

# Retention Efficiencies of Balston® Air And Gas Filters At Small Particle Size - 0.010 Micron

*Dr. G.J. Kennard, Fiber Engineering Scientist, Parker Hannifin Corporation*

## Summary

The efficiencies of Grades AQ, BX, and DX filters manufactured by Parker Hannifin Corporation were measured by means of monodisperse DOP<sup>1</sup> aerosols of 0.015, 0.030, 0.050, 0.070, and 0.100  $\mu$ . The face velocity was held constant at a nominal 10 cm/sec for each tube by using a constant air flow for testing the same diameter filter tubes and letting the filter pressure float. The results confirm our earlier report, and that in the body of literature for filter efficiencies; that the efficiency is best examined at a particle size between 0.09 and 0.15  $\mu$  (very near 0.100  $\mu$ ), and not at 0.010  $\mu$  as others contend. The filter efficiencies were 99.99999% for the AQ, 99.99994% for the BX and 99.9996% for the DX at 0.015  $\mu$ . This particle size test did not represent a means for discriminating between the efficiencies of the tubes as did the tests at 0.100  $\mu$  particle which yielded efficiencies for the AQ, BX, and DX of >99.999999; 99.99994; and 99.856 % respectively. Extrapolation of the data to 0.010  $\mu$  from these results is scientifically sound showing excellent but non-discriminating efficiencies for BALSTON AQ, BX, and DX filter tubes at 0.010  $\mu$  and we deem it sound to extrapolate to all filters of depth type construction. The Partial Filter Efficiency of BALSTON Depth Filters is excellent whether measured at 0.010, 0.100 $\mu$ , or at The Most Penetrating Particle Size for total efficiency.

## Experimental

This report describes the results of tests on the microfibre Air and Gas filters manufactured by Parker Hannifin Corporation of Haverhill, Massachusetts. The objective of this study was to extend the parameters for filter efficiencies to smaller particle size and determine the most discriminating efficiency test for filter tubes for us and our customers. Pressure drop for the filters was allowed to float as the equipment employed, a TSI Incorporated Particle Instruments Model 8160 Automated Filter Tester is limited in DP measurements to 150 mm H<sub>2</sub>O. At the normal face velocity employed for testing of BALSTON depth filters of 10 cm/sec<sup>2</sup>, this is too low for the BX and AQ filters. Monodisperse aerosols of DiOctyl Phthlate (DOP, CAS # 117-81-7) were used in the tests. The monodisperse particle size was generated as described in the TSI "CertiTest model 8160 Automated filter Tester Product Information bulletin<sup>3</sup>." To recap, a monodisperse challenge aerosol is produced using a TSI Electrostatic Classifier. The classifier selectively strips out a narrow particle-size range from a polydisperse aerosol generated within the system by a Constant Output Atomizer. Two Condensation Particle Counters (CPCs) then detect aerosol particles simultaneously upstream and downstream of the filter under test. The CPCs cause alcohol vapor to condense around small particles in the sample stream, enlarging them until they can be detected using a light-scattering technique. The CPCs employ a highly stable laser-diode light source for particle detection. The particle sizes employed for this study were 0.015, 0.030, 0.050, 0.070, and 0.100  $\mu$ . The 0.015 $\mu$  particle represents the smallest particle that can be statistically replicated and counted using this state of the art method. The largest particle size repeats previous studies<sup>4</sup> and was added as experimental evidence has shown this to be the greatest determinant of fractional filter efficiency. Test times were inordinately long because these filters are so efficient at all the particle sizes employed. In one case only one particle was detected in ten minutes passing through the filter. Thus ten minutes was set as the sample time for each test. "Despite this many of the results were for less than 100 counts in the 10 minutes of testing at each size."<sup>5</sup> The sample holder used on the Model 8160 was a duplicate of the one custom designed by TSI for the Model 8140 built for Parker Hannifin Corporation for our Statistical Process Control Testing and ISO 9001 collaborative testing.

**Experimental Results** The principal experimental results for the three filter classes tested are presented in Table 1. These results are presented graphically in Figure 1. As can be seen from both Table 1 and Figure 1 there is little difference between the filters at the smallest particle size tested, 0.015  $\mu$ , to discriminate which is better for use in a given application. As can be seen at all these small particle sizes the larger 0.100  $\mu$  particle shows the greatest difference in fractional efficiency between the filters. In this experimental study the 95% confidence levels are low for the data in general because of the tremendous fractional efficiency of our filters. The only highly precise data is that for the DX filter at the three largest particle sizes tested, 0.050, 0.070, and 0.100  $\mu$  where the downstream counts achieved sufficient numbers for precise counting in the CPCs. All other data is approximate and only gives trends. The problem in interpreting this data is a problem of "nines." There are so many nines in the number that there is no real evaluation of the filters ability compared to the lesser efficient filter. All the filters are extremely efficient at small particle size even though the known efficiencies are in the order AQ>BX>>DX from testing of duplicate filters on our TSI Model 8140 at the geometric mean Near Most Penetrating Particle Size or NMPPS of 0.14  $\mu$  with a rather wide standard deviation of particle size, results from previous studies<sup>6</sup> and a long history of testing our tubes using the Moore or NAFLA test<sup>7</sup> for verifying the quality of our filters. Figure 2 presents a generalized representation of Percent Efficiency vs Particle size (microns) as published in reference 3. Table 2 gives the statistical results of testing our Depth Filter Tubes at the NMPPS on the TSI 8140. The results show that the preferred method of obtaining meaningful results is at the NMPPS. The tubes with the highest design efficiency test to be the most efficient, the lesser efficient filters test so, and the least efficient show the least efficiency.

Lastly we present figure 3 from reference 6 which has been corroborated down to 0.010  $\mu$  for efficiency by sound scientific interpolation. Here we reiterate the conclusions of Professor Liu and Dr. Rubow which can be summarized as follows: *Brownian Motion is an extremely efficient means of capturing particles below 0.10  $\mu$  in size by depth filters and increases in efficiency with decreasing particle size.*

## Conclusion

The best measure of efficiency for a filter element is the NMPPS of 0.14  $\mu$ , a fractional monodisperse particle between 0.09 and 0.150  $\mu$  and not the 0.010  $\mu$  particle as is recently given for comparison of filter efficiencies. The Partial Filter Efficiency of Balston Depth Filters is excellent whether measured at 0.01 $\mu$ , 0.100  $\mu$  or at the Near Most Penetrating Particle Size and unsurpassed in the industry for comparable filters.

1. DOP is dioctyl phthalate, IUPAC *1,2-Benzenedicarboxylic acid bis(2-ethylhexyl) ester* CAS # 117-81-7,
2. Face Velocity is the air flow in volume per unit time divided by the area of the filter impinged by the air stream. In these tests it is the flow in liters/min. divided by the inner cylindrical surface as the filter is tested with flow inside to out and sealed at the upper and lower ends of the cylinder and converted to standard metric derived units. Efficiency is dependent on Face Velocity.
3. Product Information Bulletin, "CertiTest Model 8160 Automated Filter Tester", TSI Incorporated Particle Instruments, 500 Cardigan Road, PO. Box 64394, St. Paul, MN 55164 U.S.A., Copyright © 1993 TSI Incorporated.
4. BALSTON TECHNICAL BULLETIN, Bulletin TI-105, "Retention Efficiency of Balston Air And Gas Filters," Prof. Benjamin Y.H. Liu and Dr. Kenneth L. Rubow, ©Parker Hannifin Corp. 1986,1993.
5. Private communication, Mr. Timothy Johnson of TSI Particle Instruments Division, February 9,1996, detailing the results of the TSI Cert Test 8160 tests. Our thanks to Mr. Johnson for his kind assistance in this study.
6. Note 3 plus work performed in house and at Parker Hannifin Ltd., England.
7. The Moore test employs a detector using sodium flame attenuation hence Na(trium) (Fla)me yielding th acronym NAFLA to detect solid sodium particles by flame and later DOP.

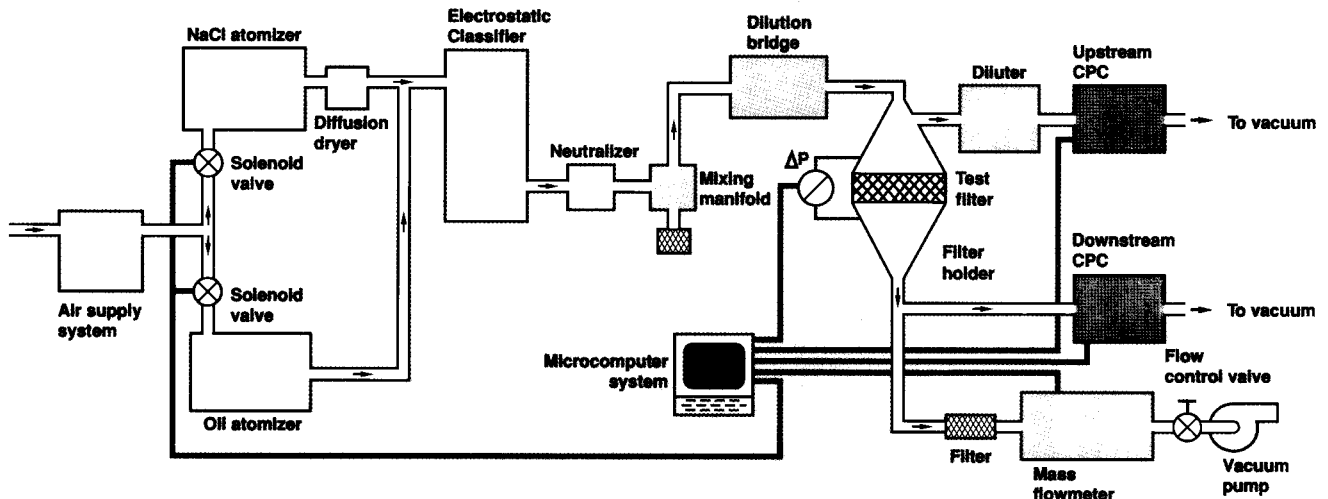
**Table 1**  
 Partial Efficiencies for  
 Baston Depth Filter  
 Cartridges with  
 Monodisperse Aerosis

Particle Size $\mu$	Efficiency %		
	AQ	BX	DX
0.015	99.99999	99.9998	99.9991
0.015	—	99.99994	99.9996
0.030	> 99.999999	99.999995	99.99994
0.050	99.999999	> 99.999999	99.997
0.070	> 99.999999	99.99999.3	99.974
0.100	> 99.999999	99.99994	99.856

**Table 2**  
 Efficiencies of Balston  
 Depth Filter Cartridges at the  
 NMPPS<sup>1</sup> with Measured  
 Differential Pressure Across  
 the Filter Wall

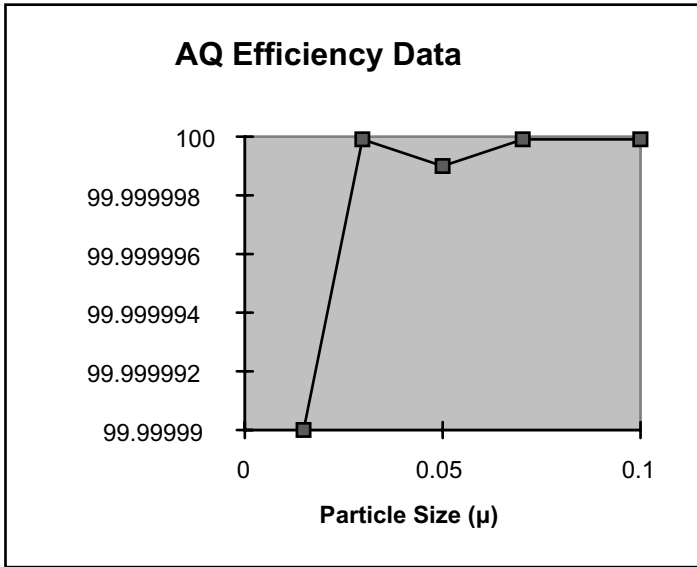
Grade Filter Cartridges <sup>2</sup>	Measured Efficiency % <sup>3</sup>	$\Delta P$ <sup>4</sup>
AAQ	99.991 (9)	44.01 (1.0)
AQ	99.999 (2)	25.7 (.8)
BQ	99.996 (11)	9.4 (.2)
BX	99.96 (2)	5.4 (0.4)
DQ	96.8 (7)	1.94 (.12)
DX	97.4 (8)	3.49 (.47)

- 1 Near most Penetrating Particle Size (see text).
- 2 All are one inch (2.54 cm) diameter except the BX which is 0.50 inch (1.27 cm).
- 3 Average for 10 individual tubes at 10 cm/sec. face velocity. ( ) give 1 standard deviation (1s).
- 4 Pressure measured across the filter wall @ 10 cm/sec on the TS18140 ( ) are 1s.
- 5 To ensure consistent product performance and reliability, use only genuine Balston replacement parts and filter cartridges.



Schematic of Experimental Set-up

Figure 1



(a)

Figure 2

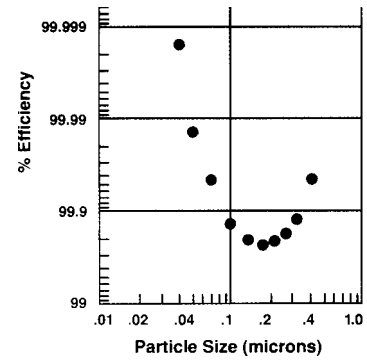
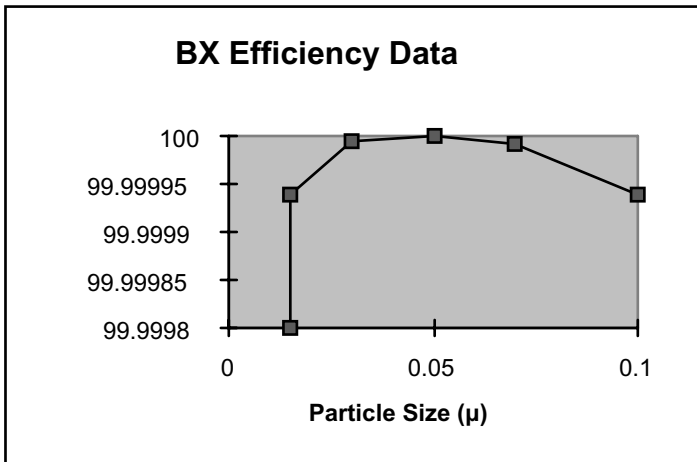
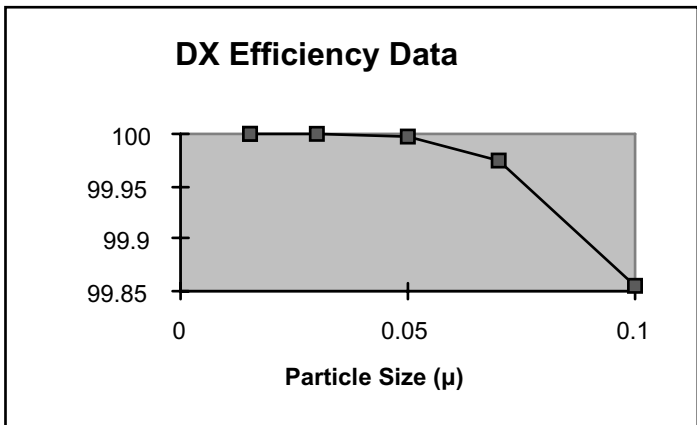


Figure 3



(b)



(c)

