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Description:	Staff Analysis of Air Filter Pressure Drop and Air Filter Sizing (April 2018) *** THIS FILE SUPERCEDES TN# 223245-14*** and corrects an issue where tracked edits to a paragraph were shown.
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Staff Supplement to CASE Report #2019-RES-IAQ-F

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Subject: Staff Analysis of Air Filter Pressure Drop and Air Filter Sizing (April 2018)

Staff acknowledges the valuable support provided by the Codes and Standards Enhancement (CASE) team and the staff of the Applied Technology Services (ATS) facilities in San Ramon, CA who produced the air filter testing results described in this supplement report.

DESCRIPTION OF PROPOSED REGULATORY CHANGES

Staff has reviewed the CASE Team Comments on HVAC System Filter Requirements TN #: 222628 (Comment Letter), and the newly completed Appendix E titled "HVAC System Filter Testing for Pressure Loss" which was added to the CASE report for Residential Indoor Air Quality, #2019-RES-IAQ-F dated February 2018 (Appendix E) which proposes the following changes to the 45-day language:

1. CASE team recommendation: The first CASE team recommendation is to eliminate all mandatory requirements related to filter pressure drop and size, and instead rely on the verification of fan efficacy to ensure that all system components, not just filters, are properly designed and installed.

    - Staff does not recommend the change proposed by the CASE team to eliminate requirements related to filter pressure drop and size. Staff finds the conclusions stated in the Comment Letter and Appendix E to be incorrect.

      A deeper filter grill provides benefits to airflow and filter selection beyond facilitating the use of low-static-pressure MERV 13 filters. Specifically, while staff finds that 1" depth MERV 13 filters are available with pressure drop characteristics comparable to or lower than some MERV 6 filters, staff also finds that a 2" filter depth is valuable in allowing filters to have airflow characteristics that are superior to a 1" filter, and may facilitate use of even higher MERV filters (such as the MERV 16 recommended by the California Air Resources Board in their comments) if chosen as replacement filters by system owners. A 2" depth filter grille may also allow the return grille face area to be reduced by up to 50% as compared to that required for a 1" depth filter (of the same media type and pleat density) while maintaining the same airflow rate and pressure drop. Further reductions of the face area are possible when filter depths greater than 2" are used.

Staff therefore finds that a 2" (or greater) depth filter addresses stakeholder concerns that low pressure drop filters may take up too much area on the ceilings or walls of homes. The pressure and airflow characteristics due to increased filter depth are verifiable by design methodology available in literature[1].

The proposed alternative to the 2" depth requirement allows use of 1" depth filters with pressure drop of 0.1 inch w.c. or less and requires filter sizing of the face area, based on a maximum 150 ft/min face velocity. This alternative provides direction for proper filter grille sizing and filter selection to ensure the filter will not negatively impact the system performance. Research conducted to support development of the 2013 Building Energy Efficiency Standards has recommended similar filter grille face area sizing criteria and recommends use of a maximum filter pressure drop of 0.05 inch w.c[2] when designing systems.

By including both options, the proposed Standards allows builders to address filter pressure drop either by ensuring filter grilles will have adequate face area or by ensuring filter grilles will have increased depth, as appropriate for a given building project. Staff also confirmed that soffit-mounted air-handling unit models used in multifamily dwellings are available that provide 1" depth filter grilles that have face areas large enough to meet the 150 ft/min face velocity sizing criterion mentioned above[3], ensuring both options are feasible and available to builders.

Staff arranged for additional laboratory testing of air filters (described below in this supplement document) and confirmed that 1" MERV 13 filters meeting the 150 ft/min and 0.1 inch w.c. performance specification are readily available in California from several filter manufacturers, and staff anticipates additional manufacturers are likely to be recognized as meeting this performance when the Title 20 air filter labeling requirement becomes effective which will require all manufacturers who sell air filters in California to certify the MERV rating and pressure drop performance for their models submitted to the Energy Commission's Appliance Efficiency database. The Title 20 air filter labeling requirement is expected to become effective in 2020. The required filter label format is shown below:

MERV	(µm)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	[val 1]	[val 2]	[val 3]	[val 4]	[val 5]*	*Max. Rated Airflow
[value]	PSE (%)	[value]	[value]	[value]	Initial Resistance (IWC)	[value]	[value]	[value]	[value]	[value]	

[1] Saleh, Ahmed & Tafreshi, Hooman. (2014). A simple semi-numerical model for designing pleated air filters under dust loading. Separation and Purification Technology. 137. 94–108. 10.1016/j.seppur.2014.09.029. Available at: http://www.people.vcu.edu/~htafreshi/Reprints/SPT2014.pdf

[2] Proctor, John, Rick Chitwood, Bruce A. Wilcox. (Proctor Engineering Group, Ltd., Chitwood Energy Management, Inc. Bruce A. Wilcox). 2011. Efficiency Characteristics and Opportunities of New California Homes. California Energy Commission. http://www.energy.ca.gov/2012publications/CEC-500-2012-062/CEC-500-2012-062.pdf.

[3] Product literature for First Company CDXX-HW(-C) Series Horizontal Recessed Ceiling Fan Coil. The "IAQ Panel" option allows for face areas sized using 400 cfm/ton design airflow rate and 150 ft/min face velocity. https://www.firstco.com/documents/ProductDocuments/cdxx-hw517.pdf

- Figure 3 in the Comment Letter (Figure 11 in Appendix E) is incorrect with regard to the data it represents for the curve identified as "3M Filtrete 1900 M13-1 (from label)", shown as having a pressure drop curve that is almost the same as the lowest pressure drop 2" depth filter tested, displayed as a dashed green line. Staff acquired a 1" depth Filtrete 1900 M13-1 and found the label data is very different than what is plotted as the dashed green line. As the line labeled "3M Filtrete 1900 M13-1 (from label)" does not seem to represent the content of this product's label, staff finds that it should be ignored.
- Separately, staff confirmed the data represented as "3M Filtrete Basic M13-1" in Figure 3 in the Comment Letter (Figure 11in Appendix E) is mislabeled, and should have been labeled "3M Filtrete 1900 M13-1".

2. CASE team recommendation: In Section 150.0(m)12Bii, prescribe a design maximum filter pressure drop of 0.15 inch w.c. and a maximum velocity of 225 feet per minute (fpm) instead of 150 fpm.
   - This recommendation is contradictory to the first recommendation made by the CASE team (above).
   - The CASE team asserts that properly designed space conditioning systems should use 0.7 inch w.c. as the design static pressure. Staff finds that 0.5 inch w.c. is the typical rated cooling speed static pressure for residential furnaces. Laboratory testing of gas furnaces was performed by the CASE team and the results were reported by Proctor Engineering as support for the 0.45 w/cfm fan efficacy proposal for the 2019 Building Energy Efficiency Standards[4]. The performance reported for the 10 gas furnaces tested indicated that if system static pressure was increased from 0.5 to 0.7 inch w.c., the values for fan efficacy for many of the furnaces increased by approx. 0.05 w/cfm, and two of the furnaces increased by approx. 0.1 w/cfm. The energy cost savings from operating at lower static pressure may cover the reoccurring costs of replacement air filters for the life of the system. Staff would therefore not recommend designing space conditioning systems to operate at increased static pressure in order to reduce the face area or depth of air filters.
   - The CASE team assertion that ACCA Manual D recommends 500 ft/min face velocity for air filters is incorrect. Table A1-1 in ACCA Manual D specifies 300 ft/min maximum face velocity for filter grilles[5]. 300 ft/min is consistent with the common choice of 295 ft/min face velocity for residential air filter testing according to the ASHRAE 52.2 method of test for MERV which specifies selection of a test airflow rate near the upper limit of the tested air filter's application range.

[4] Proctor Engineering Group, 2017. Residential Furnace Blower Performance Testing. https://efiling.energy.ca.gov/getdocument.aspx?tn=222296
[5] ANSI/ACCA Manual D, third edition, 2009.

3. CASE team recommendation: Reference the CALGreen mandatory measure for ACCA Manual D sizing in Part 6 section 150(m)12 to reinforce the requirement.

    - Staff does not find that it is necessary to reference the CALGreen mandatory measure for ACCA Manual D sizing.

STAFF ANALYSIS

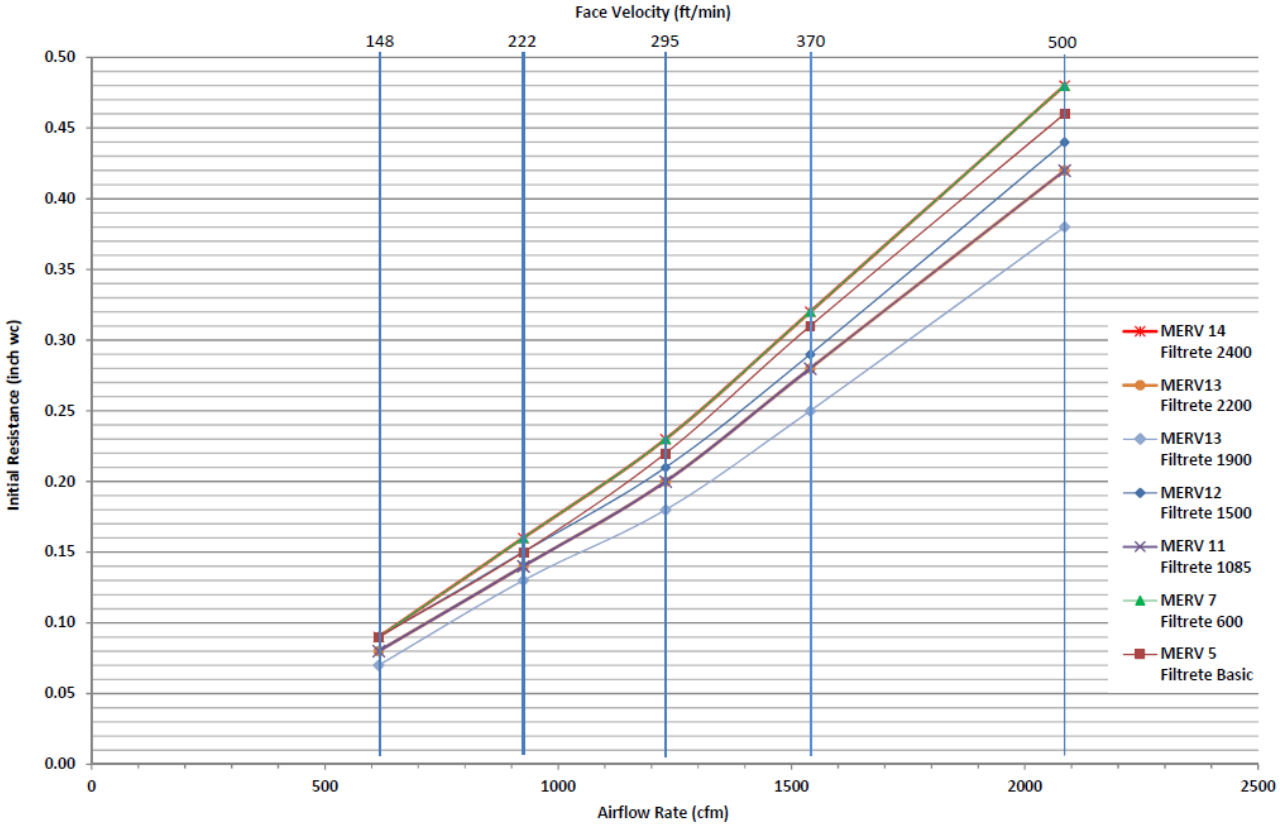
Air filter pressure drop can be reduced by increasing the amount of air filter media surface area available to the system's airflow. Increased media surface area can be accomplished by adjusting one, two, or all three of the following factors:

1. Number of pleats of media per inch inside the air filter frame. The number of pleats per inch inside the filter frame is determined by the manufacturer's filter model design, and is held constant for all filter sizes of the same manufacturer's model (e.g. all 3M Filtrete 1900 filters will have the same media type, the same MERV rating, and the same number of pleats of media per inch inside the filter frame regardless of whether the nominal filter size is 20" X 30" or 24" X 24", etc.). Generally, as the number of pleats per inch is increased, the pressure drop is reduced if all other factors remain constant. The pressure drop characteristics of air filters varies widely between air filter manufacturers and air filter models, largely due to the number of pleats per inch in the manufacturer's air filter model design. The manufacturer's filter model pressure drop characteristics will be listed on the manufacturer's filter product label.
2. Face area of the air filter and filter grille. Face area is the nominal area of the air filter face, or the area of the filter grille opening in the ceiling or wall. The face area is determined by multiplying the length times width of the filter face (or filter grille opening). The face area for a filter corresponds to the face area of the filter grille in which the filter is installed. (e.g. a 20" X 30" filter has a face area of 600 in^2 and would be installed in a 20" X 30" filter grille). Generally, as the values for the system air filter face area increase, the pressure drop is reduced if all other factors remain constant. Total system air filter face area can be increased by using one larger area filter, or by using additional/multiple return grilles/filters, summing the face areas. The filter face area is specified by the system designer or installer.
3. Depth of the filter and filter grille. Air filter depth is the nominal filter dimension parallel to the direction of the system airflow. Nominal filter depths readily available for purchase include one, two, four, and six inches. Generally, as the values for the system air filter depth increase, the pressure drop is reduced if all other factors remain constant (e.g. increasing filter depth from one inch to two inch nominally doubles the filter media surface area without increasing the filter face area). The filter depth is specified by the system designer or installer.

Staff acquired pressure drop performance data from product labels available on 3M brand air filters offered for sale at local home improvement supply stores. The labels on these 3M filters conform to the proposed Title 20 air filter label format. Labeled pressure drop performance data for 1" MERV 5, 7, 11, 12, 13 (two MERV 13 models), and 14 are plotted in Figure 1 below. The

data indicate there is no significant correlation between MERV rating and pressure drop for these models. Note the highest pressure drop performance in this dataset is shared by MERV 7/MERV 14, the second highest pressure drop is for MERV 5, and the lowest pressure drops correspond to the MERV 13 models. Thus, the often-heard concern that MERV 13 filters would cause higher pressure drop in space conditioning systems does not apply to this 3M filter model lineup. Staff's understanding is that 3M air filter products represent a major share of California air filter sales.

Figure 1. Pressure Drop for 20" X 30" X 1" Depth Air Filters – 3M Label Data



Staff arranged to have laboratory testing of MERV-rated air filters performed at PG&E's Applied Technology Services facilities in San Ramon, CA in January of 2018. The pressure drop measurements were performed in accordance with the procedures specified by ASHRAE Standard 52.2[6].

The purpose of the laboratory testing was to:

- Confirm the pressure drop information reported on selected 3M air filter labels.
- Compare the pressure drop characteristics of MERV rated filters in the range of MERV 6 through MERV 13 from several manufacturers.
- Gain a better understanding of the pressure drop performance of currently available 2" depth MERV 13 filters and compare to available 1" depth MERV 13 filters.

Where possible staff specified testing of a 1" depth MERV 13, MERV 11, and MERV 7(or 6) from each manufacturer, and a 2" depth filter from each manufacturer. Ultimately, procurement of all of the filters in the list was not possible. A total of 15 filters were tested as noted in Table 1 below.

Table 1. Filter models proposed for testing, and accounting of filter models tested.

Status	ΔP @ 295 fpm (IWC)	SIZE	MERV RATING	BRAND	MODEL DESCRIPTION
Tested	0.18	24×24×1	13	3M	Filtrete HVAC Basic (3MHBR13.012424)
Tested	0.37	24×24×1	13	Nordic Pure	Pleated Air Filters MERV 13
		24×24×1	13	US Home Filter	MERV 13 Pleated Air Filter (SC80-24×24×1-6)
Tested	0.22	24×24×1	13	FilterBuy	AFB Platinum MERV 13 24×24×1 (AFB24×24×1M13)
Tested	0.30	24×24×1	13	Flanders	Pre Pleat M13 (90013.012424)
Tested	0.23	24×24×1	11	3M	Filtrete 1085 MPR Micro Allergen Extra
		24×24×1	11	Nordic Pure	Tru Mini Pleat AC Furnace Air Filters MERV 11
		24×24×1	11	Flanders	Extended Surface Pleated Filter PrePleat 62RM11 - High Capacity
Tested	0.26	24×24×1	11	FilterBuy	AFB Gold MERV 11 24×24×1 (AFB24×24×1M11)
Tested	0.22	24×24×1	6	FilterBuy	AFB Bronze MERV 6 24×24×1 (AFB24×24×1M6)
Tested	0.23	24×24×1	7	3M	Filtrete 600 MPR Dust & Pollen
Tested	0.20	24×24×1	7	Nordic Pure	Pleated Air Filters MERV 7
		24×24×1	7	Flanders	Extended Surface Pleated Filter Economy Pleats MERV7
		24×24×2	13	3M	Filtrete HVAC Basic MERV 13
		24×24×2	13	US Home Filter	MERV 13 Pleated Air Filter (SC80-24×24×2)
Tested	0.25	24×24×2	13	Nordic Pure	MERV 13 Pleated Air Filters
Tested	0.13	24×24×2	13	FilterBuy	AFB Platinum MERV 13 24×24×2 (AFB24×24×2M13)
Tested	0.17	24×24×2	13	Flanders	Pre Pleat M13 (90013.022424)
	Alternates:				
		24×24×1	11	Honeywell	Superior Allergen Pleated FPR 9 Air Filter (90901.012030)
Tested	0.15	**25×25×1**	6	Flanders	Flanders Air Filter MERV 6 (81255-012525)
		Extras:			
Tested	0.20	24×24×1	5	3M	Filtrete 300 HVAC Basic Dust
Tested	0.23	12×24×2	11	Flanders	Flanders Air Filter 62R STD MERV 11 (85655-021224)

[6] ANSI/ASHRAE Standard 52.2-2017. Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size.

The results of the air filter tests conducted at the ATS laboratory are shown in Figure 2, Figure 3, and Figure 4 below.

Figure 2 compares the 3M manufacturer's filter pressure drop data measured in the ATS laboratory with the pressure drop performance data from their product labels also plotted to facilitate comparisons. The manufacturer's label data is plotted with either a dashed or dotted line along with the performance data measured in the laboratory which is shown as a solid line. The tested pressure drop corresponded closely to the manufacturer's label data generally, and where the measured data diverges slightly from the published label data, the actual measured pressure drop is less than the published performance values, thus the actual performance was equal or better than published pressure drop and airflow specifications.

Figure 2. 3M Manufacturer Pressure Drop Label Data Compared to Laboratory Measurements

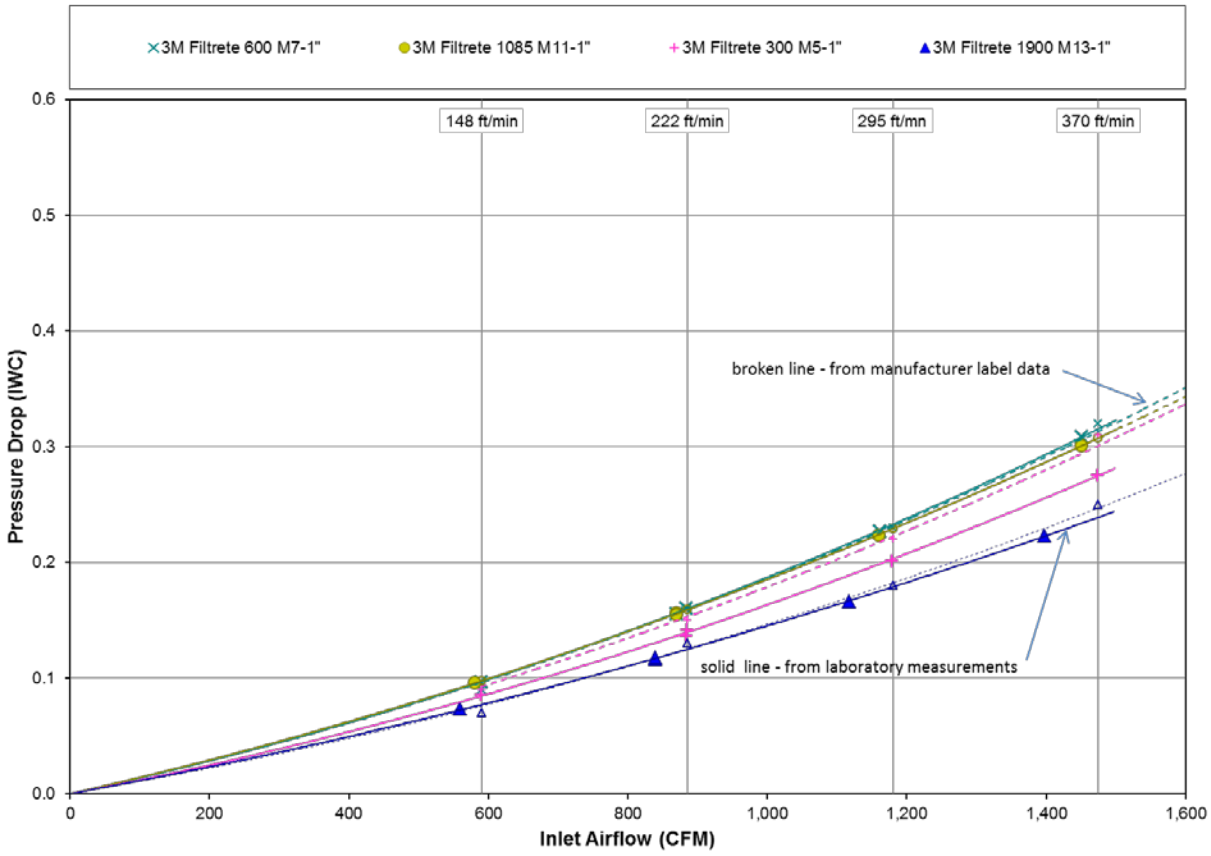


Figure 3 displays measured pressure drop for all fifteen filters tested in the ATS laboratory. Filter particle removal efficiencies in the test set included filters rated at MERV 6, 7, 11, and 13. Four of the filters were 2” depth, and the other 11 filters were 1” depth. The data indicates that there is no significant useful correlation between MERV rating and pressure drop for these models, consistent with the consideration of filter labels in Figure 1.

Figure 3. Pressure Drop Measurements – MERV 6, 7, 11, 13 Filters with 24” x 24” Face Area

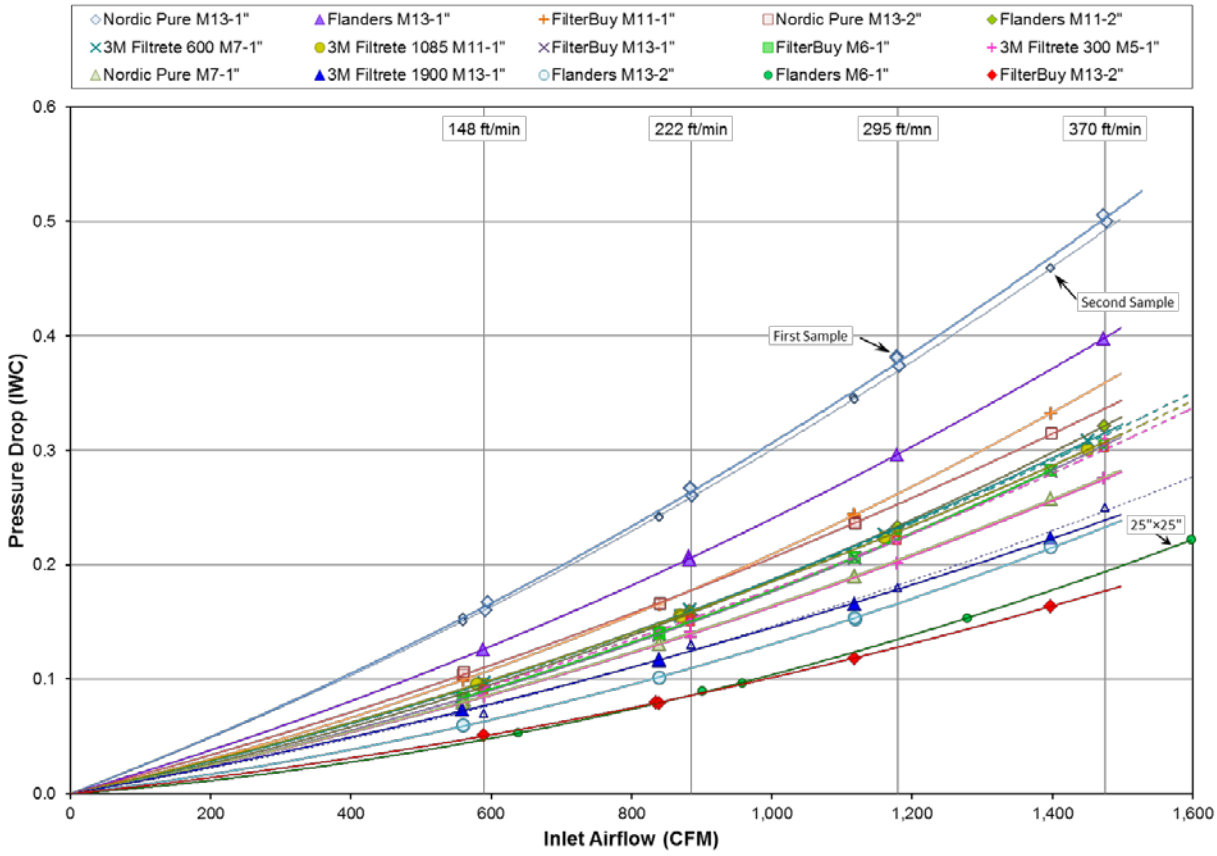
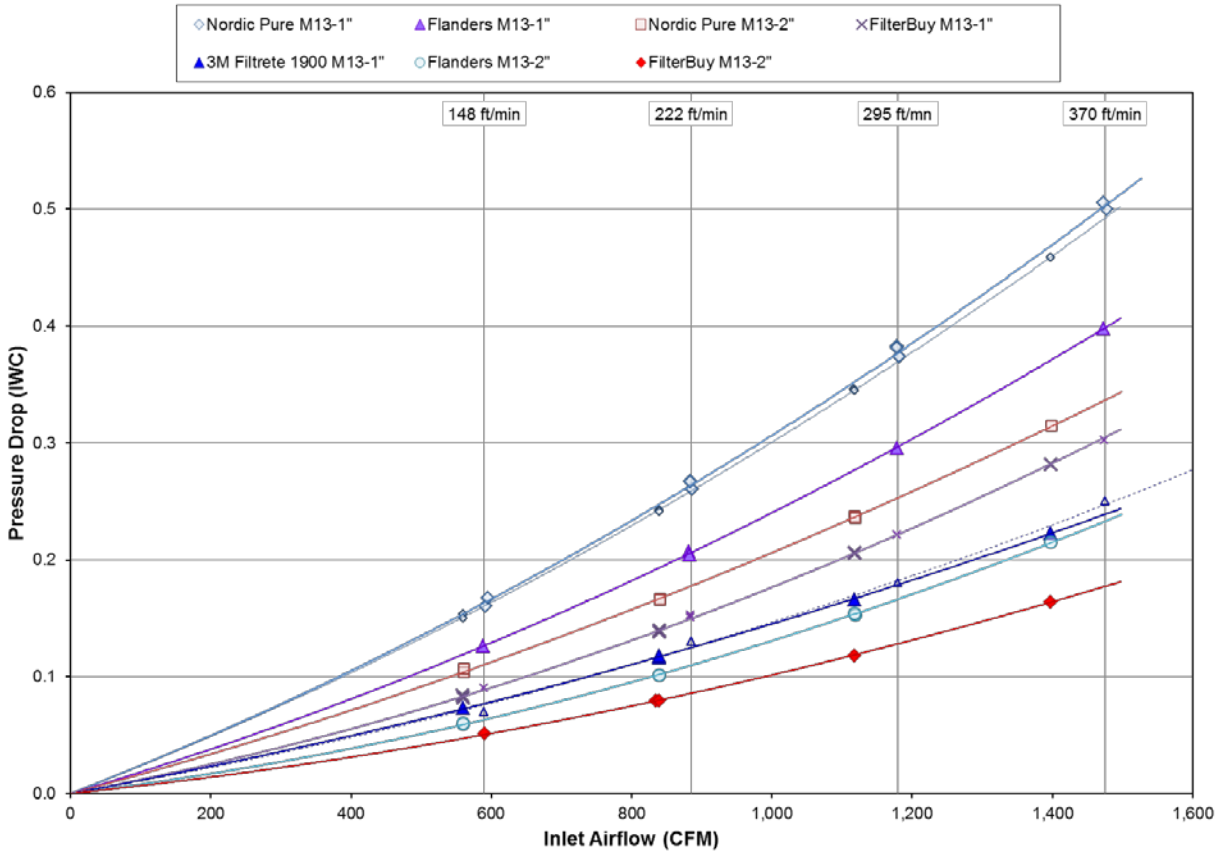


Figure 4 shows the subset of the tested filters that have a MERV 13 rating. Three of the filters are 2” depth, and the other four filters are 1” depth. Four of the filters have pressure drop less than 0.1 inch w.c. at 150 ft/min. 2” depth filters in this data set generally have lower pressure drop as compared to 1” depth filters. The filter with the highest pressure drop had measured airflow less than 400 cfm at 0.1 inch w.c. static pressure. The filter with the lowest pressure drop had measured airflow of approx. 1,000 cfm at the same 0.1 inch w.c. static pressure. This emphasizes the importance of air filter labeling since all of the 24” X 24” filters in this dataset could be installed in the same 24” X 24” filter grille in a system, but only one of these filters could meet a system requirement for approx. 1,000 cfm at 0.1 inch w.c. pressure drop.

Figure 4. Pressure Drop Measurements – MERV 13 filters with 24” x 24” Face Area



STAFF CONCLUSION

The results of the ATS laboratory testing of 15 air filters determined that:

- The 3M filter label pressure drop information corresponded very closely to the actual clean filter performance (see Figure 2).

- The pressure drop characteristics of these air filters varied widely, and there is no significant or useful correlation between MERV rating and pressure drop for the observed filter models, which ranged from MERV 6 to MERV 13.

- Three 2" depth MERV 13 filters were tested, and two of those had the lowest pressure drop performance over all others in the dataset, thus indicating that 2" depth filters are readily available that provide improved pressure drop performance compared to 1" depth filters. The best performing 2" depth filter provided approximately 30% greater airflow at 0.1 inch w.c. as compared to the best performing 1" depth MERV 13 filter at 0.1 inch w.c. in this dataset.

- MERV 13 rated models with clean filter pressure drop performance below 0.1 inch w.c. at 150 ft/min are readily available from multiple manufacturers.

Staff has analyzed the submitted CASE-authored material and reached the following conclusions for the measures included in the Express Terms:

- Staff finds that the new information does not necessitate a change to the proposed measures. The energy savings presented in the docketed CASE Report appears to have been appropriately modeled, and staff finds it to be credible. Staff finds the additional data submitted to the rulemaking record to be supportive of the proposed measures, for the reasons stated above.

- Staff finds that the alternatives proposed by the CASE team, while reasonable, are not equally effective in achieving the purposes of the proposed regulations.