Cab air-quality systems, such as the RESPA system from Sy-Klone, can be factory-installed by OEMs on cabs for a wide range of off-highway equipment.

Cab air quality: A CRITICAL COMPONENT OF OPERATOR COMFORT

Focus on defining cab air quality, measuring it, and designing the needed performance into cabin designs and HVAC systems is intensifying.

by Jeff Moredock

Review the design specs for any new haul truck, excavator, dozer or other off-road machine, and you're not likely to find requirements related to cab air quality—yet. However, standards are changing and the need to optimize cab enclosure environments for air quality will grow.

Consciously or not, equipment cab engineers ask themselves questions like these: What forces or factors can potentially harm operators in equipment cabs? How can design mitigate these potential hazards? It's thinking like this that has resulted in industry-standard operator enclosure safety features such as fall-on protection (FOPS) and rollover protection (ROPS) to counter accidental external forces, as well as ergonomic features inside the cab to prevent physical fatigue and discomfort.

Now, regulatory and standards agencies, equipment owners and OEMs alike are giving more attention to the air operators breathe inside cab enclosures.

This article examines the attributes of cab air quality, the ways in which both operators and HVAC design impact air quality, the changing regulatory and standards landscape, and an engineering design approach for meeting cab air-quality performance requirements.

Defining cabin air quality

The quality of indoor air is typically determined by four factors: CO_2 concentration levels, dust concentration or particle levels, temperature and humidity. These concepts aren't new, but what is new is a second look at the role of CO_2 and how it can affect operator comfort—and how, in turn, operator comfort can affect safety.

According to ISO 16000, the standard value CO_2 concentration for medium indoor air quality is 800 parts per million (ppm). Unless a cab receives a continuous supply of fresh air, an operator who is simply breathing normally can rapidly exceed the medium indoor air quality CO_2 value.

This was demonstrated in a study conducted at a mining site on a large wheel loader. The test observed operator behavior in a sealed, dust-free cabin that was at a pleasant temperature. The operator chose not to run the HVAC, meaning there was no supply of fresh air. Within one hour, CO_2 levels of 4,000 ppm were reached, well on the way to exceeding the **Occupational Safety and Health Administration**'s (OSHA) occupational exposure limit of 5,000 ppm of CO_2 in an eight-hour period.

Higher levels of CO_2 in a sealed cabin mean lower levels of O_2, which can impair cognitive function resulting in riskier decision making. It also causes air to feel stale and stifling, which could lead operators to open their windows, allowing exposure to outside airborne hazards.

Evolving standards and regulations

Currently, there are two international standards that comprehensively address the issues associated with the manufacture, testing and rating of human-respiratory filters used in low-airflow operating environments such as a machine operator cab. One standard is published under the European Commission as a European Norm (EN1822), and the other is published under the **International Standards Organization** (ISO 29463).

Now, with an increased focus on cabin air quality, standards organizations are developing new standards that address these issues. The **American Society for Heating, Refrigerating and Air-Conditioning Engineers** (ASHRAE) is aggressively looking for an alternative to replace its 52.2 standard, which deals with testing air filters by measuring the particle counts upstream and downstream of the air-cleaning device being tested.

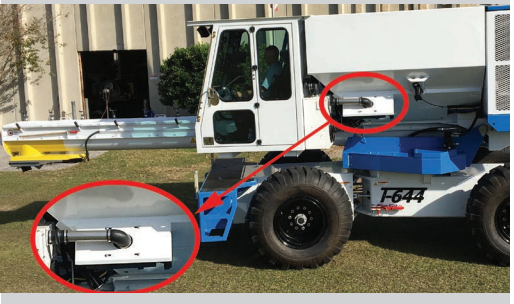
SY-KLONE

Testing for clean cab air—a demonstration

RESPA cab and enclosure air quality products from **Sy-Klone International** can be found as first-fit systems by several off-highway equipment OEMs. RESPA systems are also custom-fit into special-application equipment and aftermarket installations, exemplified in a recent installation by **Tucker's Machine & Steel Service** of Leesberg, Florida.

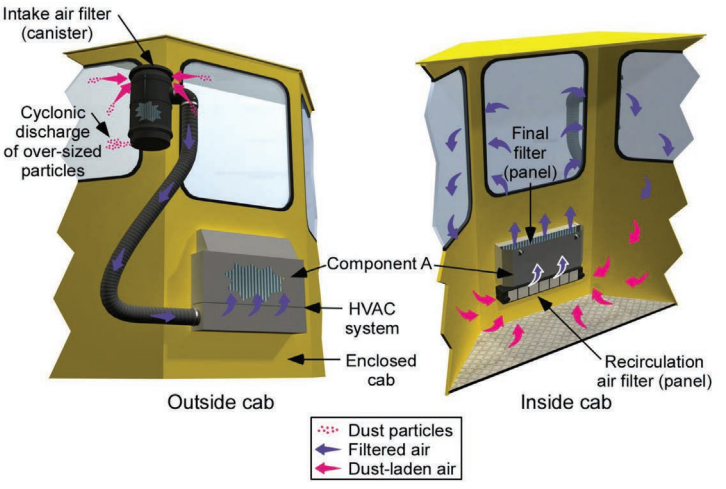
In this application, a newly completed Tuckerbilt T-644 concrete transporter was customized with a RESPA-equipped cab. To confirm the performance of the cab's clean air systems, the **International Society of Environmental Enclosure Engineers** (ISEEE) in-field testing method, which uses test aerosol, was performed. First, the fresh-air intake on the machine was deluged with over 200,000 µg/m³ of aerosol; nonetheless, the average dust concentration in the cab remained at 2 µg/m³.

Then the aerosol generator was sealed in the cabin of a running machine with the HVAC fan on high. The generator was allowed to run until the aerosol concentration rose to just over 521,000 µg/m³, after which the aerosol generator was turned off. Within three minutes, the average aerosol concentration had fallen to 2.6 µg/m³.



OEM-engineered machine designs that incorporate cab air-quality systems, as shown on this Tuckerbilt concrete transporter, allow for optimal performance and an integrated appearance.

FROM TOP: NIOSH; TUCKER'S MACHINE & STEEL SERVICE, INC.



This NIOSH example of a cab air-quality system starts with a cyclonic precleaner with integrated high-efficiency filter to positively pressurize the cab, used in conjunction with the machine's recirculation filtration.

Similarly, **SAE International** is exploring standards to replace the current ISO 5011 engine filter test when applied to human operating environments. The **American Society of Agricultural and Biological Engineers** (ASABE) recently published a new standard for agriculture that will result in improved air quality in operator cabs working in contaminated work environments.

OSHA issued Standard 29 CFR 1926.1153 in 2016, introducing new requirements for reducing employees' exposure to respirable crystalline silica dust. Since then, many individuals and organizations have issued responses to the initial proposed standard, including the 300,000-member **International Union of Operating Engineers** (IUOE).

In its response, the IUOE called the standard an "innovative solution to a complex problem," but noted several ways the standard could be further refined to help inform the development of even better protective measures. While the standard was a necessary update to the previous regulations (which were more than 40 years old), on August 15, 2019, OSHA issued a request for information asking for stakeholder input on how the standard can be further improved.

A design guide for cab air quality

In its 2019 Dust Control Handbook for Industrial Minerals Mining and Processing, the **National Institute for Occupational Safety and Health** (NIOSH) concluded that the most effective cabin filtration and pressurization systems are those integrated directly into the HVAC. These systems include the following:

- A powered precleaner that uses high-efficiency filtration to collect and eject more than 90% of dust and other harmful particles from the air before it even reaches the high-efficiency filter.
- A high-efficiency filter (MERV 16 is recommended) that captures 95% or more of the toxic respirable particles in the range of 0.3 to 10 µm.
- A recirculating-air unit, also using a MERV 16 filter, which continuously filters air as it recycles through the cabin.
- A cabin-pressure monitor that continuously monitors air pressure and alerts the operator if it drops below a preset level.
- A CO_2 monitor that provides real-time readings of carbon dioxide levels in the cabin to ensure levels stay within the safe zone.
- Unidirectional airflow, established through venting design, to ensure a steady, continuous supply of fresh air that dilutes any buildup of CO_2 to help maintain a healthy level of 800 ppm.

It's clear that cabin air quality is going to be an important off-highway equipment design issue going forward. Standards organizations, OEMs and equipment owners are all working toward a future where heavy-equipment operators are guaranteed a safe, healthful, comfortable working environment that is clearly defined and performance proven. ■

Jeff Moredock, an executive vice president at Sy-Klone International, wrote this article for *Truck & Off-Highway Engineering*. He also serves as the international project lead for ISO 23875 (Mining—Operator enclosures—Air quality control systems and air quality performance testing) and serves on various SAE, ASABE, AEM, AIHA, and ISO committees and work groups.

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