RESULTS OF APPLICATION OF A CERTAIN STANDARD

In the previous article, entitled „Is Immision a serious problem or not?” it was stated that air pollutants measurement is carried out incorrectly by monitoring stations, but in accordance with the EU standard EN 12341. The equipment that is used currently, because of its structure, underrate the value of concentration of the pollutants in the air in the presence of wind. **The stronger the wind, the stronger the pollutants concentration measurement error.**

In order to describe this problem, it is necessary to carefully read the EN 12341 standard and explain what follows from it. The standard describes three types of „aspiration head reference samplers” for small, medium and large capacities of the sucked air. In order to describe the phenomena taking place around and inside the head from the aerodynamical point of view, we will analyse the structure of the LVS-PM10 sampler, that is, the smallest head with sucked air capacity 2.3 m^3/h.

General conclusions for the small LVS-PM10 head will also apply to the larger HVS-PM10 and WRAC-PM10 heads.

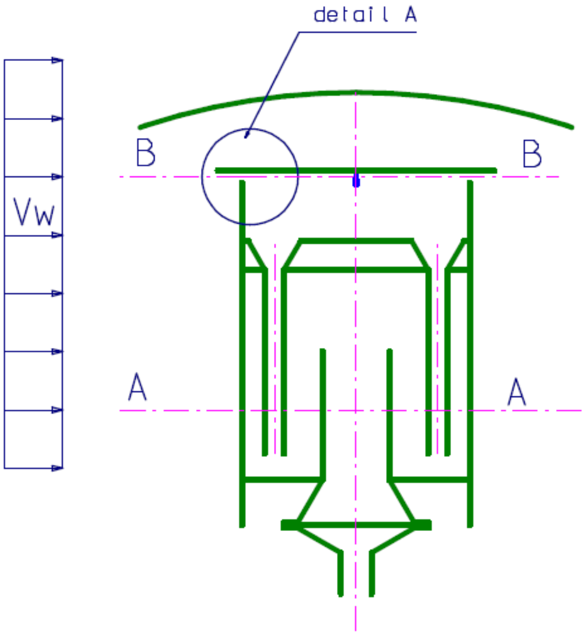

Fig. 1.

Fig. 1 depicts the structure of the LVS-PM10 head. From the outside, it looks like a cylindrical “jar with a cover”. The diameter of the jar is 78 mm, and between its brim and the cover, there is a 4 mm gap. h/D ratio determines the value of proportions, on the basis of which pressure losses are calculated. For h/D = 0.05, pressure loss is significant and amounts to 0.8 of the value of pressure difference outside and inside the jar.

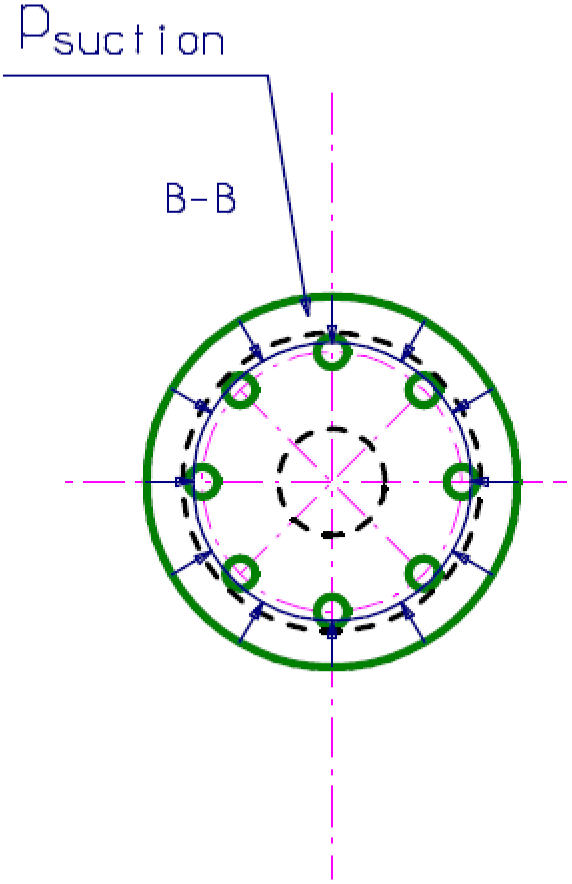

Fig. 2.

The LVS-PM10 head sucks in the air correctly when there is no wind. It was depicted in Fig. 2; pressure losses at the gap can be easily compensated by an increased output of an air compressor and air capacity stability control. When the wind blows, situation changes and to explain this, we must first consider air flow around the jar at level A [Fig. 1], where there is no gap. Air flow can be described in two ways: 1) for perfect flow, when air viscosity is not taken into account; 2) for actual flow, taking the viscosity into account, i.e. friction of the air against the wall of the shape in question. For the considered flow (low wind velocity, up to a few m/s), differences between perfect and actual flow are small, that is why we will consider the actual velocity and pressure distributions and their values will be given as for perfect flow.

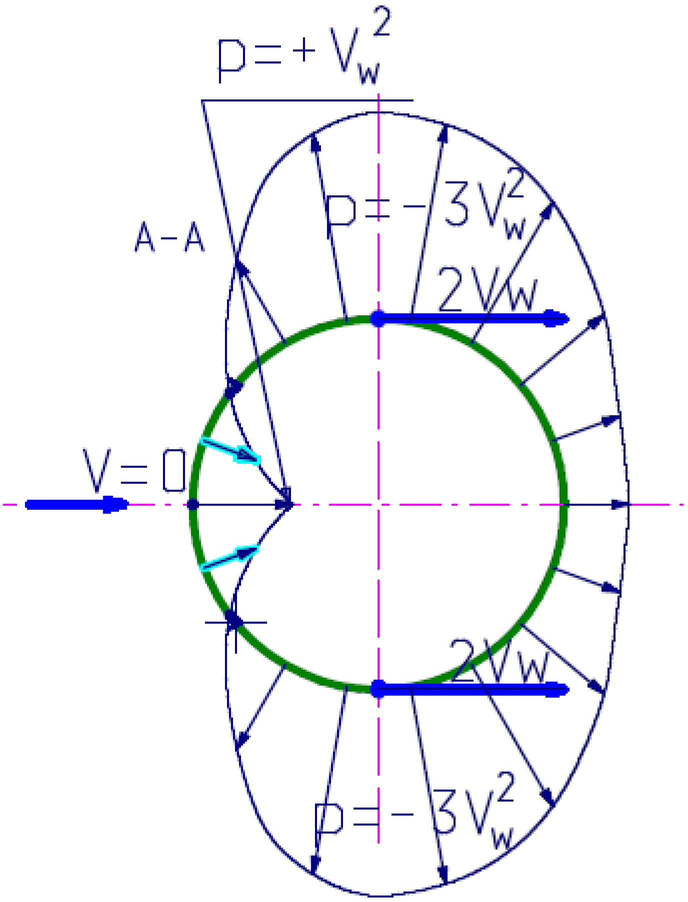

Fig. 3.

Flow at level A, without the gap is as depicted in Fig. 3. Opposite the wind direction there is a pressure concentration proportional to the square of wind velocity and at this point, the wind is stopped. Then the air around the wheel starts accelerating to the velocity almost twice as high as the wind velocity. At this point, there is maximum vacuum reaching proportionally to three fold value of wind velocity square. What changes will occur when we consider the air flow at level B, that is, in the middle of the gap? Because of the significant air flow resistance in the gap, values of pressure distributions and flow velocity changes will be similar, but lower. It is so because what cannot get inside the gap, must flow around it. It is depicted in Fig. 4

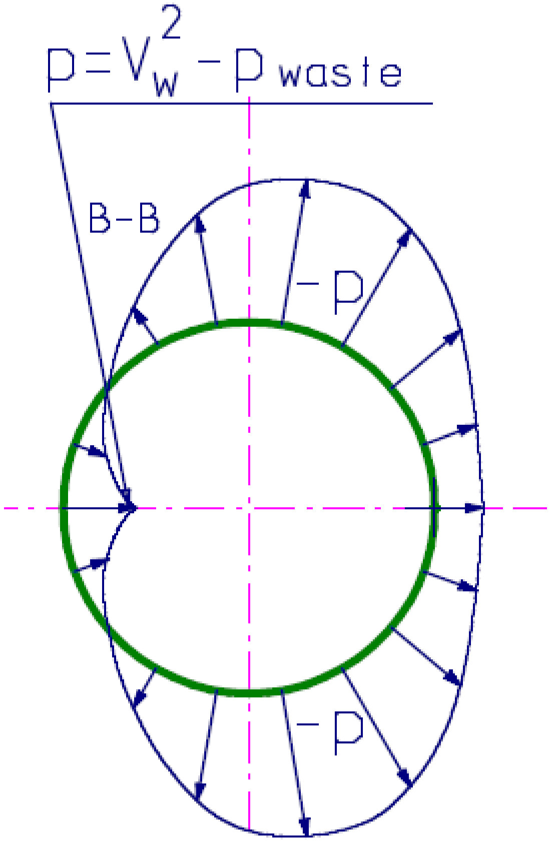

Fig. 4

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To the pressure distribution determined around the gap, depicted in Fig. 4, we can add pressure distribution of the air sucked into the device. The result of this superposition (adding or subtracting pressures) is depicted in Fig. 5.

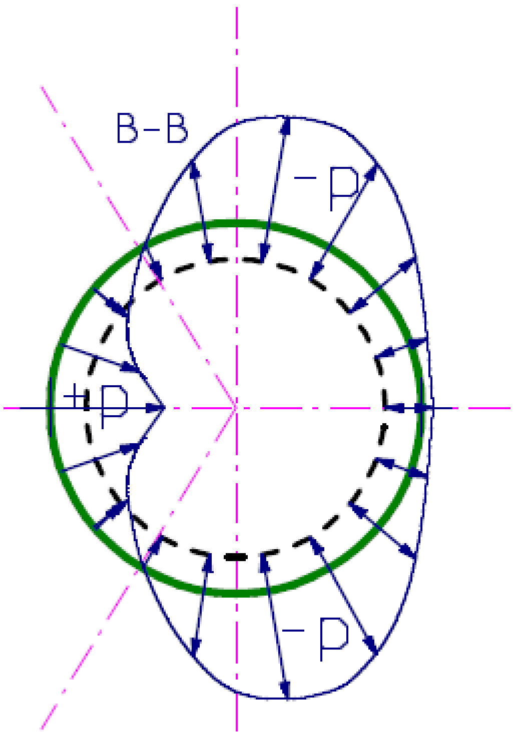

Fig. 5.

It is a resultant of the pressure distribution with blowing wind and air sucking device. In order to assess the influence of this distribution on pollutants concentration distribution, we must analyse velocity distributions in the gap, depicted in Fig. 6.

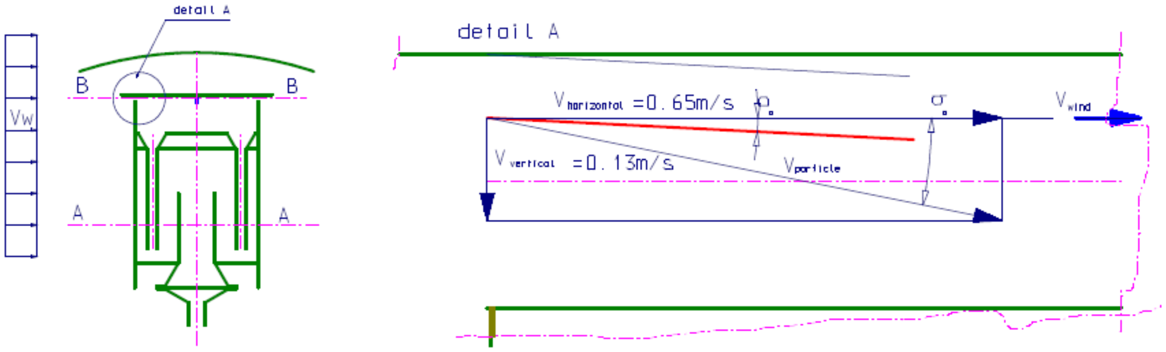

Fig. 6.

When there is no wind, all particles sucked in through the gap continue their flow through the device. Then, for capacity of 2.3 m^3/h, horizontal velocity in the gap amounts to 0.65 m/s and vertical velocity in the jar of diameter of 78 mm amounts to

0.13 m/s, which results in a particle descent angle $\beta = 11^\circ$. The device has certain critical angle $\alpha = 6^\circ$, $\mathrm{tg}\ \alpha = 2h/D$. The angle of particle descent can be significantly affected by wind. The stronger the wind, the lower the particle descent angle. If there is wind, the descent angle β will be lower than the critical angle $\alpha = 6^\circ$, then part of particles will be blown back out of the device through the gap. It is depicted in Fig. 7, showing particle movement trajectory during the wind.

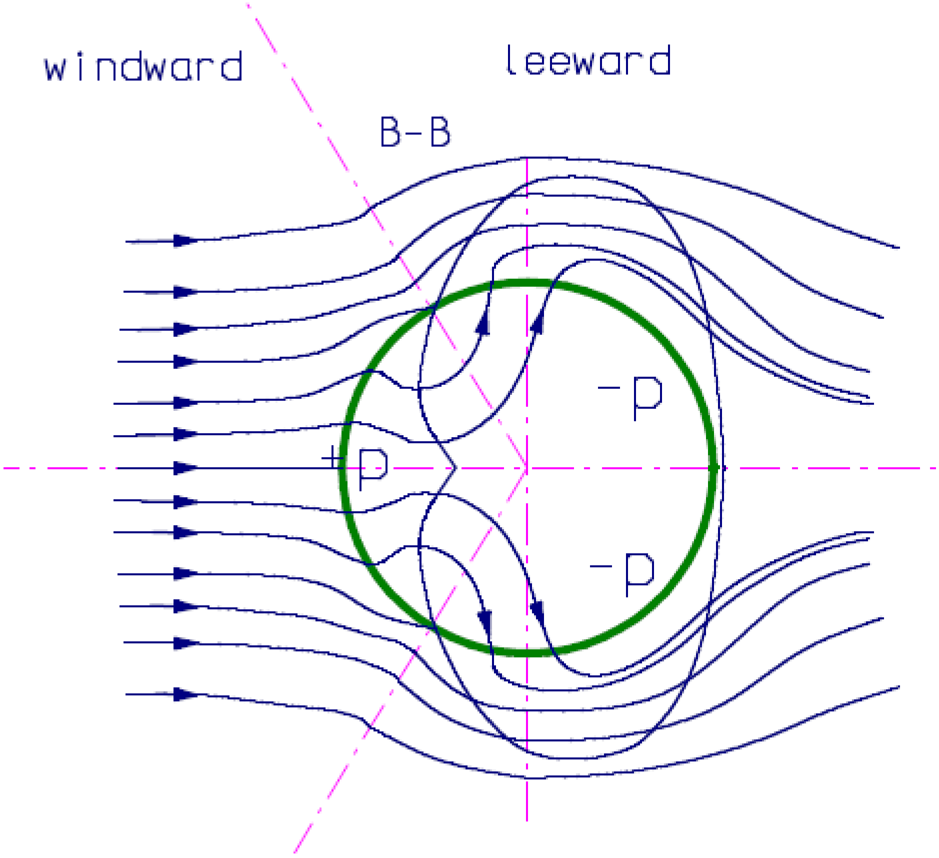

Fig. 7.

Resultant pressure and velocity distribution is completely different from that in Fig. 2 (no wind). **Due to this velocity distribution, in some areas of jar circumference not only there is no particle sucking, but some particles coming in from the windward side are ejected. It results in a decrease of the measured particle concentration.** This effect is visible in all air purity measurements, published in the Internet. An additional problem connected with this aerodynamically inefficient design is impactor particle size division. The average particle ascent velocity behind impactor nozzles amounts to 0.94 m/s, but here there is a certain velocity profile which will decrease from the wall of the axial duct of the device to the external wall. Particles coming out of the impactor nozzle with average velocity of 2.4 m/s, turning towards the axis, will have higher ascent velocity than those turning towards the external wall.

The simple structure of the impactor and diversified velocity profile result in a varied separation of particles of the same material.

And what about particles having different specific gravity? According to the EN12341 standard, impactors in the LVS-PM10 head were designed for separation of particles with aerodynamical diameter lower than 10 micrometres.

Aerodynamical diameter is a conventional value, applying only to particles whose dimensions are equivalent to specific gravity when $\gamma = 1\ g/cm^3$.

Separation with an impactor employs centrifugal force, as a result of which, particles of a certain mass and aerodynamic resistance can get to a certain area (opening) or not. If they fall into the opening, they continue their movement, if not, they are retained.

The spherical particles centrifugal force formula is as follows:

$$F = \frac{\Pi}{6} * d^3 * \gamma * \frac{V^2}{r} \ ,$$

where: d - particle diameter

γ - mass density

V - particle velocity

r - particle trajectory curvature radius

for determined conditions $d^3 * \gamma = C$

where: $C = F * \frac{\gamma}{V^2} * \frac{6}{\Pi}$

For $\gamma = 1$ g/cm^3 everything is correct, but what should we do if γ amounts to a few g/cm^3 or, as in the case of lead, 11.4 g/cm^3 ? Centrifugal force is ruthless and only particles that are proportionally smaller than $d = \sqrt[3]{\frac{C}{\gamma}}$ will be separated to the filter and **the content of lead in PM 10 may be many times lower than the actual value in the whole PM.**

Why should we pay attention to this? Because lead poisoning may occur not only through the lungs, but also through the gastrointestinal tract. Then we should take into account the content of lead in the airborne dust. In case of ingestion, aerodynamical diameter does not matter.

CONCLUSION

In Appendix D of the EN 12341 standard, „Introduction to selection of equivalence determination”, there is a section entitled „Comparison of a field test with the wind tunnel procedure”. There are many remarks concerning certain inconsistencies in the use of the equipment recommended by this standard. For example, different results of tunnel and field tests. Tunnel tests are always carried out with air flow, and field tests can be carried out when the air is calm.

It is a proof that the considerations concerning the aerodynamical properties of the LVS-PM10 reference sampler contained in this article are true. Hence, **measurements carried out with the equipment complying with the EN12341 standard are erroneous**. Therefore, we should limit the use of devices that give different results in typical weather conditions, with and without wind.

The following conclusion can be drawn: „Jars and wind do not mix”.