OPERATOR ENCLOSURES AND COVID-19

Nanoparticle filtration is essential to reduce airborne exposures to COVID-19 in operator enclosures

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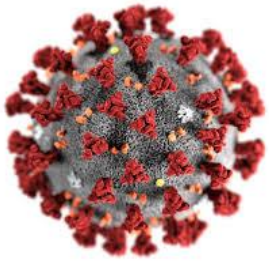
An Introduction to ISEEE

The International Society of Environmental Enclosure Engineers (ISEEE), a nonprofit organization, was established in 2012. Since its founding, ISEEE members have focused on developing research, best practices, and educational material around environmental enclosure air quality engineering. The ISEEE Advance Cab Theory Workshop remains the only course in the world specifically focused on designing, performance testing, and certifying functioning operator enclosures in their real-world environments. ISEEE provides education, expertise for standards development, and consultation on environmental enclosure air quality engineering.

The novel coronavirus pandemic has created renewed interest in understanding how filter media, and testing filter media relate to provide protection from the COVID-19 Virus (SARS-CoV-2). According to a recent article published in the New England Journal of Medicine (February 2020), the physical size of the COVID-19 Virus ranges from 60 nanometers (nm) to 140 nm. To understand air filter effectiveness in removing the airborne virus, the testing method should be able to evaluate filter efficiency at particle sizes near and within the 60 nm to 140 nm range.



COVID-19 Virus
60 nm to 140 nm

The study of aerosol physics and toxicology led to many discoveries that have changed our understanding of how sub-100 nm particles behave and affect public health. Research on how nanoparticles interact with the human respiratory system highlight that small particles have a greater specific surface area and can act as a vehicle for carrying biologically active compounds into the lung.

The onset of the development and manufacturing of printed circuit boards and microchips resulted in health concerns for exposure to nanoparticulates. Over the past few decades, efforts to address filtration testing to allow for the development of filter media capable of removing nanoparticles have been developed. In 2009, the European Norm (EN) published *EN 1822 High efficiency air filters (EPA, HEPA and ULPA) parts 1-5* (EN 1822). This standard addressed filter testing, classification, and quality control for high efficiency filter medias, providing a criteria for their development and manufacturing.

In 2011, the International Organization for Standardization (ISO) adopted, and homologated EN 1822, into *ISO 29463 High efficiency filters and filter media for removing particles from air parts 1-5* (ISO 29463). The ISO 29463 standard remained consistent with EN 1822, except for removing the lowest classification of filter efficiency.

The ISO 29463 criteria applies a fundamental understanding of aerosol mechanics to determine the classification of filter efficiency based on the Most Penetrating Particle Size (MPPS). This is the particle size that the filter is least efficient at removing from the air. In other words, it is the particle size that can pass through the filter, at the highest rate.

Figure 1 provides an example of how the MPPS and Filter Efficiency is determined. Concentrations of nanoparticles are measured before (upstream), and after (downstream) air has passed through a filter media. The particle size with the highest percent of penetration, is the MPPS. Filter efficiency is determined by subtracting the penetration percent from 100.

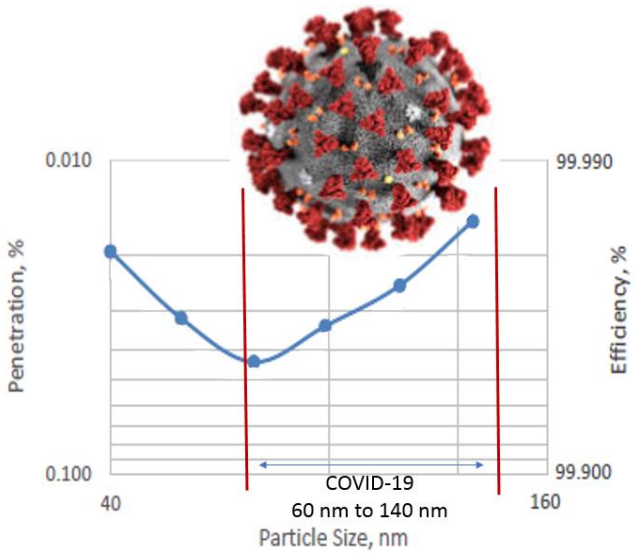
Figure 1 – MPPS and Filter Efficiency

Port	Particles at: (in nanometers)					
	40	50	MPPS 63	79	100	126
Upstream	1002553	1004613	1008577	1006247	1012146	1028185
Downstream	302	394	468	404	349	228
Penetration %	0.030	0.039	0.046	0.04	0.034	0.022
Efficiency %	99.970	99.961	99.954	99.960	99.966	99.978

Therefore, the filter efficiencies of the various particle sizes are indicated in Figure 1. The filter efficiency at MPPS (63 nm) in Figure 1, is 99.954%. As particle size increases or decreases from 63 nm, the efficiency of the filter increases.

The information provided in Figure 1 can be applied, in principle, to the COVID-19 Virus particulate size range, of 60 nm and 140 nm, from the recently published in the New England Journal of Medicine (February 2020). At the smallest particle size of 60 nm, the filter efficiency would be slightly higher than 99.954 % and at the largest particle size of 140 nm, the filter efficiency would be >99.978 %, as the particle size is >126 nm. A filter with the performance characteristics demonstrated in Figure 1, would be highly efficient at removing the COVID-19 Virus. Figure 2 compares the filter efficiencies and filter penetration of the example filter test in Figure 1, to the 60 nm – 100 nm particulate size range of the COVID-19 Virus.

Figure 2 – Filter Efficiency in Comparison to COVID-19 Virus Size



In this illustration the MPPS is 63 nm at 99.956% efficiency. A filter with these performance characteristics would be highly efficient at removing the COVID-19 Virus, with a particle size range between 60 nm and 140 nm.

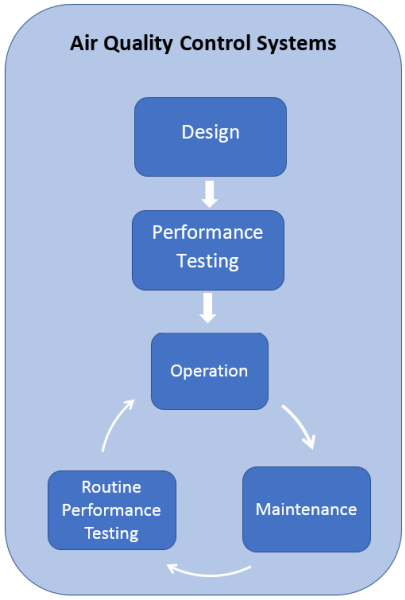
The ISO 29463 filter efficiency test method is appropriate to determine the MPPS of high efficiency filters, which have MPPS's below 100 nm.

CONCLUSION:

High efficiency filters that are tested and classified under EN 1822 or ISO 29463 are applicable when addressing the removal of the COVID-19 virus through means of air filtration. Although there is not a standard or regulation that mandates a level of filter efficiency for removal of the COVID-19 virus, it is understood that the higher the efficiency classification under ISO 29463 and EN 1822, the more effective the filter will be at removing the COVID-19 virus from the air.

APPLICATION OF FILTRATION REQUIREMENTS UNDER ISO 23875 (A STANDARD UNDER DEVELOPMENT) IN OPERATOR ENCLOSURES FOR PROTECTION AGAINST COVID-19

Figure 3 – Life-Cycle Approach of ISO 23875 – Mining - Operator enclosures - Air quality control systems and air quality performance testing



ISO 23875 provides requirements, best practices and information to achieve sustained quality in the design, manufacture, performance testing, use, and maintenance of the operator enclosure air quality control system.

Requirements in ISO 23875 are intended to prevent exposure to harmful respirable particulates within an operator enclosure. As the COVID-19 Virus is a particle, these aspects of the standard can also be applied when evaluating effective exposure control from airborne COVID-19 Virus through air filtration for the equipment operator.

In relation to air filtration, ISO 23875 specifies that external intake, and recirculation air filters are present and have a minimum filter efficiency classification of ISO 15 E, which is 95% efficient at their MPPS. A higher level of filter efficiency classification, ISO 35 H, is recommended by the standard, which is 99.95% efficient at MPPS. As illustrated in Figure 2, an ISO 35 H filter may remove the COVID-19 virus from the air at a minimum efficiency of 99.95% at 60 nm, and at a higher efficiency on particles > 60 nm and < 60 nm.

The COVID-19 virus can become airborne when an infected person talks, coughs, sneezes or laughs. In each of these cases, water droplets that contain the 60 nm to 140 nm sized virus, are emitted from the mouth and/or nose. When this happens inside an operator enclosure or operator station, the airborne droplets may follow the airflow and eventually enter the recirculation air system, or the airborne droplets may settle on surfaces inside the operator enclosure.

If the recirculation air system does not have a recirculation air filter, the droplets will pass into the evaporator/heater core where they may become stuck in the condensate, or evaporate. These virus laden droplets may stay in the ventilation duct work or possibly re-enter through the ventilation system into the operator enclosure. If the ventilation is directed toward the operator, the virus can enter the breathing zone of the operator. If a COVID-19 infected operator contaminates the ventilation system, the potential exists for exposing the next operator to COVID-19 when the ventilation system is turned on.

To provide the highest level of protection from potential airborne COVID-19 virus, the engineering design of the operator enclosure must include, external intake air and recirculation airflow filtration at a minimum efficiency of ISO 15 E, or higher efficiency of ISO 35 H. These filters must be applied through a device or configuration that ensures that there will not be any seal leakage in the filter housing. The potential for COVID-19 contaminated air to re-enter and contaminate the operator enclosure is significantly reduced when external intake and recirculation filters are used to prevent the virus from entering the Heating, Ventilation and Air Conditioning (HVAC) mixing plenum and connected ventilation ducting. The air filtration efficiency is critical, however, it must be coupled to an effective leak free delivery system.

As previously noted, virus laden water droplets may settle on surfaces within the operator enclosure. Therefore, it is also important that measures are taken to prevent transmission of the COVID-19 virus by touching contaminated surfaces. These measures may include, but are not limited to:

1) operate equipment with all windows and doors closed
2) use good hand hygiene practices and use good respiratory hygiene practices (sneezing or coughing into your arm) to prevent contaminating surfaces within the operator enclosure
3) cleaning and disinfecting all easily touched, or frequently touched surfaces when first entering (beginning of shift), re-entering or leaving (end of the shift) the operator enclosure
4) cleaning and disinfecting all easily touched, or frequently touched surfaces between different operators, as this may happen more frequently than once per shift
5) Personal Protective Equipment (PPE) should be worn when changing operator enclosure external intake and recirculation air filters, to prevent exposure to COVID-19 virus for maintenance personnel

Implementing measures to prevent transmission through contact are necessary, however, the ventilation system cannot be easily cleaned and disinfected between shifts, or different operators. This magnifies the importance of the recirculation air filtration as a key component of an operator enclosure's effectiveness at reducing exposure risk to the COVID-19 virus.

Conclusion

Proper application of high efficiency filtration is essential to reduce airborne exposure risk to the COVID-19 Virus. In ISO 23875, the engineering design and maintenance requirements to ensure exposure risk reduction to any airborne particles are addressed. If applied in accordance with ISO 23875, filters classified under ISO 29463, can be effective in reducing airborne exposure risks to viruses like COVID-19 within an operator enclosure.

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