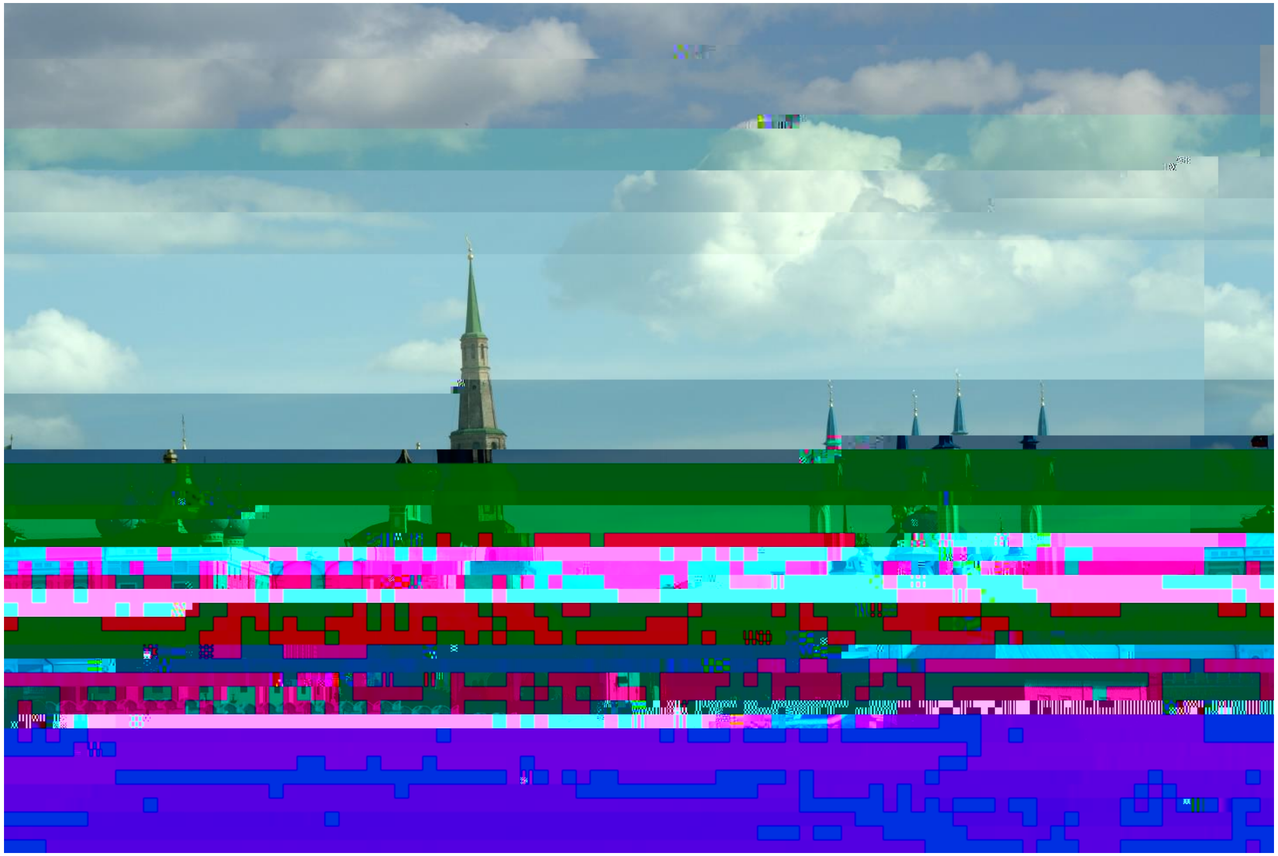



Founded in **1804**, Kazan University is the second oldest university in the Russian Federation, and now is an internationally acknowledged center of academic excellence.

Before 1878 Kazan University was the farthest Eastern university of the Russian Empire:
its academic district included the Volga Region, Kama Region, Ural Region, Siberia and Caucasus.



The main center of higher education for a vast region, KFU has over 47,000 students, who follow 310 major degree programs.



Thank you for attention