OPTIMAL LENGTH OF THE PLAIN LOSCERTALES MOBILITY ANALYZER

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See:

Loscertales, I. G. (1998) Drift differential mobility analyzer. *J. Aerosol Sci.* **29**, 1117–1139.

Zeleny, J. (1898) On the ratio of velocities of the two ions produced in gases by Röngten radiation, and on some related phenomena. *Philos. Mag*. **46**, 120–154.

The calculation of optimal lenght of the plain analyzer is presented, as in my conference abstract, also in Section 2 of the innovative paper by Loscertales. The two similar presentations have a common origin: my review to the manuscript by Ignacio G. Loscertales.

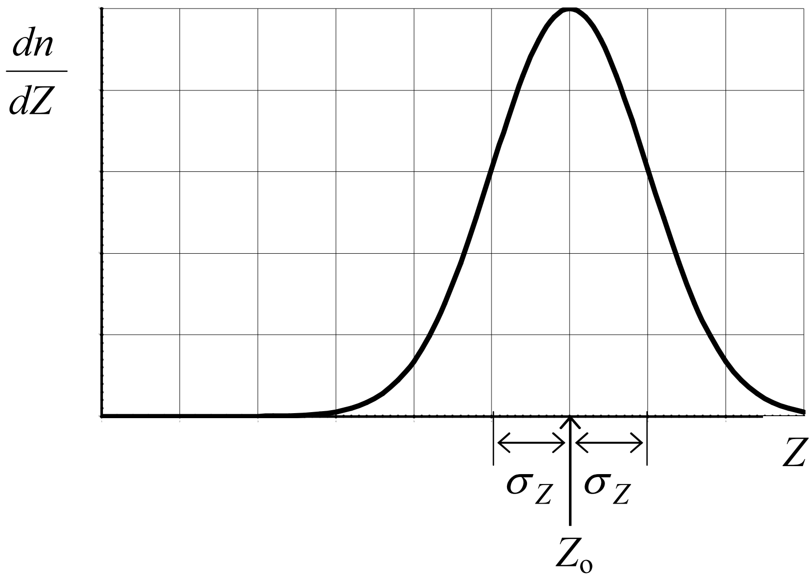
I do not wish to repeat the printed information. Instead, I am going to:

- explain the physical essence and the position of the Loscertales method among the traditional methods,
- point out the centennial anniversary of a fundamental paper by John Zeleny,
- propose an alternative version of the method of inclined velocities.

OUTLINE of the talk:

1. Calm air analyzer (TOF method, drift tube).
2. Perpendicular flow analyzer (aspiration condenser).
3. Inclined flow analyzer (Loscertales instrument).
4. Parallel flow analyzer (Zeleny blow-through-grids instrument).
5. Position of the Loscertales method among the traditional methods.
6. Method of inclined grids.

The talk will be concentrated on the fundamentals of diffusion limit of the resolution of mobility analyzers. Signal noise and space charge effects will be neglected and the simplest plain configurations of analyzers will be considered.

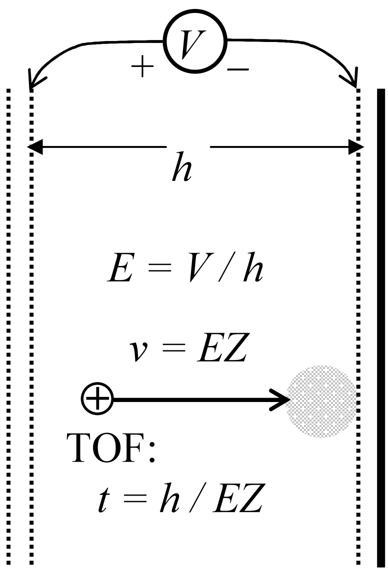


Broadening of a mobility line is expected Gaussian, its width is measured by standard deviation σ_Z and the mobility resolution is measured by the relative standard deviation:

$$\delta = \frac{\sigma_Z}{Z_\circ}$$

Calm air analyzer (TOF method, drift tube).

History: AC method by Rutherford 1898, contemporary configuration simultaneously by Van De Graaff 1928 and Tyndall 1928.



Mobility: $$Z_\circ = \frac{h}{Et}$$

$$\left.\begin{array}{l} h \text{ fixed } t \text{ measured} \\ t \text{ fixed } h \text{ measured} \end{array}\right\} \text{resolution nearly the same}$$

$$\delta = \frac{\sigma_Z}{Z_\circ} \approx \frac{\sigma_h}{h} \qquad \sigma_h = \sqrt{2Dt} = \sqrt{2\frac{kTZ}{q}t}$$

$$\delta = \sqrt{2\frac{kTZt}{qh^2}} = \sqrt{2\frac{kT}{qV}}$$

$$\boxed{\delta_\circ = \sqrt{2\frac{kT}{qV}}}$$

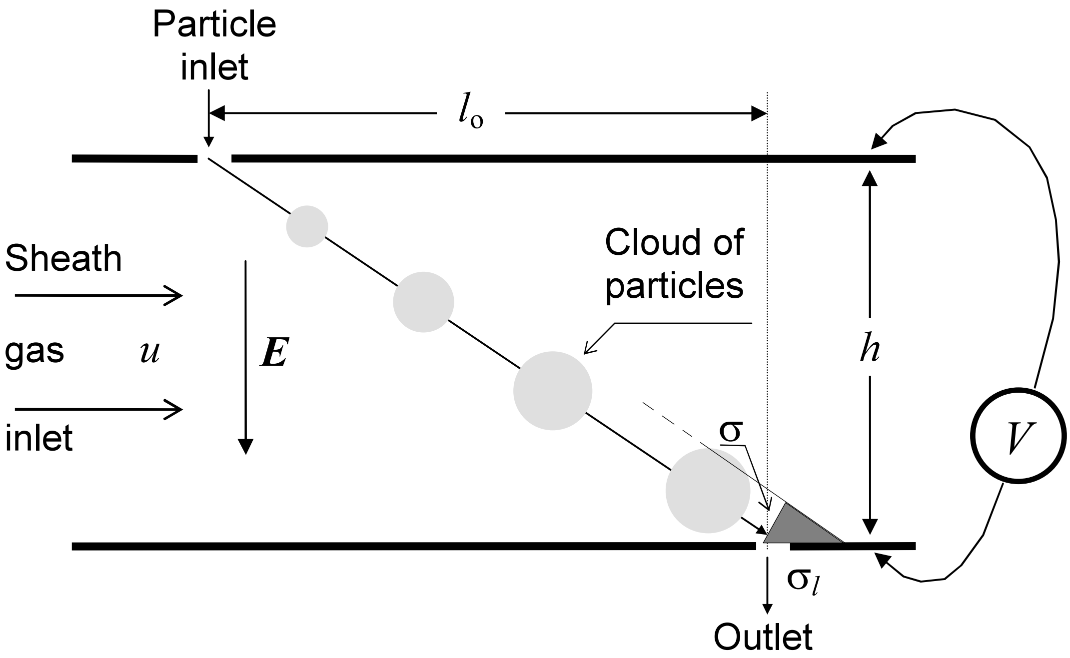
Example (q = 1 e, T = 20°C, any value of Z)

V =	1 V	10 V	100 V	1000 V
$\delta_\circ$ =	22%	7%	2.2%	0.7%

The molecular-kinetic interpretation, see on page 67 in:

Tammet, H. (1970) *The aspiration method for the determination of atmospheric-ion spectra*. IPST, Jerusalem.

Perpendicular flow analyzer (aspiration condenser).



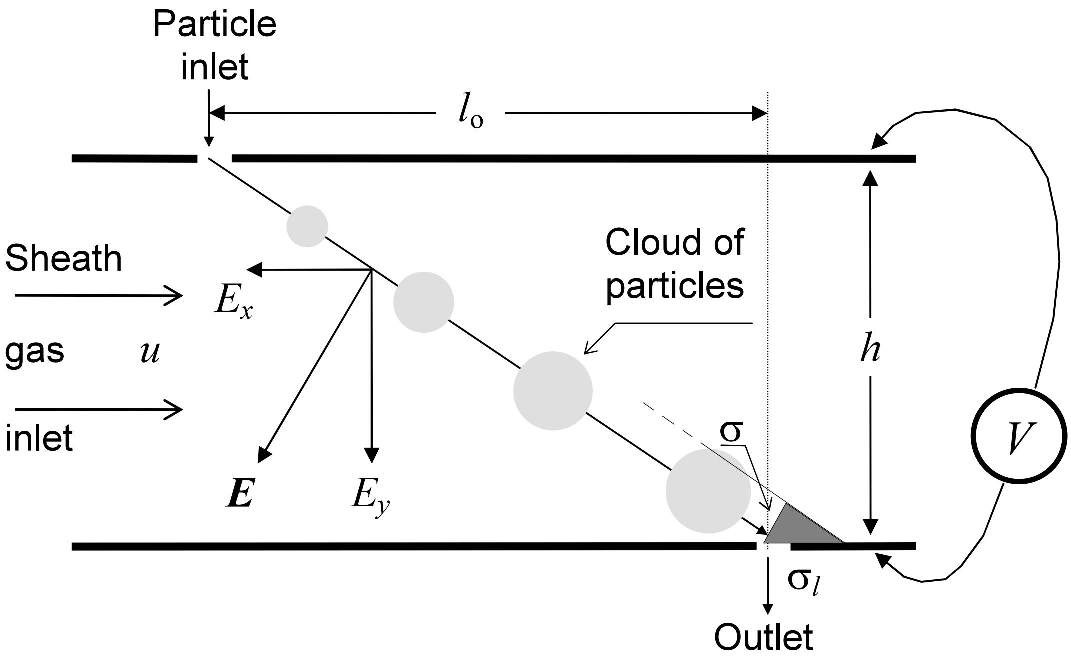
$$Z = \frac{uh^2}{Vl} = \frac{\text{const}}{l}, \quad \delta = \frac{\sigma_l}{l_\circ}, \quad \text{..............................}, \quad \delta = \delta_\circ \sqrt{1 + \frac{h^2}{l_\circ^2}}$$

Why not $l_o \to \infty$? V = const & $l_o \to \infty \Rightarrow \mathrm{Re} \to \infty$.

If Re = const, the optimum is at $l_\circ = h$ and $\delta = \delta_\circ \sqrt{2}$. See:

Rosell-Llompart, J., Loscertales, I. G., Bingham, D., Fernandez de la Mora, J. (1996) Sizing nanoparticles and ions with a short differential mobility analyzer. *J. Aerosol Sci.* **27**, 695–719.

Inclined flow analyzer (Loscertales instrument).

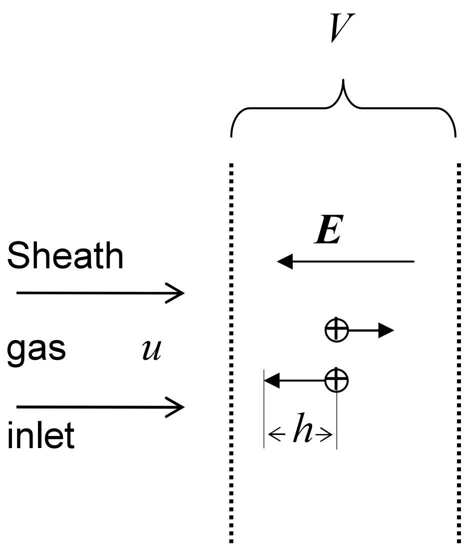


$$\mathrm{Lo} = \frac{E_x}{E_y} \quad \text{(in a classic aspiration analyzer Lo = 0)}$$

$$\delta = \sqrt{2\mathrm{Pe}\frac{1+(l_\circ/h)^2}{\mathrm{Lo}+l_\circ/h}} = \delta_\circ \frac{\sqrt{1+\dfrac{l_\circ^2}{h^2}}}{\mathrm{Lo}+\dfrac{l_\circ}{h}} = \frac{\delta_{\mathrm{Lo}=0}}{1+\dfrac{h}{l_\circ}\mathrm{Lo}} \qquad \delta_{l_\circ=0} = \frac{\delta_\circ}{\mathrm{Lo}}$$

How it is possible to have $\delta < \delta_\circ$?

Parallel flow analyzer
(Zeleny blow-through-grids instrument, 1898).



$$v = EZ - u$$

drift along E during t: $h = EZt - ut$

$$Z = \frac{h}{Et} + \frac{u}{E} \qquad \sigma_Z = \frac{\sigma_h}{Et} = \frac{1}{Et}\sqrt{2\frac{kTZ}{q}t}$$

$$\delta = \sqrt{2\frac{kT}{qE(EZt)}} = \sqrt{2\frac{kT}{qE(h+ut)}}$$

$h + ut = h_{\text{Lagrange}}$ $\qquad$ $E\,(h + ut) = W =$ work of electrical force

$$\delta = \delta_{\circ}\sqrt{\frac{h}{h_{\text{Lagrange}}}} = \sqrt{2\frac{kT}{W}}$$

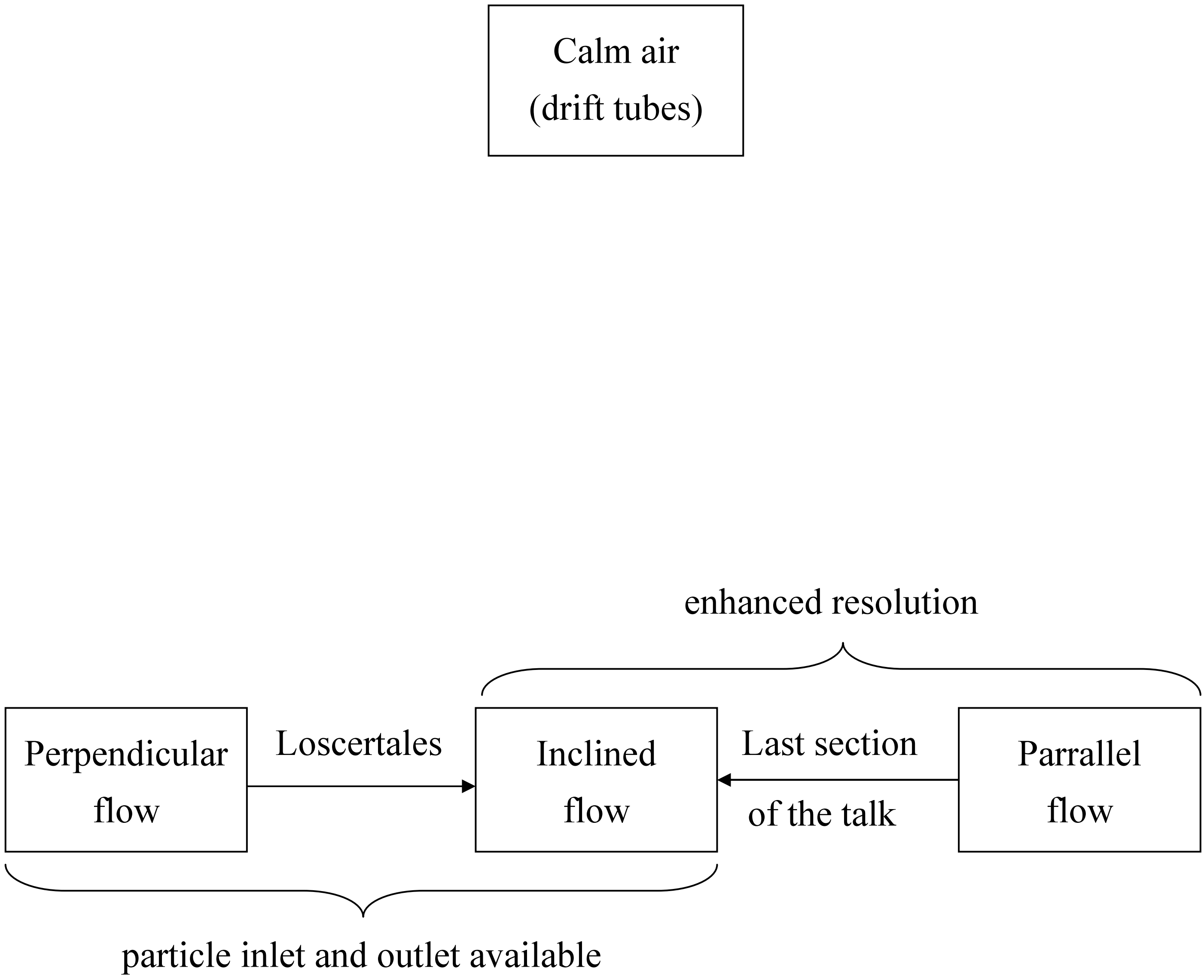
A problem: Aerosol inlet and outlet are not available it this instrument.

We have posed a question about the Loscertales analyzer:

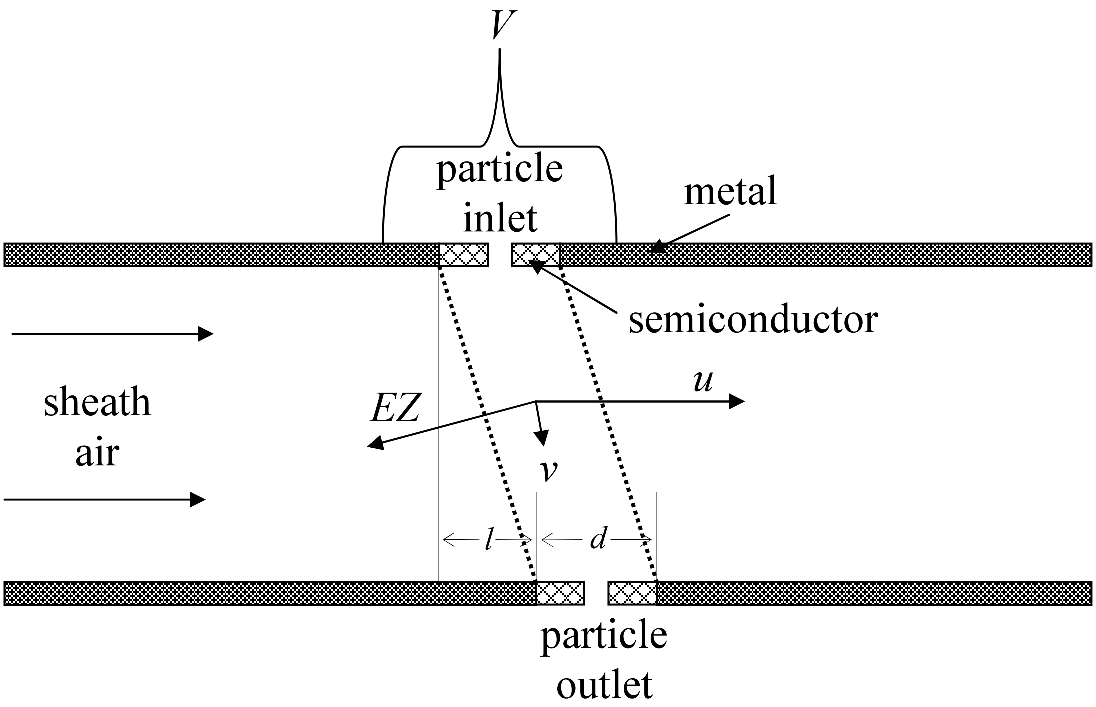
The question: how it is possible to have $\delta < \delta_{\circ} = \sqrt{2\frac{kT}{qV}}$?

The answer: since $h_{\text{Lagrange}} > h$ and $W > qV$.

Position of the Loscertales method among traditional methods.



Method of inclined grids.



This is a straightforward modification of the Zeleny grid method. However, the configuration of fields is just the same as in a plain Loscertales analyzer. The equations will be the same after a replacement:

Loscertales instrument	Inclined grid instrument
V	$\frac{l}{d}V$

Why grids?

1. Grids suppress the turbulence and maintain the plug flow profile.
2. The required total voltage is less than in the Loscertales instrument.
3. The voltage dividers are short and simple.
4. Sheath air can be easily cleaned from background particles using a third grid as a filter.