Are you receiving realistic performance data?

AMC filter lifetime estimates depend on how filters are tested

Chemical filters to remove airborne molecular contamination (AMC) are usually provided with some kind of performance claim, either a lifetime in weeks, months and years, or a capacity figure of how much contaminant it can adsorb. Unfortunately, there is no standard for filter test concentrations and as a result, performance claims vary widely from vendor to vendor.

WHAT IS THE DIFFERENCE BETWEEN FILTER LIFETIME AND CAPACITY?

Filter lifetime, as worded, should be something expressed in time units (hours, days, weeks, months, or years). Lifetime changes with concentration; higher concentration causes shorter lifetime.

Filter lifetime needs boundary conditions under which that estimate is valid. For example, a specific lifetime can only be achieved if the concentration of the contaminant does not exceed a maximum value, and if type of contaminant, temperature, and flow rates are constant. Lifetimes are usually provided for budget planning but are often unrealistic or require too much information to be valid. If boundary conditions change, quoted lifetimes no longer apply.

Filter capacity, as used in adsorption physics, should be something expressed in mass of contaminant per mass of adsorbent (for example, g/g, often expressed as mg/g or mg/kg). Capacity also changes with concentration, but it actually gets higher with higher concentration.

Lifetime estimates are ultimately based on an absolute capacity that has less boundary conditions. Flow and temperature still need to be constant, but higher concentrations do not invalidate the capacity.

CAPACITY DEPENDS ON TEST CONCENTRATION

Capacity changes (non-linearly) with the contaminant concentration as described with the adsorption isotherm. The adsorption isotherm is a physical principle that applies to all physical adsorbents such as activated carbon, mol sieve, silica gel, etc., where absolute capacity of a specific amount of adsorbent increases with increasing concentration, Figure 1. This is important because it affects filter lifetime estimates.

AMC Filter Capacity as a Function of Test Concentration

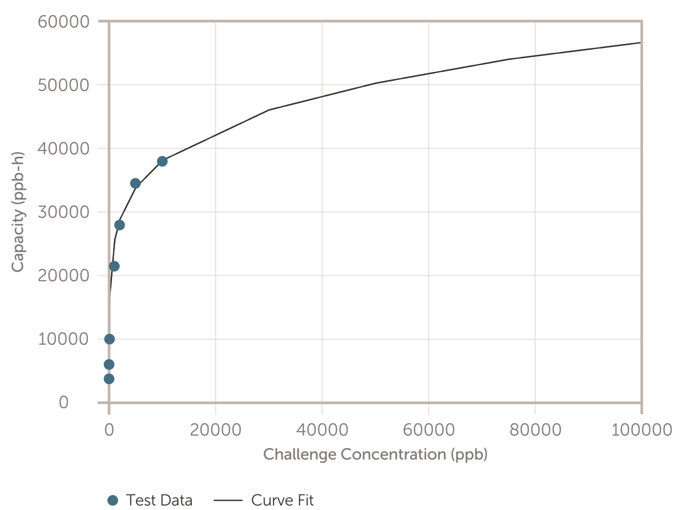

Figure 1. An adsorption isotherm test. Filter capacity as a function of test concentration.

The HVAC industry often tests filters at concentrations as high as 1000 parts per million (ppm, 10^{-6}). Many AMC filter vendors test filters (or sometimes only adsorbent samples) at concentrations between 3 and 100 ppm. The ISO standard 10121-1:2014 suggests a range of 9 – 90 ppm, all far above real-world applications, which might be as low as a few parts per billion (ppb, 10^{-9}), a factor of 1000 – 100000 below these test concentrations.

Entegris filter test wind tunnel.

As a result, estimated capacity from these tests is inflated and provides unrealistic lifetimes that cannot be achieved at low, real-world application concentrations. Figure 1 shows that dependency. Entegris used its state-of-the-art filter test tunnel system to measure how filter capacity changes with varying test concentrations. The seven data points in Figure 1 up to 10 ppm (10000 ppb) are actual test results, the dashed line up to 100 ppm is a power curve fit. That extrapolation is conservative and may be much steeper.

Table 1 summarizes these results. Many critical industry environments operate in the low ppb range, we assumed 10 ppb as the reference. High test concentration is an unavoidable necessity to accelerate the performance tests but increasing concentration to 1 ppm (the Entegris standard) already increases the resulting capacity by a factor of 5 – 6.

Increasing test concentration to 10 ppm, a commonly used level, inflates capacity by a factor of 10. Some test labs specialize in the use of 100 ppm concentrations to achieve very short test times, but those results are at least 15 times higher than real world applications, a very unrealistic scenario. If a lifetime of two years is quoted from 100 ppm testing, real-world lifetime at 10 ppb maybe as short as two months! Unfortunately, many companies make purchasing decisions based on these estimated lifetimes and do not question how realistic they are.

Concentration (ppb)	**Capacity (ppb-h)**	**Lifetime inflation**	**Comment**
10 ppb	38000	1	Tested
50 ppb	60000	2	Tested
100 ppb	100000	3	Tested
1 ppm	215000	6	Tested
2 ppm	280000	7	Tested
5 ppm	345000	9	Tested
10 ppm	380000	10	Tested
30 ppm	460600	12	Extrapolated
50 ppm	503000	13	Extrapolated
75 ppm	540000	14	Extrapolated
100 ppm	567000	15	Extrapolated

Table 1. Test and extrapolation results from Figure 1. 10 ppb was chosen as the reference = 1.

For a tolerable compromise between accelerated test time and real-world application, Entegris tests AMC filters at 1 ppm (1000 ppb), with many specialty tests and compounds tested as low as 30 ppb. Capacity results are then rounded down and quoted with a 20% uncertainty. We found that test concentrations much higher than 1 ppm yield unrealistic results.

Boundary conditions for these tests were 22°C (72°F), 45% relative humidity and a flow with face velocity of 0.5 m/s and an end-of-life removal efficiency of 50%, common conditions for production facilities.

This concentration dependence does not apply to purely chemical adsorbents, such as ion exchangers capturing base compounds like ammonia. With purely chemical adsorption, capacity does not depend on concentration, making lifetime easier to estimate.

Entegris is the only AMC filter vendor to provide a commercial filter test service to determine remaining capacity/lifetime for used filters (www.entegris.com/as), to make decisions that are best for protecting sensitive processes and lower cost of ownership.

HOW TO CALCULATE LIFETIME FOR ENTEGRIS PRODUCTS

As easy as it is to test capacity, the g/g figure is not very useful, because an end user does not know the mass of adsorbent in a filter and calculations depend on the molecular masses of contaminants.

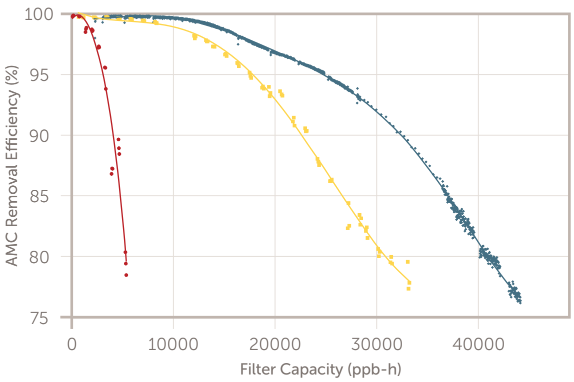

Figure 2. Capacity curve as found on Entegris AMC filter product sheets.

For an easy-to-use capacity figure, Entegris uses a ppb-hours value, the product of concentration (in parts-per-billion, ppb, 10^{-9}) and time (in hours). This is a very useful metric because it allows users to easily calculate the time that the filter remains useful.

To do so, the user must determine the average challenge concentration in their environment (in ppb) through AMC measurement, something that should be routinely done anyway. Then they can consult the capacity curve of the Entegris product sheet, Figure 2. After deciding the end-of-life removal efficiency, the user simply divides the measured AMC concentration into the ppb-h capacity to get the hours of lifetime of the filter. This is most realistic because it uses actual challenge concentrations for the application (without the filter supplier having to know it).

If needed, Entegris Analytical Services can provide in-field AMC measurements (www.entegris.com/as) to determine AMC concentrations in your application environment at the sub-ppb level.

FOR MORE INFORMATION

Please call your Regional Customer Service Center today to learn what Entegris can do for you.
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