Is There a Downside to High-MERV Filters?

The new high-MERV filters extract an energy penalty.

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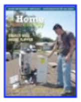

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Filters were originally conceived to protect heating and cooling equipment—for example, to prevent large particles from clogging the air passages of coils. The old familiar fiberglass filters do a fair job of protecting equipment but do little to enhance indoor air quality. Over the past several years, energy efficiency and green programs have begun to adopt requirements for filters that can remove the smaller particulates that cause allergic reactions and other health problems. The Energy Star Indoor Air Package, DOE Builders Challenge, LEED for Homes, and EarthCraft programs all call for a MERV rating of 8 or better.

On the left is a 1-inch MERV 8 pleated filter, which is similar in appearance to all other 1-inch pleated filters tested. In the middle is the washable MERV 8 WEB filter, and on the right is a typical fiberglass filter that was used for comparison. At the bottom is a 4-inch MERV 12 pleated filter.

MERV, the acronym for Minimum-Efficiency Reporting Value, is a measure of the efficiency with which filters remove particles of specific sizes. The test protocol for determining MERV ratings is described in ASHRAE Standard 52.2-2007, "Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size." A MERV 8 filter can remove particles down to 3 microns in size at an efficiency of 70% or greater (1 micron is about 0.04 thousandths of an inch). Fiberglass and washable filters are typically 1–4 MERV, and can filter out particles of 10 microns and larger.

According to the Standard 52.2 application guidelines, particles in this size range include pollen, dust mites, mold spores, hair spray, powdered milk, and, of course, snuff. Higher MERV ratings (from 13 to 16) are needed to remove bacteria and smoke particles. At the top of the scale are HEPA filters with MERV ratings from 17 to 20, which can filter out particles smaller than 0.3 microns, including some viruses.

It stands to reason that the ability to filter smaller particles would come with the penalty of increased resistance to air flow. Could the shift to better filters mean that they could cause problems with inadequate air flow or greater fan energy use? Are all high-MERV filters equal, or do some have less pressure drop than others? How much better are 2-inch and 4-inch-thick pleated filters than 1-inch filters? Are larger ducts required to offset the added pressure drop of the filter? With a pat on the back from our Building America program sponsors, my colleagues and I at Davis Energy Group, in Davis, California, decided to run some tests to answer these questions.

Test Methods

Table 1. Filters Selected for Testing

FILTER MAKE AND MODEL	Thickness	MERV
3M Filtrete 1000	1 in	11
3M Filtrete 1085	1 in	11
3M Filtrete 1550	4 in	12
3M Filtrete 1700	1 in	12
3M Filtrete 600	1 in	8
Ace 30 Day Model 10004.011625	1 in	2
Ace Microparticle, Model No. 4122354	1 in	11
Ace Pleated, Model 4044566	1 in	8
Aeolus Synthetic Mini-pleat	2 in	13
American Filters Dirt Demon Dust Shield	1 in	6
Flanders NaturalAire Standard	1 in	8
Flanders Pre-pleat 40	2 in	8

We selected 13 filters for testing (see Table 1). The objective was to choose filters that homeowners would be likely to purchase to replace the filter provided by the builder, so we selected brands and models that are found in most big-box and chain retail stores, and that represent a variety of MERV ratings and thicknesses. We chose one fiberglass filter (ACE 30 Day) as a reference. Its rating was not listed, and we assumed that it was MERV 2. All except the Ace 30 Day and WEB Lifetime filters have pleated media. We purchased all but one of the filters (the Aeolus, a 2-inch MERV 13) from chain retail stores.

We decided to limit our tests to filters having outside dimensions of 16 inches x 25 inches. This is a commonly available size that allowed us to compare a wide range of products. Standard 52.2 specifies that filters be tested at 492 feet per minute (fpm) face velocity, which equates to 1,367 CFM for the 400 in^2 face area. Applying the 400 CFM-per-ton rule of thumb, this size would be

WEB Lifetime	1 in	8

appropriate for 3- to 3½-ton air conditioners.

Our testing evaluated filter pressure drop and blower motor energy over a range of air flow rates for each filter type. The test apparatus and measurement of standard air flow was based on ASHRAE Standard 41.2, "Standard Methods for Laboratory Airflow Measurement," (and used the equipment diagrammed in Figure 1). The apparatus included a calibrated nozzle box with integral pressure balancing fan, pressure sensors for measuring air flow and filter pressure drop, temperature and relative humidity sensors to normalize air flow to standard conditions, and power monitors for measuring blower energy. The filters were attached to a typical air handler that was coupled to the nozzle box. The blower wheel of the air handler was 12 inches in diameter by 10 inches wide.

Calibrated Nozzle Box Used to Test Filters

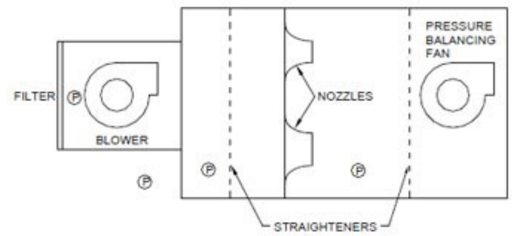


Figure 1. The variable speed blower motor was adjusted to the desired airflow rate and the pressure balancing fan was used to maintain approximately 0.5 inch WC of static pressure downstream of the blower to simulate ducting. The circled P's denote pressure measurement points.

We tested the filters using a standard ¾ hp PSC motor and a 1 hp GE ECM 2.3 variable-speed motor connected to the same blower. Most economy-priced furnaces use permanent split capacitor (PSC) motors. These respond to increasing flow restriction by moving less air with little change in power. The air flow reduction that occurs with PSC motors can affect the amount of power consumed by the compressor, and can also result in a decrease in cooling capacity, extended run times, and therefore greater energy use. Many higher-priced furnaces and heat pumps use electronically commutated motors (ECMs). These respond to increasing flow restriction by maintaining a fairly constant air flow rate, but at the expense of increased power and increased energy use. Testing with the ECM motor allowed us to "dial in" the air flow rate, whereas the flow rate for the PSC motor was whatever it could deliver at its three different tap settings.

We wanted to determine the incremental impact of the filter on air flow and fan power beyond what the cooling coil and ductwork would contribute. California field studies have found that the median pressure drop for residential duct systems is 0.18 inches, and for cooling coils is 0.27 inches, resulting in a static pressure downstream from the filter of 0.45 inches. (The same field studies found that median pressure drops are 0.15 inches for both return ducts and filters, resulting in a total external static pressure of 0.75 inches (excluding the effects of the air handler/furnace internal system).

To simulate ductwork, we adjusted the pressure balance fan until the air flow and pressure drop fell on a typical flow versus pressure curve. The curve was developed by assuming that 1,400 CFM would produce 0.45 inches of static pressure at the discharge of the air handling unit. Thus, at different measured air flows, the virtual duct and coil pressure drop followed this curve, just as it would for a normal installed system.

With the ECM motor installed, we evaluated filters at nominal air flows of 750, 1,000, 1,250, and 1,500 CFM. These air flows were set using a control that generates a pulse width modulation (PWM) signal that is proportional to the air flow the motor is programmed to deliver. The PSC motor was tested at each of its three tap settings. Second-order polynomial curve fits of each data set were used to interpolate filter pressure drop and power at the standard velocity of 492 fpm (air flow rate of 1,367 CFM).

Questions and Answers

We wanted to find out what penalties homeowners pay for switching to more efficient HVAC filters. Are the decreased air flow due to high-MERV filters and the added load on fans—meaning more energy used—worth the increase in indoor air quality that better filters bring? Here is what we found, in the form of questions and answers.

Airflow Versus MERV Rating

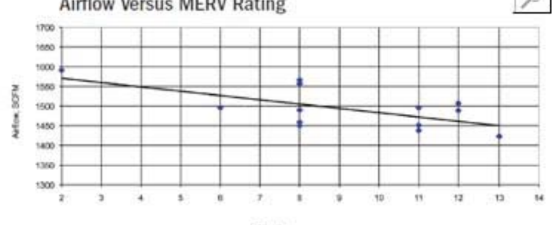
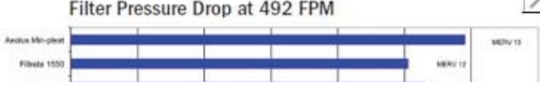


Figure 2. The graph shows a trend toward decreasing air flow when the blower was powered with a PSC motor. Note the wide variation in air flow for the different MERV 8 filters. Very little air flow variation was seen when the PSC motor was replaced with an ECM motor.

Filter Pressure Drop at 492 FPM



Do high-MERV filters reduce air flow?

Though there are considerable differences in how different filters affect air flow, there is a definite trend toward lower air flow with higher-MERV filters for systems using PSC motors (see Figure 2). Over the range of filters tested, there was no such correlation between air flow and filter MERV rating for the ECM motor, which can maintain constant air flow over a large range of external static pressure.

Do some high-MERV filters have higher pressure drop than others? Is pressure drop lower for thicker pleated filters?

There was a significant variation in pressure drop, particularly among the five MERV 8 filters tested, and not as close a correlation between pressure drop and MERV rating as we had expected to find (see Figure 3). The WEB Lifetime, a washable electrostatic filter, was the best high-MERV performer. Its MERV 8 rating is surprising, given the relatively open appearance of the media compared to the replaceable filters.

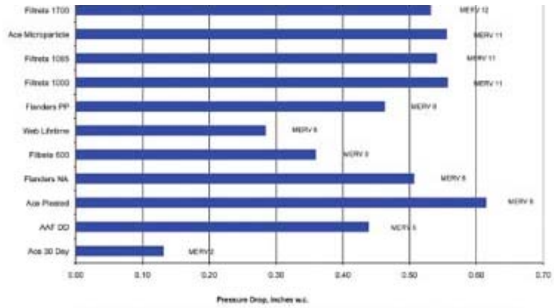


Figure 3. The MERV rating is not a direct indicator of filter pressure drop. The thicker (2-inch and 4-inch) filters did not provide as much advantage as expected, at least not in the clean condition in which all the filters were tested.

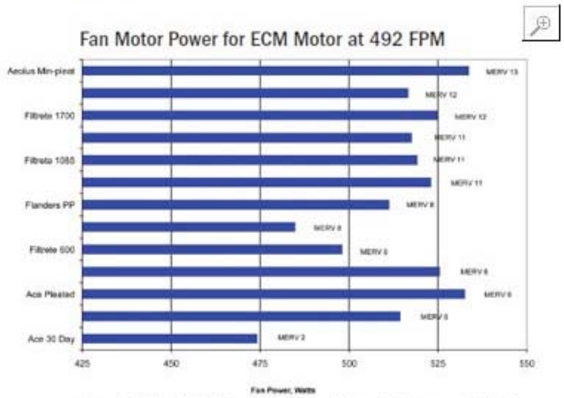


Figure 4. When the ECM motor was used to maintain a constant 492 feet per minute velocity we saw a considerable variation in fan energy. This graph appears similar to Figure 3 because the blower must work harder to push air against a higher static pressure.

We also expected to see a lower pressure drop for the deeper 2-inch and 4-inch filters, because of the increased surface area and the reduced velocity of air passing through the media. Surprisingly, the 4-inch Filtrete 1550 (MERV 12) was only marginally better than the 1-inch Filtrete 1700 (also MERV 12) and the two other MERV 11 filters of the same brand (1000 and 1085). Of the two MERV 8 Flanders filters tested, the 2-inch Pre-pleat performed marginally better than the 1-inch NaturalAire. The other 2-inch entry, the MERV 13 Aeolus, had the second highest pressure drop of all filters tested. Because of their greater surface area, the thicker pleated filters may incur less pressure drop as they become loaded with particles, and may require less frequent replacement, but our testing was limited to clean filters only.

Most of the high-MERV filters tested substantially exceeded the median pressure drop of 0.18 inch obtained from the California field studies mentioned above. (According to Rick Chitwood, an energy consultant who has worked with the California Energy Commission, filters in these field studies were mostly inexpensive builder-installed fiberglass models.)

Do high-MERV filters increase fan energy use?

If the higher-MERV filter reduces air flow, as is the case with systems using PSC motors, it has only a very slight impact on fan energy use. But if ECM motors are used, the impact can be significant (see Figure 4). Figure 5 illustrates the difference in energy use of PSC and ECM motors relative to filter pressure drop. Although higher MERV filters will increase the fan energy use of ECM-equipped systems, ECM motor energy use is far less than that of PSC motors.

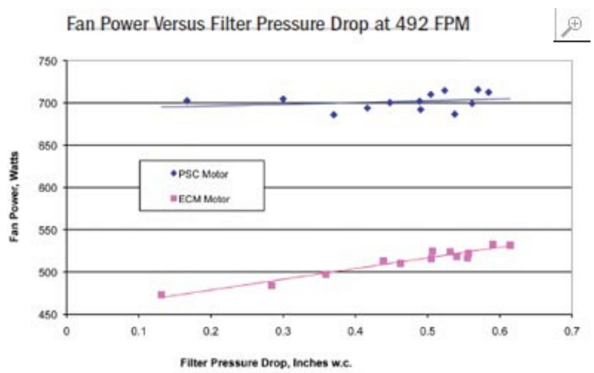


Figure 5. The power requirement of PSC blower motors varies little with filter static pressure, but airflow is compromised. ECM blower motors keep the airflow reasonably constant as the static pressure increases, but power is compromised. However, due to its superior efficiency, the ECM blower motor uses far less power, even at the highest static pressures.

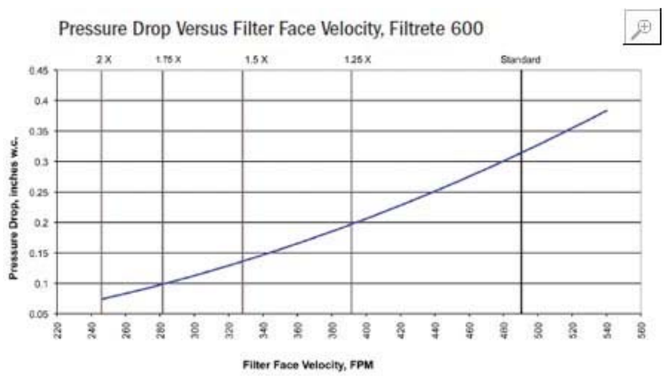


Figure 6. This curve illustrates that filter pressure drop can be decreased by decreasing the air velocity, and this can be accomplished by installing a larger filter. For example, doubling the face area of a standard size filter would reduce the pressure drop four-fold from about 0.32 inches to 0.08 inches.

Will the reduced air flow rates of high-MERV filters in PSC systems affect compressor energy use?

Air conditioner and heat pump rated performance is a function of air flow over the indoor coil. Lower air flows can decrease capacity and consequently the energy efficiency ratio or heating seasonal performance factor of the system. We looked at representative manufacturers' performance curves and found that, over the less than 200 CFM reduction in air flow observed between the MERV 2 and MERV 13 filters (see Figure 2), the effect of the filters on compressor power is very slight. However, the pressure drop of filters can more than triple when they are fully loaded with dust particles, so loaded filters probably will affect system performance. The deeper pleated filters allow the dirt to be spread over a larger surface area, reducing pressure drop and making it possible to change the filter less often without significantly affecting system performance.

What can be done to mitigate the added pressure drop of high-MERV filters?

Friction contributed by coils, ductwork, and filters is additive, so reducing the friction of one component will offset the added friction of another. When completing ACCA Manual D duct sizing, a realistic filter pressure drop should be used. If using a MERV 8 or higher filter, a pressure drop value of at least 0.5 inches should be entered for the filter. In one Manual D example we ran, we found that increasing the