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Tackling the fine dust challenge

Standards covering the performance of HVAC units in train interiors are becoming progressively more stringent. High quality air filter design is central to mitigating the health and hygiene risks from fine particulate matter.

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Environmental awareness and sustainability are increasingly placing concrete demands on railway operators, suppliers and maintenance companies. Moreover, incremental action is clearly no longer enough: a fundamental rethink of our collective approach is required in the face of a looming climate emergency.

Quite justifiably, the rail industry has been keen to emphasise its green credentials. But there are certain technical aspects where more work is needed for the sector to be truly sustainable. Some of these are directly related to human health.

Take, for example, the issue of air quality and particulate matter. Looking beyond product design and material selection, air-conditioning specialists must now address the impact of dust concentration and fine particles on our collective wellbeing.

The air we breathe

Humans inhale up to 12 000 litres of air every day, transporting it deep into their lungs. As well as oxygen and other gases, various particles enter the respiratory system and can accumulate there. Most can be decomposed or transported away by the body's immune system, but those that remain can have negative effects on health.

Some particulate matter is so small that it can get into the lungs and even directly into the bloodstream. The human body is capable of separating dust particles with sizes between 3 µm and 10 µm via mucous membranes in the nose and throat. Particles smaller than 3 µm are 'respirable', and those of less than 1 µm are particularly critical. Such particles are able to enter the bloodstream or release pollutants into it, permeating through the entire body.

1 µm

Size below which particles are able to enter the bloodstream

As in the wider environment, particles of various sizes can be found in rail vehicles. Fine dust concentration levels are especially concerning in enclosed spaces, so this is a particular challenge for metro trains and those serving underground stations.

Most rolling stock in Europe is fitted with air-conditioning or ventilation units where the filters only separate out coarse dust particles. But the regulatory environment is now changing, in recognition of the risk that fine dust poses to passengers and, perhaps to a greater extent, staff. As a result, high-quality multi-stage fine dust filtration is now stipulated in the regulations.

The Grisu and WU families of fully synthetic panel filters developed by Kalthoff are a good example of modern designs. They capture and store the majority of coarse dust in the filter medium whilst also preventing some finer dust particles from penetrating. The filters are able to separate 50% of all particles up to 10 µm.

Understanding rail applications

The development of advanced filters for rail use requires extensive knowledge of the conditions in which trains will operate. Field tests and particle counts are carried out on vehicles in regular operation, using a mix of vehicle types and varying geographical conditions to record data on both the interior and exterior particle concentrations.

This empirical approach enabled Kalthoff to challenge some underlying assumptions about onboard air quality. For example, there had been an erroneous assumption that the dust concentrations of PM10 are 0·2 mg/m^3 in outdoor areas and 0·4 mg/m^3 in train interiors. In real-world conditions, we measured values in most European

Kalthoff's GRISU WU-100-4FR panel filter design.

countries that were lower by a factor of 10. This would have a significant effect on filter design.

Evolving standards

The European standards applying to HVAC filters changed significantly in July 2018 when DIN EN 779:2012 was replaced by DIN EN ISO 16890. The earlier standard evaluated filters according to their efficiency at a particle diameter of 0·4 µm. However, this failed to recognise the much larger spectrum of particles encountered in real environmental conditions.

The ISO 16890 specification covers a wider range of particles between 0·3 µm and 10 µm. Filter classification is based on the average collection efficiencies for PM10 fine dust particles (0·3 µm – 10 µm), PM2·5 (0·3 µm – 2·5 µm) and PM1 (0·3 µm – 1 µm). Unfortunately, the different test procedures between the two standards make a direct translation of filter classes impossible.

When it comes to passenger coach interiors, the filtration challenge needs to be clearly segmented. Light rail vehicles, metro or suburban trains on short-distance services see a high level of air exchange, which can generate considerable amounts of dust. By contrast, inter-regional or inter-city trains have much less natural air circulation, leading to a higher concentration of fine particles.

To enable the effective absorption of dust, filters should have a large surface area and a carefully optimised internal structure. Mat filters, whether supported by wire meshes or not, no longer meet the technical requirements, while knitted wire meshes can be prone to leakage. Both types are now being replaced by processed, pleated filters, which can increase the surface area many times over.

Kalthoff's Grisu and WU filters use a bespoke medium with a three-dimensional structure and a pleated fold design. The structured pore system is intended to store and retain particles with different fineness levels, helping to ensure that no coarse particles escape on the clean air side. In addition, the Kalthoff Grisu filters are able to process within the ISO Coarse ePM10/50% classification.

There are also health issues, as all too often poor filtration leads to hygiene risks. Common problems include the use of low-quality media, filters that are not properly fitted, missing elements and poor materials that leave the filter open to organic attack. All of these can lead to mould and spores penetrating or bypassing the filters to settle and multiply on the surfaces. Such spores can then be transported into the passenger saloon along with the filtered air.

Cardboard frames in particular are no longer appropriate for modern rolling stock. Being made of cellulose, the frames form a suitable base for the absorption of moisture and the associated growth of micro-organisms. In addition, they are often not mechanically stable and prone to leakage.

Certification challenges

The European EN 45545-2 fire safety standard which came into force five years ago has already driven change across the component supply chain (RG 11.15 p58). Whilst it has largely succeeded in unifying a variety of national regulations, there are doubts about how far EN 45545-2 is being interpreted uniformly across the market.

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Certification is a particular challenge: the standard requires that individual components be tested in their final structural assembly, as they would be installed in a rail vehicle. It is not sufficient to measure the filter medium on its own in a 'lie flat' lab test. This incorrect interpretation of the test standard risks falsification of the results in meeting the requirements on flame retardation as well as the development of flue gas and toxicity of the filter.

The Grisu filter has now been certified under EN 45545-2 for a second time. It also meets the more stringent HL-3 category for rail applications needing the highest class of hazard management. The WU filters meanwhile are certified under the DIN 5510 standard in accordance with grandfather rights.

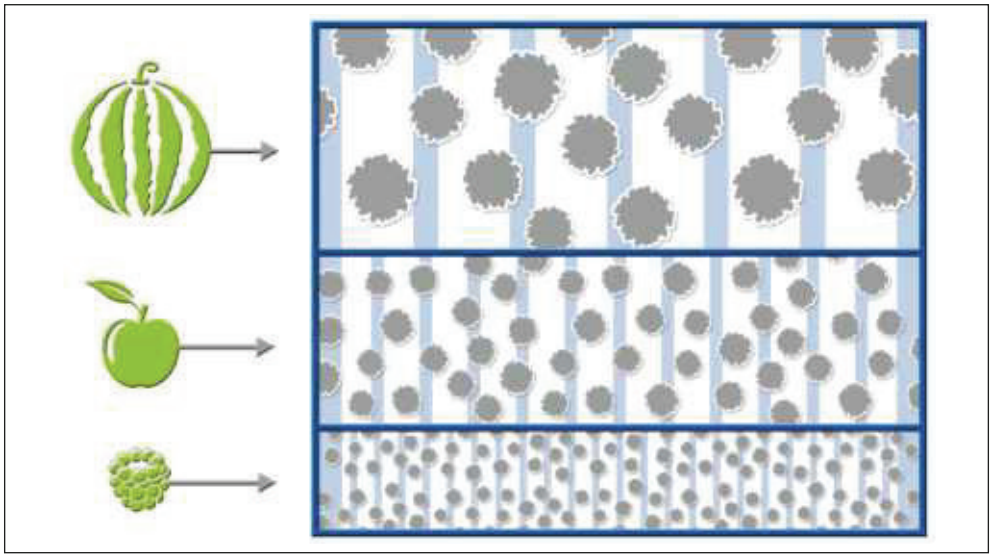
Delivering sustainability

Filters play a prominent role in determining the energy consumption of an HVAC unit. Parameters such as the initial pressure drop must be kept as low as possible to ensure efficiency over the life of the product. However, minimising energy use must be balanced against the fundamental performance of the unit, including the filter.

HVAC unit designers also need to consider the health of maintenance staff in the depots. Kalthoff's panel filters and filter medium have been designed to ensure that no further cleaning is needed during routine maintenance, and no separated dust can get back into the circulating air. This in turn helps to improve depot air quality.

The latest filter designs can achieve service lives of between six and nine months for long-distance trains and three to six months for suburban and urban rail vehicles. Although the life of a filter depends on conditions in the region where it is deployed, product durability has improved in recent years. And products must be capable of environmentally friendly disposal without major effort or expense.

Although a new generation of higher quality filters is emerging to address the issue of fine dust in the rail sector, truly sustainable HVAC design remains some way off.



Effective filtration requires the development of a progressive filter medium to trap both larger particles from 'dirty' air and progressively smaller particles in a single design.