Camfil Farr

Technical Services Bulletin

ASHRAE Testing for HVAC Air Filtration
A Review of Standards 52.1-1992 & 52.2-1999

The *American Society of Heating, Refrigeration, and Air Conditioning Engineers* (ASHRAE) publishes two different Standards that allow users to evaluate air filters to be applied in an HVAC system.

Standard 52.1-1992 provides three important evaluation criteria: dust spot efficiency, arrestance, and dust holding capacity. *Standard 52.2-1999* provides a filter's initial efficiency as a function of particle size, as well as a numeric value that allows a user or engineer to specify a product minimum efficiency reporting value (MERV). Both Standards also provide a filter's initial resistance to airflow, an important denominator no matter which Standard is preferred.

Evolution and Procedures of ASHRAE 52.1-1992

This Standard addresses a filter's ability to protect machinery and coils and the filter's ability to remove staining size[1] particles.

In the era of the metal mesh filter, testing filter performance was based upon a gravimetric differentiation measurement of a synthetic test dust with a broad particle size distribution. Even though such a filter may have been 50% efficient on synthetic test dust, soiling in control areas continued as demonstrated in the following example:

- Suppose a filter is efficient at removing 50% of the synthetic test dust by weight. Assume further that the filter is 100% effective removing particles 5 microns in size, but 0% effective removing 1-micron size particles
- A 5-micron size particle has a relative weight of 125.
- 125 1-micron size particles have a relative weight of 125.

If 126 particles (one 5-micron & 125 1-micron particles) are fed to this filter, the one 5-micron size particle is captured and the 125 1-micron size particles pass through. This filter may be deemed efficient at removing 50% contaminant by weight. However, the efficiency of this filter by particle count is 1/126 of 0.088% or less than 1%.

Such a hypothetical filter would be designated by this method as a 50% efficiency filter when capturing dirt as a function of contaminant weight. All of the smaller airborne particles (1 micron) would pass through the filter. It is this fine airborne particulate which accounts for the soiling of surroundings. In the typical air sample more than 98% of all particles are under 1-micron in size.

The ability to determine the efficiency of removing these fine airborne contaminants became even more crucial as technology advanced. As HVAC systems became more efficient, coil fins on these systems moved closer together. Air conditioning manufacturers have noted that their coils may have an arrestance value of 40-80%. In some cases, the coils could have a higher arrestance than the filter that is supposed to protect them. Additionally, fine airborne matter can cause increased coil fouling, decreased thermal transfer, and increased energy usage. The *Dill Dust Spot Test* and the *National Bureau of Standards* (NBS) addressed the methods for testing these fine airborne particulates. Both tests rated the filter efficiencies by different methods:

- Efficiency of removing only airborne atmospheric particles.
- Efficiency of removing synthetic test dust consisting of Cottrell Precipitate and lint.

[1] Although not directly related to particle size, the filter's listed dust spot efficiency under this Standard seems to correspond to the filter's particle size versus efficiency value in the range of 0.5 to 1.0 micron size particles.

A filter could be tested by either of these methods, yielding different efficiency rating results. A filter could be 18% efficient at removing atmospheric air contaminants or 90% efficient in removing the synthetic Cottrell Precipitate dust. Engineers and users had trouble when trying to evaluate different products.

ASHRAE 52.1-1992

In response to user demands, ASHRAE evolved a Standard to better address these concerns. Originally titled *ASHRAE Standard 52-76*, the purpose and scope of the present *ASHRAE 52.1-1992 Standard* is as follows:

1. To establish a uniform comparative testing procedure meaningful to users and manufacturers for evaluating performance of air cleaning devices used in general ventilation for removing particulate matter.
2. To establish specifications for the test equipment used in conducting such tests.
3. To establish a uniform method for reporting the results obtained from the specified procedure.

ASHRA*E 52.1-1992* test provides three specific measurements that outline filter performance. They are:

1. *Atmospheric dust spot efficiency*—expressed as a percentile.
2. *Arrestance*—expressed as a percentile.
3. *Dust holding capacity*—expressed in grams.

The dust spot efficiency and arrestance are averaged over a dust loading procedure. The dust loading procedure is a time accelerant to the filter testing in an attempt to simulate a filter's life in an HVAC system. Because efficiency, arrestance, and dust holding capacity are sometimes confused, the following definitions detail each of the critical values presented by ASHRAE 52.1-1992.

Atmospheric dust spot efficiency is a measure of a filter's ability to remove atmospheric dust from test air. The method of determining this quantity is based upon light transmission through previously evaluated target paper. This is accomplished by adjusting the air ratio sampled through targets upstream and downstream of the test filter so that equal changes in light transmission occur. The ratio is converted to an efficiency that is expressed as a percent. A high dust spot efficiency results in a high resistance to staining.

Arrestance is a gravimetric measure of the ability of a tested filter to remove ASHRAE synthetic dust from the test air. The number is also expressed as a percent.

Dust holding capacity is determined by the product of the quantity of synthetic test dust fed to the test filter, expressed in grams, and its average arrestance.

52.1-1992 ASHRAE Test Procedure

ATMOSPHERIC DUST SPOT EFFICIENCY

1. Weigh the test filter.
2. Install the test filter in the test duct and obtain clean air filter resistance or initial pressure drop.
3. Dust spot efficiency is a soiling index that utilizes the opacity of a target paper as a means for measurement. Zero the opacity meter using a standard light blockage.
4. Evaluate target papers by measuring light transmission through the papers. Typical results are 80-85% light transmission or a 15-20% light blockage.
5. Match two target samples with similar light transmission readings (i.e., 81% versus 82%).
6. Install target papers in the target paper holders. One target paper is installed upstream of the test filter and one target paper is installed downstream of the test filter. There are certain criteria that must be satisfied during this test:

    - The sampling of atmospheric air must be long enough that the opacity of the target has significant change. Since the downstream target will receive the cleanest air, the minimum sampling time is longest on clear days and with higher efficiency filters. The minimum opacity change by *Standard 52.1-1992* is 10%.

    - The sampling time cannot be so extensive that the opacity change exceeds 40%.

- Anticipated filter efficiency must be considered to properly schedule opacity readings of the target papers. Final opacity readings of the target papers must be within 20% of each other.

Having established a sampling schedule representative of the efficiency, test airflow is established and dust spot sampling begins. Testing is continued until a minimum of 10% change in opacity is obtained. Efficiency of the dust spot test is then determined by the following equation:

E = 100 1-Q1/Q2 X O1/O2, where:

Q1 = Total air drawn through upstream target

Q2 = Total air drawn through downstream target

O1 = Opacity of dust spot on upstream target

O2 = Opacity of dust spot on downstream target

The initial dust spot test is now completed. Dust spot tests are repeated again after approximately 25% of dust loading, 50%, 75%, and at final resistance.

ARRESTANCE

This test is also performed as part of the dust loading procedure in which approximately four equal dust loading increments are used.

ASHRAE synthetic dust consists of the following:

- 72% Standardized fine test dust by weight (sometimes referred to as Arizona Road Dust);
- 23% Molocco Black by weight;
- 5% #7 Cotton Linters by weight, ground in a Wiley mill with a 4mm mesh screen.

1. Cap off or cover the dust spot samplers.
2. Weigh the high efficiency final filter (95% dust spot efficiency or above) and install it downstream of the test filter.
3. Estimate the total amount of dust feed required to bring the test filter to the final resistance as determined by the manufacturer's literature. Introduce one-quarter of this requirement to the dust feeder.
4. Select a time span on the dust feeder so the dust feed approximates 2 grams per 1000 cubic feet of air through the filter. During the feed, monitor the flow rate and adjust as necessary.(As dirt loads, filter resistance increases, so airflow decreases.)
5. Any feed dust that accumulates in the test duct must be gathered, weighed and compensated for.
6. At the end of the dust feed, turn off the flow, remove the final filter and re-weigh it. The final filter weight gain is the amount passed by the test filter. The difference between total dust fed and the amount captured by the final filter is the arrestance of the test filter expressed as a percentage.

52.1-1992 Notes:

The dust spot test is run alternately with the arrestance test. The dust spot tests readings will total five. The arrestance tests readings will total four.

If the results of the dust spot efficiency test are less than 20%, than the average filter efficiency shall be reported as "less than 20%" and the true efficiency need not be reported.

ASHRAE 52.1-1992 provides an excellent tool for evaluating filters of similar construction:

- Dust spot efficiency will give a value of the filter's ability to remove staining size particles.

- Arrestance may be used, especially with lower dust spot efficiency products, as a tool for comparing one product versus a similarly constructed product (normally fiberglass, metal mesh, and polyester filters).

- Dust holding capacity may provide an indicator of relative service life when comparing filters of similar construction.

Evolution and Procedures of ASHRAE 52.2-1999

In the modern world of specific contaminant concern, ASHRAE has recognized the need to provide a Standard that would allow the user to evaluate a filter based upon that filter's ability to remove such specific contaminant based upon that contaminants particle size.

Additionally, with concern about particles that are respirable[2], a Standard was required that addressed a filter's efficiency specific to this range.

More than 12 years in development, *Standard 52.2-1999* will most likely evolve to the Standard of choice when evaluating a filter based upon improving indoor air quality.

While previous Standards also provided values based upon the average performance of a filter, users have stated that the important value is how efficient a filter is when it is first installed in a system. *Standard 52.2-1999* addresses this concern and provides information that indicates how a filter performs at its lowest point of particle capture efficiency (usually initial efficiency).

An additional goal of the Standard committee was to give the engineering community a single number value by which to select an air filter. The value is prescribed in the Standard as a MERV, or minimum efficiency reporting value[3].

In the previous Standard, atmospheric air was used in the evaluation process. Since atmospheric conditions varied significantly from area to area, and season-to-season, it was possible that the same filter could exhibit significantly different results based upon different atmospheric conditions. In *Standard 52.2-1999*, the test air is drawn from the testing laboratory (a controlled environment), cleaned using a HEPA filter, and specific air quality conditions are defined (including items such as temperature and humidity).

The Standard provides a filter's initial efficiency in each of 12 different particle ranges.

Range	Lower Limit (microns)	Upper Limit (microns)
1	0.30	0.40
2	0.40	0.55
3	0.55	0.70
4	0.70	1.00
5	1.00	1.30
6	1.30	1.60
7	1.60	2.20
8	2.20	3.00
9	3.00	4.00
10	4.00	5.50
11	5.50	7.00
12	7.00	10.00

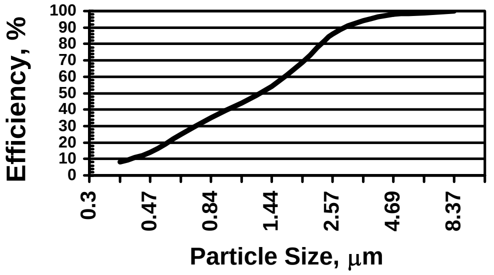
Now a user can choose a filter based upon the particular contaminant they want to remove. For example, if the particle of concern is pollen, which ranges from 5 to 15 microns in size with an average size of 7 microns, the user can select the filter based upon that particle size (select a filter with an 80% + efficiency in range 12). If the particle size of concern is mycobacterium tuberculosis (a bacteria with a length of 1 to 5 microns and an average diameter of 0.70 µ), the user would select a filter with an efficiency of 90% + in range 3.

Another important criterion in developing this Standard was the goal of providing a 'low point' of filter efficiency or, in most cases, initial filter efficiency. Most filters incorporating mechanical principles of particle capture become more efficient as they load with dirt. Rather than provide an average efficiency, the committee developed a methodology of reporting a lowest point efficiency value. In this manner, the user would know how efficient the filter is at its lowest point, which in most cases is as soon as it is installed in the system. Other test procedures provide an average efficiency, which may require extensive time to reach in actual operation.

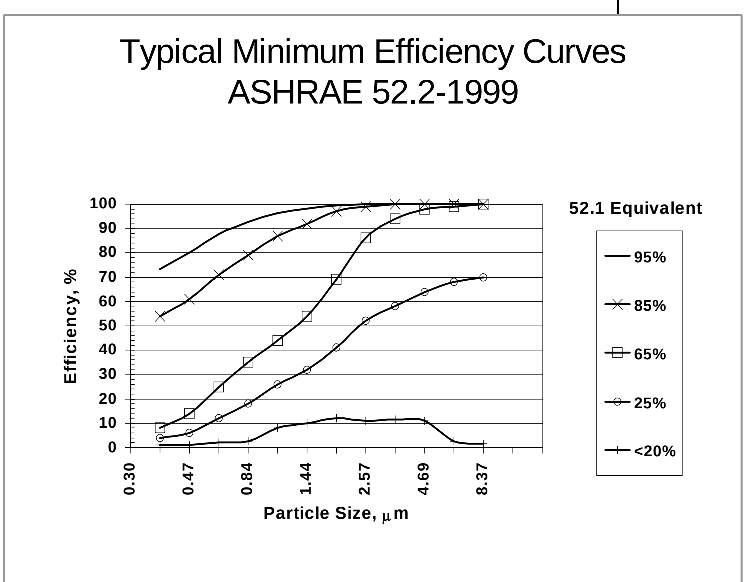
With each test report, the user receives a chart that shows the filter's initial particle size versus efficiency through all twelve ranges of particle

[2] ASHRAE defines respirable particles as lung damaging particles in the range of 0.2 to 5 micron in size. They later state that "Air filters…shall be selected for the particle size and loading encountered."
[3] ASHRAE has a guiding principle of not rating individual products. Ratings are left to outside agencies such as Underwriters Laboratories, Intertek Testing Services, etc.

capture. Following is a sample particle size versus efficiency minimum point graph.



From the above information, the geometric mean points of 0.35, 0.47, 0.62 and 0.84 are averaged to obtain a value of E_1, the points of 1.14, 1.44, 1.88 and 2.57 are averaged to obtain a value defined as E_2, and the points of 3.46, 4.69, 6.20 and 8.37 are averaged to obtain a value defined as E_3. The values E_1, E_2 and E_3 are then referenced on Table 12-1 to calculate a MERV (see page 6).The following chart, *Typical Minimum Efficiency Curves*, notes the performance of some filters commonly applied in HVAC environments and their corresponding *Standard 52.1-1992* equivalent efficiencies.



The above curves correspond to the following applications:

- 95% or MERV 14 — typically applied as the final filter in hospital HVAC systems.
- 85% or MERV 13 — typically applied in above average commercial applications.
- 65% or MERV 11 — applied in standard commercial buildings, such as office space.
- 25% or MERV 6 and 7 — pleated panel filters, applied in office environments, and as prefilters.
- <20% or MERV 1 through 5 — typical polyester or fiberglass throwaway panels and metal washable filters.

ASHRAE 52.2-1999 Test Procedure

The apparatus qualification is a significant portion of the Standard. Every care has been taken to assure that test results could be consistently repeated from one testing facility to another. Items incorporated into every test include: a background particle count check, a particle counter zero check, a particle counter accuracy check (using polystyrene latex spheres of specific sizes), pressure drop across the empty test section and other critical component operation. The actual procedure is as follows:

1. After placing the filter into the system, measure resistance versus airflow of the device (clean resistance).
2. Perform a particle size analysis of upstream challenge[4] versus downstream count across the filter.
3. Perform a filter-conditioning step that consists of loading the filter with 30 grams of ASHRAE test dust or loading test dust until the filter increases pressure drop 0.04" W.G.
4. Repeat particle size versus efficiency analysis.
5. Load the filter with ASHRAE Test Dust to 25% of the manufacturer's recommended final pressure drop.
6. Repeat particle size versus efficiency analysis.
7. Load the filter with ASHRAE Test

[4] The 52.2-1999 committee selected Potassium Chloride (KCl) as the aerosol of challenge. It is easy to generate, low in cost, commonly available, presents no health consequence for the testing personnel, polydispersed for even distribution of challenge through the required particle size ranges, and solid phase in consistency.

Dust to 50% of the manufacturer's recommended final pressure drop.

8. Repeat particle size versus efficiency analysis.
9. Load the filter with ASHRAE Test Dust to 75% of the manufacturer's recommended final pressure drop.
10. Repeat particle size versus efficiency analysis.
11. Load the filter with ASHRAE Test Dust to 100% of the manufacturer's recommended final pressure drop.
12. Repeat particle size versus efficiency analysis.
13. Examine the lowest point of efficiency at each range point and calculate E_1, E_2, and E_3 parameters based upon *Table 12-1, MERV Parameters.*

In order to determine a MERV value, a filter must meet a specific range of parameters. As an example, a filter that has an efficiency of ≥35% to <50% in the E_3 range of 3 to 10 microns would have a MERV of 6.A filter that has an efficiency of ≥75% to <85% in the E_1 range of 0.30 to 1.0 micron would have a MERV of 14.

Additionally, a filter must be operated to a minimum final pressure drop consistent with the reporting value and as published in Table 12-1. Table 12-1 also includes references to MERV 17 through MERV 20 filters. These filters are HEPA grade filters or above and are not referenced in this document (HVAC grade only)

The following table notes some of the MERV categories, the typical contaminant based upon particle size and the typical application.

ASHRAE 52.2-1999 Table 12-1, MERV Parameters

Standard 52.2 Minimum Efficiency Reporting Value	Composite Average Particle Size Efficiency, % in Size Range			Average Arrestance, % by Standard 52.1 Method	Minimum Final Resistance	
	Range 1 0.30 to 1.0	Range 2 1.0 to 3.0	Range 3 3.0 to 10.0		Pa	Inches of water column
1	N/A	N/A	$E_3 < 20$	$A_{avg} < 65$	75	0.3
2	N/A	N/A	$E_3 < 20$	$65 \le A_{avg} < 70$	75	0.3
3	N/A	N/A	$E_3 < 20$	$70 \le A_{avg} < 75$	75	0.3
4	N/A	N/A	$E_3 < 20$	$75 \le A_{avg}$	75	0.3
5	N/A	N/A	$20 \le E_3 < 35$	N/A	150	0.6
6	N/A	N/A	$35 \le E_3 < 50$	N/A	150	0.6
7	N/A	N/A	$50 \le E_3 < 70$	N/A	150	0.6
8	N/A	N/A	$70 \le E_3$	N/A	150	0.6
9	N/A	$E_2 < 50$	$85 \le E_3$	N/A	250	1.0
10	N/A	$50 \le E_2 < 65$	$85 \le E_3$	N/A	250	1.0
11	N/A	$65 \le E_2 < 80$	$85 \le E_3$	N/A	250	1.0
12	N/A	$80 \le E_2$	$90 \le E_3$	N/A	250	1.0
13	$E_1 < 75$	$90 \le E_2$	$90 \le E_3$	N/A	350	1.4
14	$75 \le E_1 < 85$	$90 \le E_2$	$90 \le E_3$	N/A	350	1.4
15	$85 \le E_1 < 95$	$90 \le E_2$	$90 \le E_3$	N/A	350	1.4
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	N/A	350	1.4

MERV	Typical Contaminant	Typical Application
13 thru 16	0.30 to 1.0 micron. All bacteria, most tobacco smoke, droplet nuclei, cooking oil, copier toner, face powder, paint pigment	Hospital inpatient care, general surgery, smoking lounges, superior commercial buildings
9 thru 12	1.0 to 3.0 microns. Legionella, lead dust, milled flour, coal dust, auto emissions, nebulizer drops, welding fumes	Superior residential, better commercial buildings, hospital laboratories
5 thru 8	3.0 to 10 microns. Mold, spores, hair spray, cement dust, snuff, powdered milk	Commercial buildings, better residential, industrial workplace, paint booth inlets
1 thru 4	Larger than 10.0 microns. Pollen, Spanish moss, dust mites, sanding dust, paint spray, dust, textile fibers, carpet fibers	Minimum filtration, residential, window air conditioners

Many contaminants emanating from a source have already been defined by particle size. A copier or printer room should use a filter with an efficiency of 65% when considered against particles 0.30 micron in size. In the terms of *ASHRAE 52.1-1992* that would be a 90-95% dust spot efficiency filter. In *ASHRAE Standard 52.2-1999* that would be a MERV 14 filter.

Other contaminants, by general particle size range, include: bacteria—ranges from 0.30 to 4 microns; droplet nuclei—averages 3 microns; many allergens, fungi and bioaerosols—at least 3 microns; visible dust—10 microns; and a human hair—at least 80 microns in diameter.

Some additional considerations when noting information given under this test include:

- *Standard 52.2-1999* offers no consideration to the service life of a filter. Dust holding capacity is not a parameter required as a reporting result. When comparing similar filters for estimated service life, *Standard 52.1-1992* is still the Standard of consideration.
- A tackified filter may perform well in the test and actually show a higher initial MERV performance than will be experienced in real-life conditions. Characteristics of tackifier migration and contaminant unloading must be considered separately by the user.
- Filters using the principle of electrostatic capture may show a high initial value inconsistent with service life due to the negation of the charge as the filter loads with dirt.

To sum up, the important items of *ASHRAE Standard 52.2-1999* are:

- The user may now select the filter based upon the size of the offending contaminant.
- The user may select the filter based upon its ability to remove respirable size contaminant.
- The user now has a single number (MERV) system by which to select and specify filters.

Is the air cleaner the only consideration? An important statement is made in the appendix of *Standard 52.2-1999* relating to a filter being a function of its holding device. If a filter does not fit securely and tightly into a system, air will follow the path of least resistance and move around the filter untreated. Appendix E 2.3 states

"Air cleaners are tested under ideal laboratory conditions where care is taken to prevent leakage of air around them. Totally lea- free hardware is unusual in HVAC equipment, so air cleaners rarely perform to the same degree of effectiveness under field conditions. Only extreme care in finding and sealing all the leak paths between the filter and the fan will ensure full performance of the air cleaner."

REMEMBER: THE SYSTEM MERV IS ALWAYS A FUNCTION OF THE FILTER AND THE AIR FILTER HOLDING DEVICE.

Camfil Farr ASHRAE Filter Selection Chart

This chart allows the user to select filters based upon a prescribed ASHRAE level of performance.
MERV numbers as listed below are minimum values.

Camfil Farr Product	ASHRAE 52.1-1992 Efficiency	ASHRAE 52.1-1992 Arrestance	ASHRAE 52.2-1999 Minimum MERV
CAMFIL FARR 20-20®	20-25%	85% Plus	MERV 6
CAMFIL FARR 30/30®	25-30%	90% Plus	MERV 7
Aeropleat®	25-30%	90% Plus	MERV 6
CAMFIL FARR Riga-Flo® XL	40-45%	96%	MERV 9
CAMFIL FARR Riga-Flo® 15	60-65%	97%	MERV 11
CAMFIL FARR Riga-Flo® 100	80-85%	98%	MERV 13
CAMFIL FARR Riga-Flo® 200	90-95%	99%	MERV 15
CAMFIL FARR Riga-Flo® E65	60-65%	97%	MERV 11
CAMFIL FARR Riga-Flo® E85	80-85%	98%	MERV 13
CAMFIL FARR Riga-Flo® E95	90-95%	99%	MERV 15
CAMFIL FARR Riga-Flo® P65	60-65%	97%	MERV 11
CAMFIL FARR Riga-Flo® P85	80-85%	98%	MERV 13
CAMFIL FARR Riga-Flo® P95	90-95%	99%	MERV 14
CAMFIL FARR Durafil® 60-65%	60-65%	97%	MERV 11
CAMFIL FARR Durafil® 80-85%	80-85%	98%	MERV 13
CAMFIL FARR Durafil® 90-95%	90-95%	99%	MERV 14
CAMFIL FARR Opti-Pac® 65	60-65%	97%	MERV 11
CAMFIL FARR Opti-Pac ® 85	80-85%	98%	MERV 13
CAMFIL FARR Opti-Pac ® 95	90-95%	99%	MERV 14
CAMFIL FARR Aeropac® 65	60-65%	97%	MERV 11
CAMFIL FARR Aeropac® 85	80-85%	98%	MERV 13
CAMFIL FARR Aeropac® 95	90-95%	99%	MERV 14
CAMFIL FARR Hi-Flo® 35-40%	35-40%	90%	MERV 9
CAMFIL FARR Hi-Flo® 45-50%	45-50%	96%	MERV 10
CAMFIL FARR Hi-Flo® 60-65%	60-65%	97%	MERV 11
CAMFIL FARR Hi-Flo® 80-85%	80-85%	98%	MERV 13
CAMFIL FARR Hi-Flo® 90-95%	90-95%	99%	MERV 14
CAMFIL FARR HP® 2A	25-30%	90%	MERV 7
CAMFIL FARR HP® 15	60-65%	97%	MERV 11
CAMFIL FARR HP® P85	80-85%	98%	MERV 13
CAMFIL FARR HP® P95	90-95%	99%	MERV 14
CAMFIL FARR Micretain®	99%	100%	MERV 15
CAMFIL FARR Ultra-Pac	99%	100%	MERV 15
CAMFIL FARR Filtra 2000 95 DOP	99%	100%	MERV 15

Camfil Farr reserves the right to continually update this information. Please check www.camfilfarr.com for the latest update. The information provided in this bulletin has been assembled from materials as noted in the enclosed document or publication references. Camfil Farr assumes no liability for misapplication or for any individual that applies concepts herein in an inappropriate manner. Your local Camfil Farr representative may address any questions or concerns for specific application. Camfil Farr reserves the right to modify or update this information at any time. Updates will be published on the Camfil Farr Web site and will be available through authorized distributors and representatives. For the latest information, or to forward comments or suggestions, contact Camfil Farr at: techinfo@camfilfarr.com or seyfferc@camfilfarr.com.