NOVEL SURFACE MODIFICATION WHICH INCREASES FILTER HOLDING CAPACITY AT CONSTANT ΔP

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1. Introduction

Most air filters are porous fibrous materials with fibers aligned perpendicular to air flow. Fiber diameters are typically less than 0.50 mm and the resultant interfibrous spaces are usually much larger than the airborne pollutants to be filtered out. More than 90% of the filter volume is void space. Direct interception does not occur frequently. At particle sizes smaller than 0.6 micron Brownian diffusion is the predominant filtration mechanism with electrostatic interactions having an effect in some cases. At over 0.6 micron inertial impaction and gravity settling predominate. In 1942, Irving Langmuir determined that minimum filter efficiency would occur at particle size of 0.3 micron with the type of filter materials available at that time. HEPA filters, a product of the Manhattan project have traditionally been defined as being a dry extended surface type filter having a minimum particle removal efficiency of 99.97 % at 0.3 micron particle size. Filter efficiency increases at sizes greater than and less than 0.3 micron. Filters are still evaluated based on performance at the point of minimum efficiency as calculated by Langmuir. Many of the air filter performance standards and analytical techniques and equipment employed today were developed during World War II as a part of personal protective mask research and chemical fog and chemical warfare research in addition to development of HEPA filters (High Efficiency Particulate Arrestors) for capture of radioactive materials.

Due to this early work and subsequent research, air filter performance has become better understood. Standardized tests have been developed to gauge filter performance. One of the more common standards which is utilized is the MERV (Minimum Efficiency Reporting Value) rating system based on ANSI/ASHRAE 52.2 – 1999. In this system filters are evaluated based on performance in regard to several observables. Among them are Dust Spot Efficiency, Minimal final pressure, Particle size efficiency, Average Arrestance, Dust holding capacity and Penetration . Air filters are assigned a value from 1 to 20 in increasing order of efficiency and discrimination. MERV 1 rated filters are generally throwaway materials meant for filtration of bulky mass, MERV 15 filters are capable of removing all bacteria and even fine aerosol such as smoke. In this paper we will focus on filter performance as relates to Dust holding capacity, Penetration, Arrestance and pressure drop

Arrestance is a gravimetric measure of the ability of a filter to remove injected synthetic dust from the test air, 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. **Caking** is the build up of particulate material on the filter surface. Typically when caking occurs percent penetration decreases holding capacity increases and delta P increases drastically indicating the end of the useful lifetime of the filter. **Delta P** is a measure of the differential pressure across the filter and is usually in units of inches of water. Typically 1.6-1.7 inches of water is maximum pressure at which point testing generally stops. It has been a paradigm of air filtration that as filter efficiency and filter capacity increase pressure drop also increases. It is also true that percent penetration is detrimental to filter performance and decrease in percent penetration usually results in increase in delta P. One of the goals of air filtration research has been to increase holding capacity, minimize penetration and delay the onset of caking while keeping delta P constant.

Over the years a variety of techniques have been employed in pursuit of the above objective. Tacking agents have been utilized with mixed results. Among the types of materials which have been employed as tacking aids are rubber latex, polyisobutylene and a variety of viscous oils. Solid powder tacking agents have also been used. Tacking agents tend to cause increases in pressure especially upon capturing solid particles. Many tacking agents tend to accelerate the onset of the caking at which point the dust holding capacity drops significantly due to re-entrainment in to the air stream. The cost of higher initial efficiency is lower arrestance when using conventional tacking agents Electrostatic charging of filter substrates is currently popular. Although this type of filter exhibits some improvements in performance, it suffers from an unfortunate phenomena whereupon it displays an increase in penetration during the early stages of loading. Additionally, oil mists and water condensation reduce the effectiveness and lifetime of the corona effect.

In this paper we will present results of testing conducted on filter media treated with a dry curable ViscoElastic Tackifier (VET*). The preliminary results indicate that this tackifier may be able to increase holding capacity at no additional pressure drop. Typical results seem to indicate that treatment with this tackifier can improve filter performance by 2 or more MERV ratings without any significant increase in pressure. It appears that the filter exhibits higher dust holding capacity with reduced re-entrainment into the air stream.

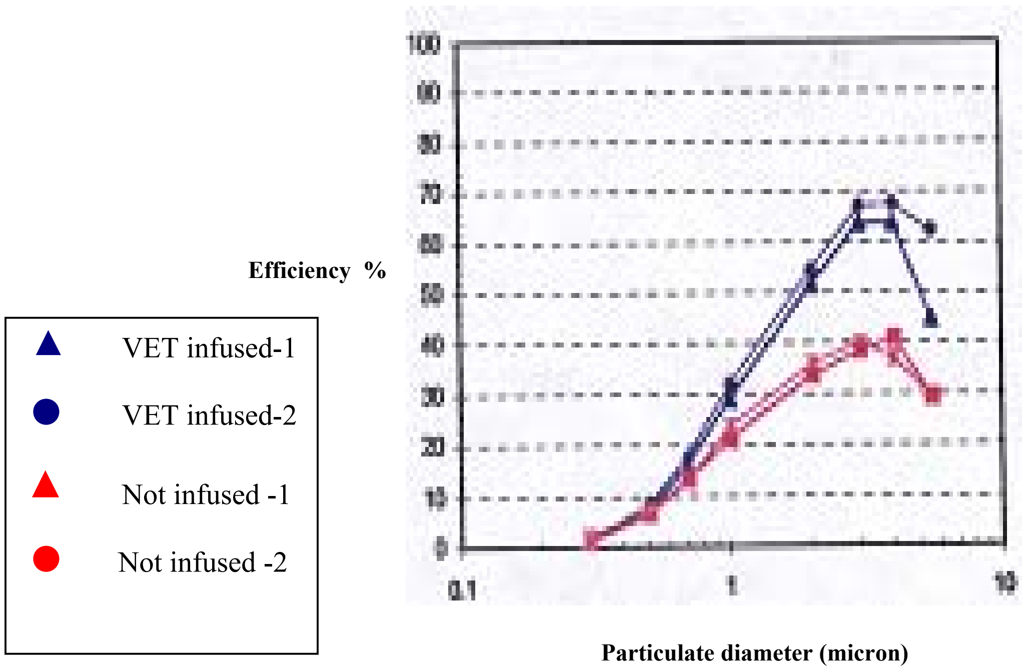
2. Experimental Results

For the purposes of this paper, all filter media utilized for testing were 19”x20”x2” pleated polypropylene filters treated with ViscoElastic Tackifier at a weight percent of less than one. The tackifier is completely dry to the touch and treated filters are indiscernible from untreated filters based on physical appearance. All tests were conducted with untreated controls. Test apparatus and methods were consistent with and conformed to industry standards. Most of the testing was conducted by independent laboratories in the process of evaluating the tackifier. Data was incorporated from different sectors of air filtration testing (filter masks, commercial, residential, military) to produce a composite result which attempted to incorporate the most challenging parts of the various standards.

* **VET (ViscoElastic Tackifier)** is a curable viscoelastic amphiphatic surface active agent. VET is patented under the brand name MYCELX and is the exclusive property of MYCELX Technologies Corporation

2.a. TEST 1: In this test treated and untreated filters are challenged with neutralized KCl over a 0.1-10 micron range and particle size efficiency is measured. The results are indicated by the graph in **Fig.1**

Fig.1 Efficiency vs Particle Diameter



Results indicate a 50% increase in performance at 0.6 micron going up to a 65% improvement in performance in the 3-5 micron range. Efficiency improvement in the 5-8 micron range is of similar magnitude. Tests were conducted at constant pressure drop of 1.6 inches of water. There was no significant pressure drop increase in either tackified or untackified filters.

2.b. Test 2: In this test VET modified filters were compared in performance to filters treated with a commercial tacking agent when challenged with Arizona Road Dust (1-10 microns with 65% of the particles in 2-3 micron size range). Tests were conducted to 1.6 inches of water differential pressure across the filter for all filters. The results are depicted in **Fig.2** and **Table.1**. The results show that the filter with the latex tacking agent exhibits slightly higher holding capacity while demonstrating lower arrestance rate accounting for the slightly longer time it took to get to terminal pressure. The VET filter had an increased arrestance rate and a very large increase in holding capacity in comparison to the uninfused control and the filter treated with commercial tacking agent.

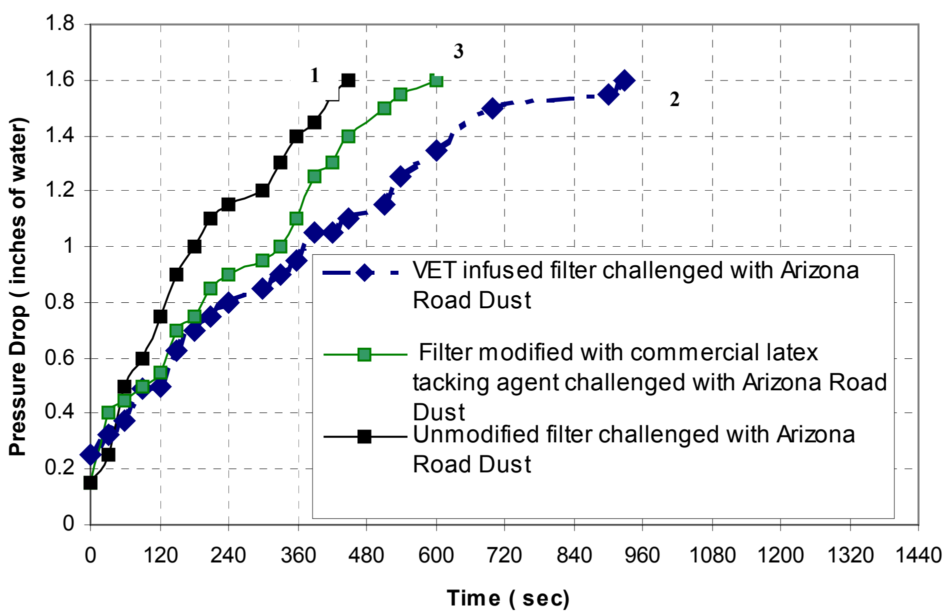
It also took approximately twice as long as the latex modified and control filter to reach terminal differential pressure drop without displaying a decrease in arrestance rate. This is a significant result.

Table.1

Challenged with Arizona Road dust alone	Arrestance %	Dust holding capacity in gms
1.Unmodified filter (Control)	37.26	14.16
2.VET infused filter	62.75	50.09
3.Filter modified with commercial tackifier	33.72	16.89

Fig.2 Comparison of Pressure Drop and Dust absorption characteristics

Arizona Road Dust (1-10 micron)



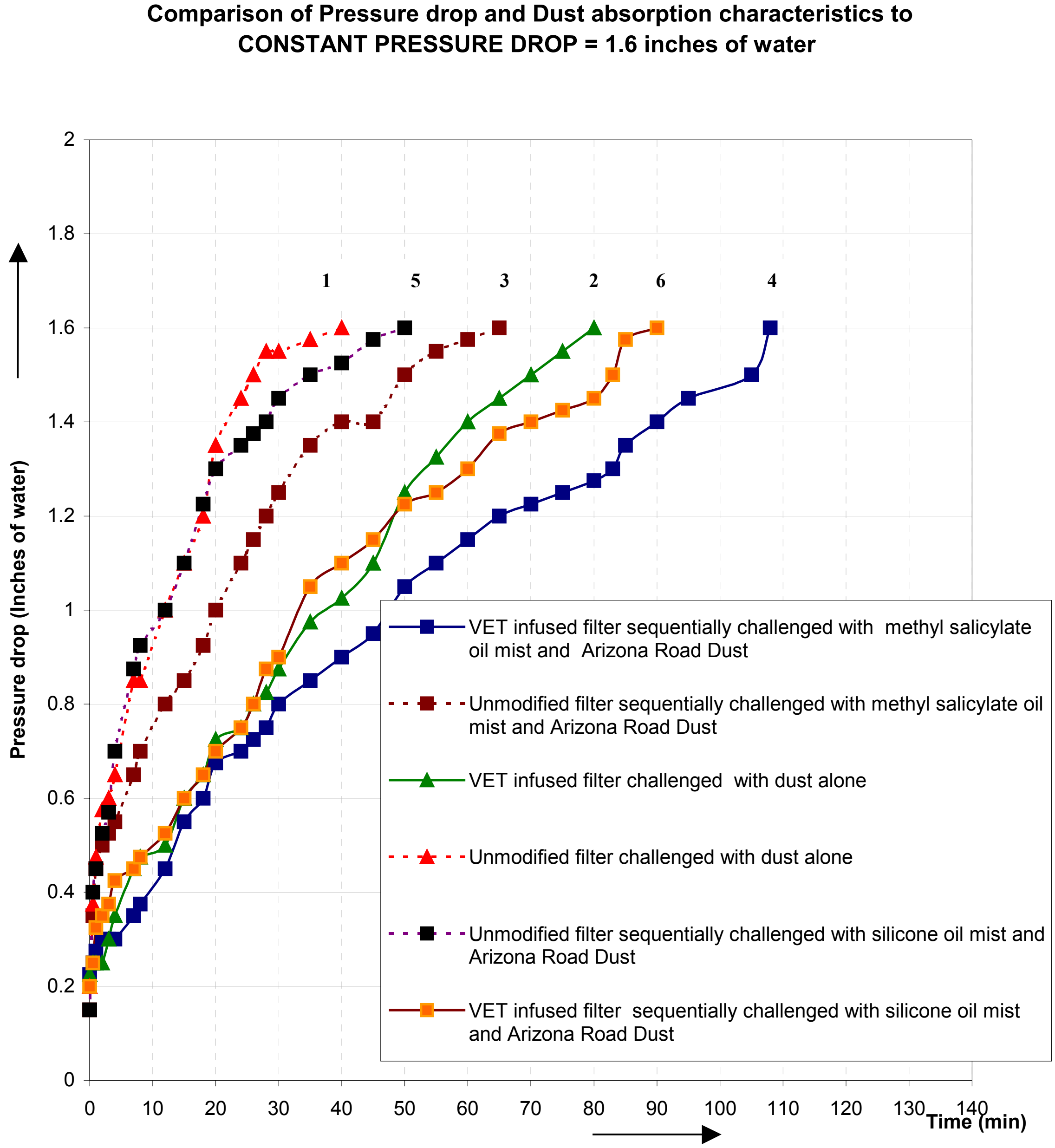
2.c. TEST.3 : One of the areas not sufficiently addressed in some sectors of air filter testing is the behavior of filters in complex composite waste streams. Often filters are exposed to oily mists, water based mists and particulate matter with different surface characteristics and affinities simultaneously. The challenges presented to air filtration devices in the presence of complex influent streams was illustrated by the post 9/11 anthrax attacks. In this regard we decided to evaluate filter performance under conditions not normally accounted for in most air filter testing. Face mask researchers have probably done the most work with combined liquid and solid aerosol influent. In the following tests VET treated and untreated filter were first challenged with oily substances in aerosol form before being tested for particle removal. In work previously conducted by Payet et. al (Journal of Aerosol Science, 1992) and Walsh et al (Journal of Aerosol Science, 1996) where filters were challenged with liquid and solid aerosols, filters exhibited a lower total holding capacity and higher degree of solid penetration. Increase in interstitial velocity and decrease in number of fibers available for capture are two factors which may contribute to this observation.

In the following tests the filter media was first challenged with a nominal coating of oily mist (Methyl Salicylate or Silicone oil) and then challenged with Arizona Road Dust. The results are illustrated in **Fig.3** and **Table.2**

Table.2

	Arrestance %	**Dust holding capacity in gms**
Challenged with Arizona Road dust alone		
1.Unmodified filter (Control)	52.6	3.42
2.VET infused filter	62.75	7.53
Sequentially challenged with methyl salicylate and Arizona Road dust		
3.Unmodified filter (Control)	36.3	3.81
4.VET infused filter	42.01	6.65
Sequentially challenged with silicone oil mist and Arizona Road dust		
5.Unmodified filter (Control)	40.6	3.05
6.VET infused filter	59.8	7.87

Fig. 3


Comparison of Pressure drop and Dust absorption characteristics to
CONSTANT PRESSURE DROP = 1.6 inches of water
Pressure drop (Inches of water)
Time (min)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
1
5
3
2
6
4
VET infused filter sequentially challenged with methyl salicylate oil mist and Arizona Road Dust
Unmodified filter sequentially challenged with methyl salicylate oil mist and Arizona Road Dust
VET infused filter challenged with dust alone
Unmodified filter challenged with dust alone
Unmodified filter sequentially challenged with silicone oil mist and Arizona Road Dust
VET infused filter sequentially challenged with silicone oil mist and Arizona Road Dust

The % arrestance of the control filters decreased by approximately 25% for both types of oil. The time to reach terminal delta P increased for both oils in the control filters indicating increasing penetration. VET filters exhibited a 30% decrease in arrestance with methyl salicylate and a 4% reduction in arrestance with silicone oil. The time to reach terminal delta P was also slightly greater indicating a slight increase in rate of penetration. The VET modified filters exhibit better performance after being pre-challenged with the silicone oil than the control filters without silicone oil. Methyl Salicylate challenged filters did have lower performance than unchallenged control filters but the reduction in performance was less than that of control filters challenged with methyl salicylate. In all cases the dust holding capacity of VET filters was approximately twice that of unmodified filters.

3. Discussion

Historically, increasing dust holding capacity and decreasing penetration without causing catastrophic delta P increase has been the goal of air filtration researchers. Tacking agents, nanofiber composites and electrostatic charging are among the leading technologies being evaluated. Although each of these approaches affords some improvements it is usually at the cost of increased delta P, penetration or accelerated cake formation.

Based on work conducted to date, VET seems to be able to improve performance with zero or insignificant increases in delta P. The patented chemistry of VET allows these improvements due to its novel compositional properties observable as viscoelasticity, high affinity for uncharged surfaces and aerosol membranes and its curability, resulting in a dry molecular level surface modification. The chemistry of VET and how it relates to filter performance will be covered in the future paper.

When VET filters are evaluated in comparison to control filters per the ASHRAE MERV rating system the results are as in **Table.3**

Table.3

	Arrestance %	Dust holding capacity in gms	Relative MERV rating
Challenged with Arizona Road dust alone			
1.Unmodified filter	52.6	3.42	6
2.VET infused filter	62.75	7.53	8
Sequentially challenged with methyl salicylate and Arizona Road dust			
3.Unmodified filter	36.3	3.81	6
4.VET infused filter	42.01	6.65	8
Sequentially challenged with silicone oil mist and Arizona Road dust			
5.Unmodified filter	40.6	3.05	6
6.VET infused filter	59.8	7.87	8 or 9

VET appears to improve filter performance by at least 2 MERV rating points as compared to control filters without any additional delta P. If these results continue to be reproducible after further independent field trials it is a significant development which will affect the way filter chemistry is viewed in relation to filter performance. Much of the work done with regard to filtration has focused on the physical characteristics on the filters to a greater extent than on the chemical affinities and other physiochemical characteristics of the filter fiber chemistry. This is an area which requires more research. An area of future work regarding VET chemistry will be to determine if the observed properties can be transferred into the filter fibers by introduction of VET to the polymer melt. Another reason for the development of VET was to try to improve filter performance in the presence of oily mists both alone and in conjunction with solid particulate aerosols. VET modified filter performance appears more robust in the presence of oils as compared to control filters and to commercially available tackifying agents. VET modified filter performance in the presence of complex waste streams renders it amenable to fulfilling outstanding requirements in military, industrial and medical applications. In this regard an area of keen future interest is the performance of VET modified filters in the presence of neutral organic particulate and liquid aerosols especially in the 0.5-5 micron range.

4. Conclusion

VET technology appears to have properties which improve filter performance relative to particulate and aerosol filtration without causing significant ancillary complications. Further research and evaluations are merited.