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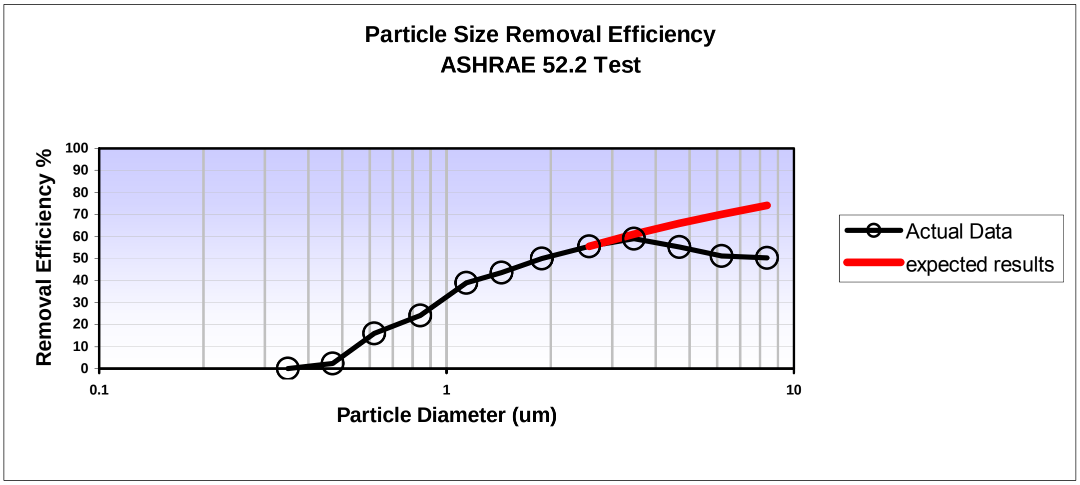
FAQ – Efficiency Curve Shape

QUESTION: Why does the efficiency vs particle size curve in ASHRAE Standard 52.2 test sometimes start turning back down at larger particle sizes? Shouldn't dust removal efficiency be higher when particles are bigger?



This is a question we get frequently. And it's the one most all of us were asking when we first started getting data during the development phase of the standard. Since then, the phenomenon has been well studied, understood and explained.

SHORT ANSWER: The two-word answer is: "Particle Bounce". Long answer is on next page.

HOW DOES AN AIR FILTER WORK: An air filter is a random arrangement of fibers. Particles are caught on the fiber surface (not trapped in the holes like a sieve). If a particle moving in an airstream collides with a fiber, it sticks to it (is captured by the filter). All other things being equal, the bigger the particle, the higher the odds it will hit a fiber. These "higher odds" translate to the words "higher efficiency" in filter terminology.

Restated - the bigger the particle, the higher the efficiency. The curve of efficiency vs particle size should never drop off. But it does. Why? That was the question, of course.

Photograph from electron microscope at 1000X magnification. Partial cross section of dirty air filter media (MERV 14). The airflow direction was from left to right. The fibers are glass with smooth circular cross section. The large fibers are 5 μm diameter; the smallest are less than 1 μm. The collected dirt particles are evident on the fibers wherever the "smooth" fiber surface looks "bumpy" or "fuzzy". Most of the collected particles here are smaller than 1 μm.

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LONG ANSWER: The answer may be more obvious to a non-filter person than it was to some of us who consider ourselves "experts." Have you already asked "Why does a particle stick when it hits a fiber." Well, it was an assumption to simplify the calculations and it seemed justified by what we knew at the time. But like a lot of things, if we use logic and take the example to extremes, that is, to absurd limits, it may shed some light on the subject. In this case, the absurd example is a baseball bat, which is a "fiber", and a baseball, which is a "particle." No one ever expects this "particle" to stick to this "fiber" when the batter swings. So the assumption is false with really large particles (73,660 μm in this example) and really large "fibers". Take my word on the next statement – "With small particles (say 0.3 μm), the assumption of sticking is true". With these two extreme examples, logic says there is a particle size somewhere between 0.3 and 74,000 microns where the particle bounce phenomenon starts. And maybe when it starts, it doesn't transition immediately from 100% sticking to 100% bouncing. In other words, there is a range of particle sizes where some particles will bounce and some will stick.

It might bounce once and then stick on a second collision (with a different fiber), or bounce twice and then stick on the third collision etc. But the efficiency drop occurs when the particle bounces multiples times from fiber to fiber as it ricochets through the filter media, coming out, (still airborne) on the downstream side without being captured by the filter.

CONCLUSION: Tests like ASHRAE 52.2 show that the transition from sticking to bouncing occurs in the 3-10 μm range of particle diameter. The drop in efficiency as particle size gets bigger is real and is due to "Particle Bounce".

ONE LAST POINT: When it occurs, "Particle Bounce" generally happens in filters that are MERV 8 and below. The lower the MERV the larger the fibers, as a rule of thumb. This bounce phenomenon requires a combination of large particles (where we can be quantitative) and large fibers (where we can only be qualitative in this presentation).

Chuck Rose
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