Parker Balston Validation Studies

Validation studies showing the effectiveness of Parker Balston filters in removing sub-micron particulate and microbial contamination from compressed air

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Validation Studies

A Study on the Efficiency of Balston® Model SA Sterile Air Filters for Producing Commercially Sterile Air

Technical Information

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Introduction

A series of experiments were undertaken to determine the feasibility of using a Balston Sterile Air Filter for producing a microbiological free air supply. It was contemplated that if this filtration unit should prove capable of producing air of such quality, then it might have applications for use by the food, pharmaceutical and related industries where commercially sterile air may be required or deemed necessary to prevent contamination to products.

Experimental Procedure and Methods

The air source was the normal compressed air supply available throughout Chenoweth Laboratory at the University of Massachusetts. For these tests, a tap was made into the main supply line to establish a branch line for attaching the filter assemblies. The mainline 50 psi pressure was reduced to 20 psi by a pressure regulator installed in the flow path. The flow rate was regulated at 8 cfm.

The filtration system was located in the line after the pressure regulator, and it consisted of, in sequence, an A912A-DX prefilter unit, an A912A-BX unit and a A33B-SA final filter unit. Connected to the outflow port of the A33B-SA filter was a four position sampling manifold to which could be connected up to four membrane filter holders for sampling the filtered air.

The sampling filters employed for testing recovery of organisms were Gelman type 4320 into which were placed GA-8, 0.02 µm, 25 mm. Gelman membrane filters. The A33B-SA filter assembly together with the attached sampling manifold and filter holders with inserted filters were sterilized by autoclaving for 10 minutes at 121°C. Following autoclaving, the entire assembly was dried in an oven at 170°C for 30 minutes and then allowed to cool to ambient room temperature before being used.

During the sampling period, the air was passed through the system and allowed to impinge on the membrane filters in their holders for 20 minutes. After this time, the membrane filters were aseptically removed from the filter units and subjected to recovery methods for fungi (yeasts and molds), mesophilic aerobic and anaerobic bacteria, and thermophilic aerobic and anaerobic bacteria.

For recovery of yeasts and molds, exposed membrane filters were placed on absorbent nutrient pads containing 2.0 ml. YM broth in 50 x 9 mm. disposable petri dishes. Tests were incubated at 25°C for a maximum of ten days and checked daily during incubation for evidence of growth.

For recovery of mesophilic aerobic bacteria, two recovery techniques were used. With the first of these, a duplicate set of exposed filters was placed on nutrient pads each containing 2.0 ml. of m-standard methods broth (Difco) in 50 x 9 mm. disposable petri dishes. The dishes, in turn, were incubated at 32°C for five days maximum, and dishes were checked daily for growth throughout the incubation period.

Another set of duplicate filters were placed individually in 25 x 200 mm. culture tubes containing tryptic soy broth (Difco). Likewise these tubes were incubated at 32°C for five days and checked for evidence of microbial growth during the period.

For recovery of thermophilic bacteria, the exposed membrane filters were placed on nutrient pads containing m-standard methods broth (Difco) as previously. These plates were incubated at 55°C for five days and checked daily for microbial growth. As before, another set of exposed membrane filters was placed in tubes of tryptic soy broth and these were similarly incubated at 55°C for five days. These parallel tests were carried out in an attempt to maximize the potential for recovery of organism contaminants.

Experimental & Results

For detection of anaerobic bacteria, exposed filters were placed into 25 x 200 mm. culture tubes containing steam exhausted liver-veal broth with 0.5% added agar. These tubes were overlayed with sterile valspar sealing mixture to provide and maintain an effective seal. One duplicate set of tubes was incubated at 32°C for recovery of mesophilic anaerobes, and the other duplicate set of tubes was incubated at 55°C for recovery of thermophilic anaerobic bacteria. Both the mesophilic and thermophilic anaerobic tests were incubated for a maximum of two weeks before being considered negative for growth and recovery.

Immediately before testing the efficiency of the filtration system, a complete set of control air samples were collected. This was accomplished by passing the unfiltered air directly through the membrane filters for 20 minutes using a by-pass shunt located in the air line ahead of the Balston filter series. Filters thus exposed were tested for evidence of microbial contamination using the same testing procedures previously described. The protocol was employed in order to evaluate the microbial quality of the line air prior to its passage through the Balston filtration system.

Results and Discussion

The results from the series of experiments made, are shown in Table 1. These results represent those that were undertaken using the standardized testing protocol previously described. A series of preliminary trials were made prior to these in order to establish criteria for developing a standard testing regimen to minimize the possibility of experimental error influencing results.

The data presented indicate that the unfiltered line air was not free from microbial contamination, since both fungal and mesophilic bacteria were recovered from the control air samples.

By contrast, these data show that microbial air contaminants were not recovered from air that had passed through the Balston filtration system employed in these tests. On the basis of these experiments, it is concluded that the Balston air filtration system, employed under the conditions employed and tested, provided an air supply that was free of microorganisms that could be recovered by the testing methods used for these experiments.

Table 1

Recovery of Microorganisms from Filtered and Unfiltered Air

	Filtered Air					Unfiltered Air				
Trial	YM	MAB	MANB	THAB	THANB	YM	MAB	MANB	THAB	THANB
1	<1	<1	Neg	<1	Neg	<1	2	Neg	<1	Neg
2	<1	<1	Neg	<1	Neg	2	15	Neg	3	Neg
3	<1	<1	Neg	<1	Neg	<1	<1	Neg	<1	Neg
4	<1	<1	Neg	<1	Neg	<1	20	Pos	<1	Neg
5	<1	<1	Neg	<1	Neg	4	4	Neg	<1	Neg
6	<1	<1	Neg	<1	Neg	10	11	Neg	2	Neg
7	<1	<1	Neg	<1	Neg	2	5	Neg	<1	Neg
8	<1	<1	Neg	<1	Neg	<1	7	Neg	<1	Neg
9	<1	<1	Neg	<1	Neg	5	3	Neg	<1	Neg
10	<1	<1	Neg	<1	Neg	3	9	Neg	<1	Neg
11	<1	<1	Neg	<1	Neg	<1	2	Neg	<1	Neg
12	<1	<1	Neg	<1	Neg	<1	7	Neg	<1	Neg
13	<1	<1	Neg	<1	Neg	<8	<1	Neg	<1	Neg
14	<1	<1	Neg	<1	Neg	3	11	Neg	<1	Neg
15	<1	<1	Neg	<1	Neg	<1	5	Neg	<1	Neg

YM = Yeast and molds
MAB = Mesophilic aerobic bacteria
MANB = Mesophilic anaerobic bacteria
THAB = Thermophilic aerobic bacteria
THANB = Thermophilic anaerobic bacteria

For additional information call toll-free 1-800-343-4048 or fax 1-978-858-0625

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Technical Information

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[1] aerosols of 0.015, 0.030,0.050,0.070, and 0.100 µ. 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 µ (very near 0.100 µ), and not at 0.010 µ 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 µ. This particle size test did not represent a means for discriminating between the efficiencies of the tubes as did the tests at 0.100 µ particle which yielded efficiencies for the AQ, BX, and DX of >99.9999999; 99.99994; and 99.856 % respectively. Extrapolation of the data to 0.010 µ from these results is scientifically sound showing excellent but non-discriminating efficiencies for BALSTON AQ,BX, and DX filter tubes at 0.010 µ 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, 0.100µ, 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_20. At the normal face velocity employed for testing of BALSTON depth filters of 10 cm/sec[2], 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[3]." 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 µ. The 0.015µ 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[4] 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."[5]. 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.

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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 µ, 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 µ 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 µ 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 µ with a rather wide standard deviation of particle size, results from previous studies[6] and a long history of testing our tubes using the Moore or NAFLA test[7] 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 µ 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 µ 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 µ, a fractional monodisperse particle between 0.09 and 0.150 µ and not the 0.010 µ particle as is recently given for comparison of filter efficiencies. The Partial Filter Efficiency of Balston Depth Filters is excellent whether measured at 0.01µ, 0.100 µ or at the Near Most Penetrating Particle Size and unsurpassed in the industry for comparable filters.

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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

	Efficiency %		
Particle Size µ	AQ	BX	DX
0.015	99.99999	99.9998	99.9991
0.015	——	99.99994	99.9996
0.030	> 99.9999999	99.999995	99.99994
0.050	99.999999	> 99.999999	99.997
0.070	> 99.9999999	99.99999.3	99.974
0.100	> 99.9999999	99.99994	99.856

Table 2
Efficiencies of Balston Depth Filter Cartridges at the NMPPS[1] with Measured Differential Pressure Across the Filter Wall

Grade Filter Cartridges[2]	Measured Efficiency %[3]	ÐP[4]
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)

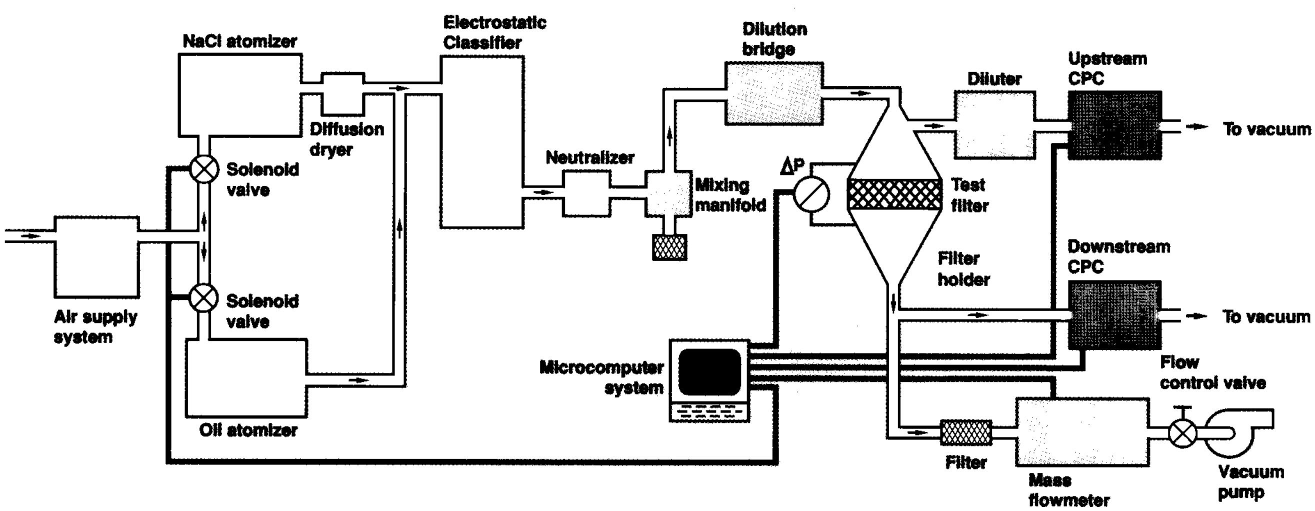
1 Near most Penetrating Particle Size (see text).

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

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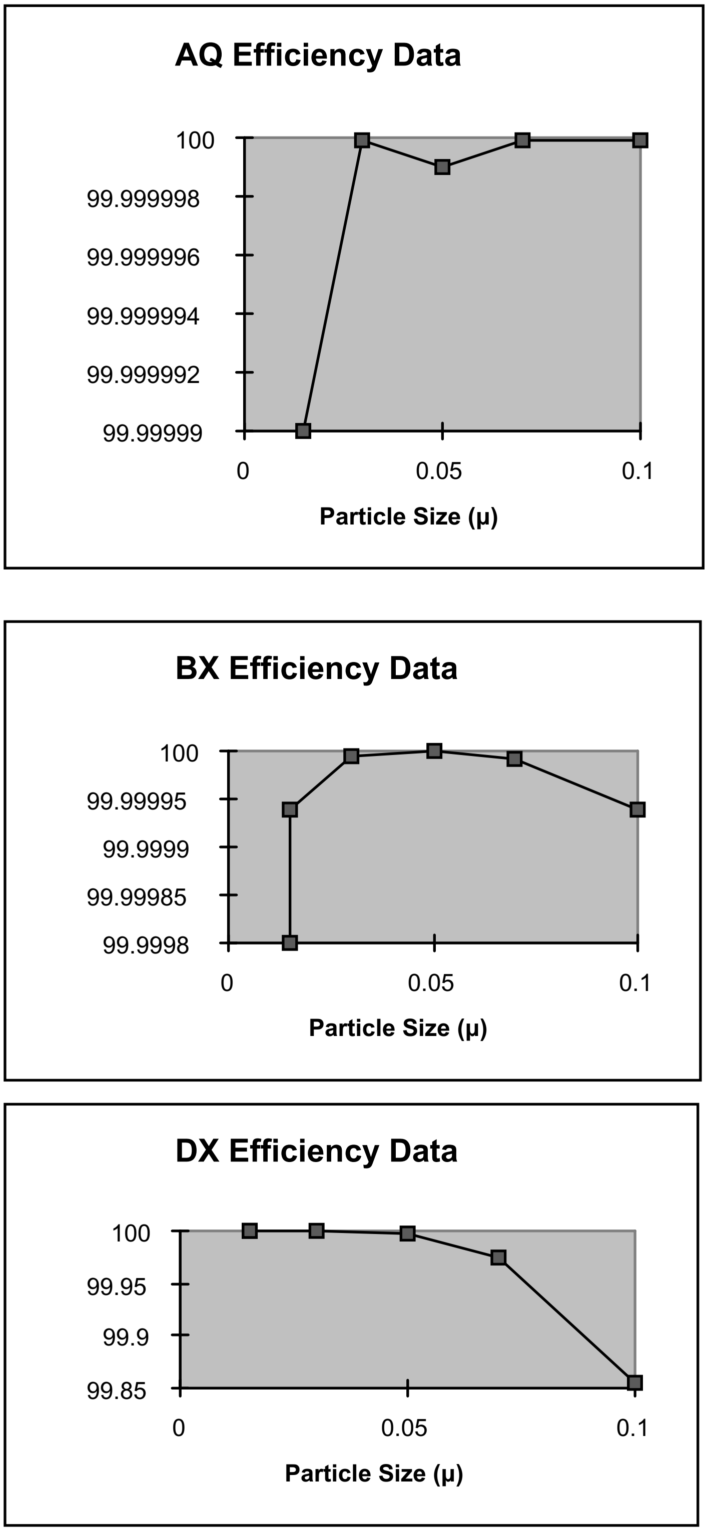
Figure 1



(a)

(b)

(c)

Figure 2

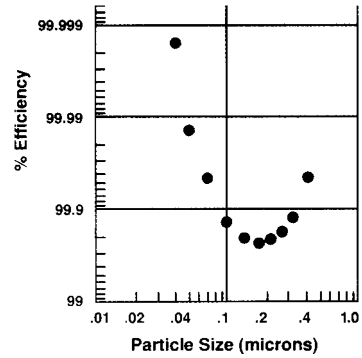
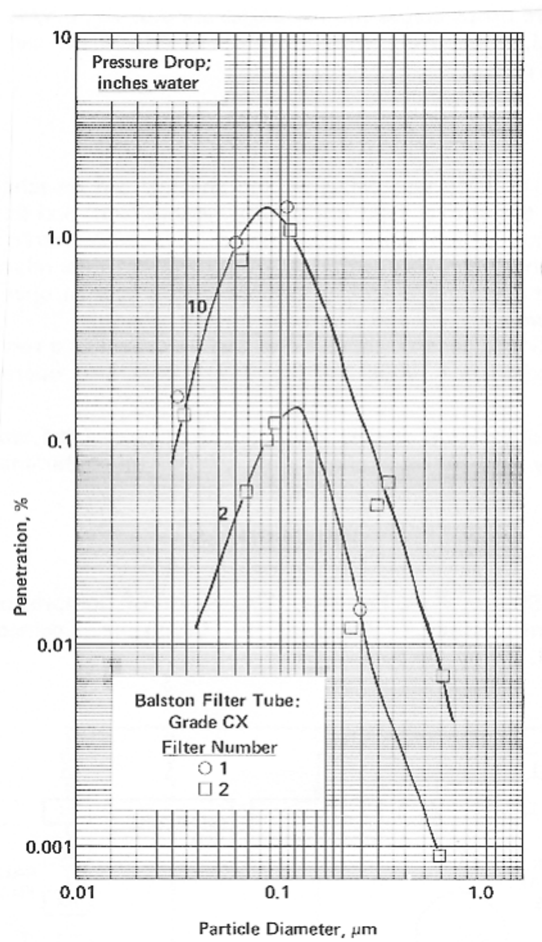


Figure 3



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Retention Efficiency of Balston® Air and Gas Filters

Technical Information Manual

The following report was prepared by Prof. Benjamin Y. H. Liu, Director, and Dr. Kenneth L. Rubow, Research Associate, of the Particle Technology Laboratory, Mechanical Engineering Department, University of Minnesota, Minneapolis, Minnesota 55455.

Summary

The efficiency of Grades AAQ, SA,, AQ, BX, CX and DX filters manufactured by Parker/Balston was measured by means of monodisperse DOP aerosols of 0.035, 0.07, 0.1, 0.3, and 0.7 µm at filter pressure drops of 2 and 10 inches of water. The filter efficiencies were found to range from a low of 93.3% for the Grade DX filter at a particle size of 0.1µm to a high which is in excess of 99.9994% for the Grades AAQ, SA and AQ filters. The most penetrating particle size, i.e., the size for which the filter efficiency is a minimum, was found to be in the vicinity of 0.1 µm for the Grades CX and DX filters. While the sensitivity of the experimental apparatus did not allow the actual determination of the most penetrating particle size for the Grades AAQ, SA, AQ and BX filters, there is reason to believe, on the basis of filtration theory, that the most penetrating particle size for these filters would also occur in the vicinity of 0.1 µm.

Experimental

This report describes the results of tests on the Microfibre Coalescing filters manufactured by Parker Hannifin Corporation of Haverhill, Massachusetts. The objective of the tests was to determine the efficiency of the filters as a function of particle size over a range of filter pressure drops. Monodisperse aerosols of dioctyl phthalate (DOP) were used in the tests. The particle size was varied between 0.35 and 0.7 µm (micron) and the pressure drop across the filter was kept at 2 and 10 in. water. The filters tested include filters of Grades AAQ, SA and AQ and of Grades BX, CX and DX.

Figure 1 is a schematic diagram of the experimental apparatus used in the test. It consists of a monodisperse aerosol generator, a filter holder containing the filter being tested and an electrical aerosol detector. The aerosol was generated by atomizing a solution of DOP in alcohol, followed by heating and re-condensing the DOP vapor to form a monodisperse aerosol. The size of the aerosol was changed by changing the DOP concentration in alcohol. The aerosol penetration through the filter was measured by first passing the aerosol through the filter and measuring the aerosol concentration with the electrical aerosol detector and then measuring the upstream aerosol concentration by sampling the upstream aerosol directly into the electrical aerosol detector. In the electrical aerosol detector the particles are exposed to unipolar ions generated by a corona discharge and the charged particles are then measured by an electrometer current sensor.

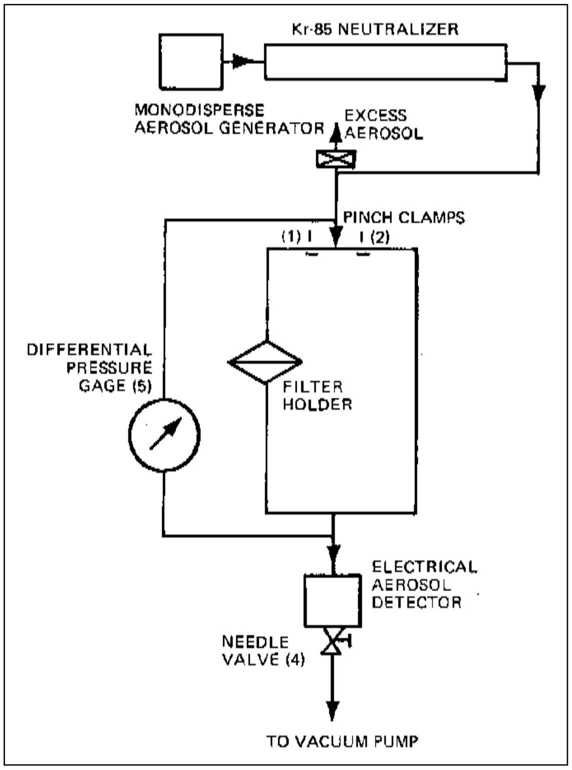

Figure 1: Schematic Diagram of Experimental Apparatus for Determining Filter Efficiency

The details of the experimental apparatus have been described by Liu and Lee (1976). More recent refinement of the apparatus can be found in the PH.D. thesis by Rubow (1981).

A Type 33G filter housing manufactured by Parker was used as the holder for the filter under test. Two such housings, each containing its own filter element, were placed in the system to allow some comparisons to be made between the two different filter elements of the same identical type. This was to check for possible leaks in the system and to see how closely the penetration through the two filters agreed with each other.

The pressure drop across the filter at a given flow through the filter was measured by setting the flow through the filter at some pre-selected value and measuring the pressure drop with a pressure gage. The flow was measured with an electronic mass flowmeter, Model 2021, manufactured by TSI, Inc. (St. Paul, MN). The integrity of the entire experimental system against unwanted leaks was tested by evacuating the system to 20 inches water and observing the rate of climb of the pressure in the system after the vacuum pump had been turned off. Duplicate runs were made on a given filter to check for the repeatability of the experimental procedure. The result shows that the experimental procedure was quite repeatable and the procedure itself contributed little to the variability of the experimental results.

Experimental Results

The principal experimental results for the five filters tested are shown in the Table. It is interesting to note that for each filter grade, the two individual filter elements tested generally gave results which were quite close to each other, indicating small experimental variability and good quality control. It is interesting to note also that even for the Grade DX filter, which carries the lowest efficiency rating, the minimum efficiency observed was 93.3%. For the other filters the efficiencies were considerably higher. Because of the limitations in instrument sensitivity, it was not possible to determine the actual filter efficiencies for the Grades AAQ, SA, AQ, and BX filters. It was possible to determine only that the filter efficiency was greater than some minimum values. These minimum measurable filter efficiencies varied with the characteristics of the experimental system, including the sensitivity of the electrical aerosol detector, the maximum aerosol concentration generated by the aerosol generator, the amount of dilution air used, etc. These minimum filter efficiency values are indicated as >99.99%, >99.994%, etc., as shown in the Table.

The influence of particle size on filter efficiency can be seen quite clearly in the Table below particularly for Grade CX and Grade DX. This shows that for both of these filters, the maximum filter aerosol penetration, i.e., the minimum filter efficiency, occurs at a particle size of about 0.1 μm, the actual minima being 0.09 and 0.14 μm for the DX filter at the pressure drops of 10 and 2 inches respectively, and 0.09 and 0.12 μm for the Grade CX filter at the same pressure drops. While data were not obtained to determine the most penetrating particle size for the Grades AAQ, SA, AQ, and BX filters, there is every reason to expect that the most penetrating particle size would also occur in the vicinity of 0.1 μm for these filters.

It should be noted that while no data were obtained for the efficiency of the filter for particle diameters larger than 0.7 μm, the trend of the data is quite clear. One would expect that particle penetration through the filters would be lower, and the filter efficiency higher, for say, 1 μm diameter particles than they are for the 0.7 μm diameter particles. For instance, if the information in the above table for the efficiency of the Grade CX filter was plotted against particle size on a graph, by extrapolating the efficiency data to 1.0 micron one would expect a filter efficiency of approximately 99.9997%. Similarly, referring to the Table for data for the Grade AAQ filter, one would expect that the efficiency of the filter for 1.0 μm particles would be in excess of 99.9994%.

Summary of Experimental Results

Filter Grade	Pressure Drop, inches water	Filter Number	Flow Rate, lpm	Efficiency, %, for Particle Diameter, μm, of				
				0.035	0.07	0.1	0.3	0.7
AAQ	2	1	00.85	>99.99	>99.993	>99.995	>99.997	>99.997
		2	0.89	>99.99	>99.993	>99.995	>99.997	>99.997
	10	1	4.44	>99.998	>99.999	>99.9994	>99.9994	>99.9994
		2	4.59	>99.998	>99.999	>99.9994	>99.9994	>99.9994
AQ SA	2	1	1.65	>99.99	>99.99	>99.99	>99.996	>99.998
		2	1.52	>99.99	>99.99	>99.99	>99.996	>99.998
	10	1	8.31	>99.997	>99.998	>99.999	>99.9994	>99.9994
		2	7.53	>99.997	>99.998	>99.999	>99.9994	>99.9994
BX	2	1	5.96	>99.994	>99.998	>99.9991	>99.9991	>99.9991
		2	5.40	>99.994	>99.998	>99.9991	>99.9991	>99.9991
	10	1	28.1	>99.99	>99.996	>99.999	>99.9991	>99.9991
		2	26.8	>99.99	>99.996	>99.999	>99.9991	>99.9991
CX	2	1	14.1	>99.994	99.936	99.81	99.986	99.9993
		2	14.8	>99.994	99.938	99.84	99.989	99.9993
	10	1	53.3	99.83	98.82	98.37	99.97	99.995
		2	54.7	99.86	99.00	98.70	99.95	99.995
DX	2	1	17.1	99.77	99.17	98.3	99.37	99.87
		2	17.8	99.98	99.44	98.6	99.66	99.98
	10	1	59.0	99.03	95.0	93.3	99.04	99.44
		2	60.2	99.29	95.3	93.3	99.23	99.49

Providing High Efficiency

How a Balston Filter Provides High Efficiency

Parker/Balston Filter systems derive their unique advantages from the proprietary Microfibre Filter Tubes, which are constructed only from borosilicate glass fibers with a chemically-resistant resin binder. The Microfibre Filter Tubes are self-supporting and self-gasketing - that is, they are sealed in place simply by compression against the flat surfaces of the filter housing. Here's how this unique filter medium delivers its unusually advantageous performance.

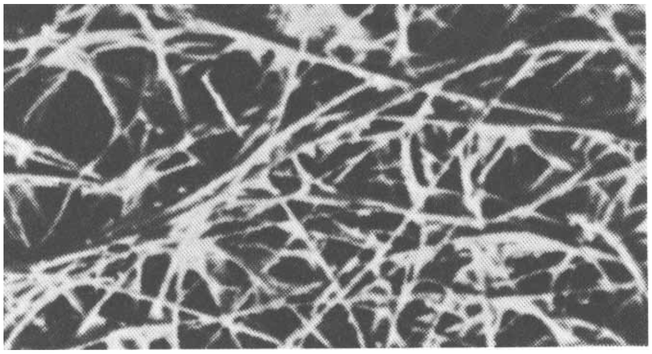

Figure 2: Photomicrograph of Microfibre Filter Tube

Collision, Not Sieving

A Microfibre Filter (Figure 2) is constructed of a random bed of borosilicate glass fibers, held in a rigid structure by the fluorocarbon resin binder. The diameter of the fibers in the photograph is about one micron; the spaces between the fibers are much larger. How can the filter capture contaminants smaller than one micron with very high efficiency? Clearly the Microfibre Filter Tube does not capture by a "sieving" action - by holding back particles too large to pass between the fibers. Rather, when a solid particle or liquid droplet collides with a fiber it adheres permanently to the fiber by intermolecular (Van der Waals) forces.

The intermolecular forces are effective for any type of particle or liquid droplet, at any relative humidity or temperature. Once the particle is captured it cannot be dislodged by shaking or vibration. Therefore, the filter will not suddenly unload the contaminants downstream when there is a surge in flow, but neither can it be cleaned by back-washing.

Momentum and Brownian Motion

As one would expect, the larger particles and droplets in the gas stream have sufficient momentum that they very likely will collide with one of the many fibers in the flow path. The right-hand dotted line in Figure 3 shows schematically the efficiency of capture by the momentum mechanism. (Please note the vertical scale on the chart in the high efficiency range is greatly expanded to illustrate the discussion.)

In filtration of gases - not in filtration of liquids - we benefit from a second mechanism of particle capture - Brownian Motion. Brownian Motion is the rapid, random motion of particles about 0.1 micron and smaller in a gas. The movement is completely independent of the overall gas flow direction, and occurs even when the gas as a whole is not flowing.

Obviously a particle subject to rapid side-to-side motion in a gas flowing through a fiber filter has a very high probability of contacting a fiber and being captured. Therefore, as shown by the left hand dotted line in the figure, Brownian Motion is extremely effective as a capture mechanism for particles smaller than 0.1 micron but of rapidly decreasing effectiveness for particle sizes increasing above 0.1 micron. The total efficiency is the sum of the capture efficiency by momentum and by Brownian Motion. The result is a curve with maximum efficiencies at both above 1 micron and below 0.05 micron, and a dip in efficiency at 0.1 micron. The ratings for Balston air and gas filters (page 2) are the retention efficiencies at the crucial 0.1 micron particle size. As shown by Figure 3, the filters will be more efficient than these ratings at any other particle size, larger or smaller.

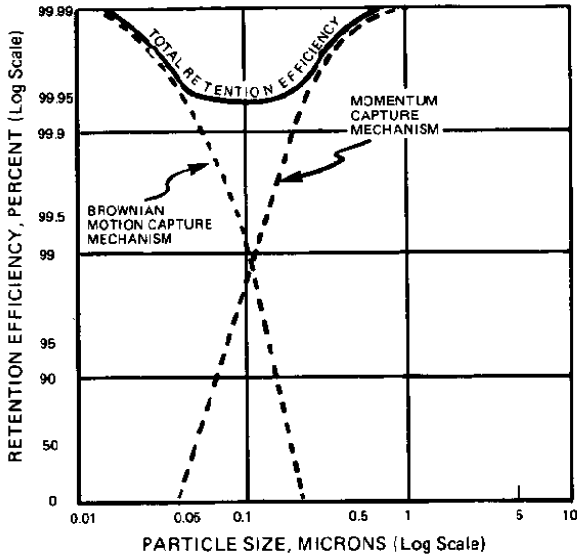

Figure 3: General retention efficiency curve for Microfibre Filter Tube

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