A GENERAL CORRELATION OF MPPS PENETRATION AS A FUNCTION OF FACE VELOCITY WITH THE MODEL 8140 USING THE CERTITEST 8160

Norman Lifshutz and Mary Pierce
Hollingsworth & Vose Company
West Groton, Massachusetts

Abstract

The CertiTest 8160 is a Condensation Nucleus Counter (CNC) based filtration test stand which permits measurement of penetration as a function of particle size. The Model 8140 is also a CNC based filtration test stand which provides a single penetration measurement for a fixed particle distribution aerosol challenge. A study was carried out measuring DOP penetration on a broad range of flat filtration media at various face velocities to compare these two instruments. The tests done on the CertiTest 8160 incorporated a range of particle sizes which encompassed the most penetrating particle size (MPPS).

In this paper we present a correlation between the MPPS penetration as measured by the CertiTest 8160 and the penetration values obtained on the Model 8140. We observed that at the lowest air face velocities of the study the Model 8140 tended to overpredict the MPPS penetration as measured by the CertiTest 8160. We also present a correlation of MPPS penetration with face velocity which may be of use for extrapolation purposes.

1. Introduction

It is a well-known phenomenon that the penetration of aerosol particles through a fibrous filtration medium is a sensitive function of the particle diameter, peaking at the most penetrating particle size (MPPS). Over the years there has been increasing emphasis by both filter element manufacturers and filter media manufacturers on measurement and specification of filter media penetration performance at the MPPS. Two recent documents that have referenced reporting the MPPS and its penetration at application velocity are IES-RP-021[1] and CEN/TC 195[2]. While this can readily be carried out using a flat sheet test stand such as the CertiTest 8160, it is a relatively slow, time-consuming process, requiring tests at a number of particle sizes. These tests are not suitable as real time quality control tools in a media manufacturing environment. An alternative is the use of a flat sheet test stand such as the Model 8140 which uses a fixed challenge aerosol having a mean particle size diameter of 0.18 micrometers and geometric standard deviation of 1.6. The test time of the 8140 is a fraction of the test time of the 8160. Thus, the first objective of this study was the comparison of the penetration performance reported by these two test instruments.

The "Holy Grail" of filtration is the simultaneous achievement of lower particle penetrations at lower filter resistance. This has led filter manufacturers to design elements operating at lower air face velocities relative to media area, with greater emphasis on measurement and specification of filter media penetration performance at these low velocities. This is again a challenge to the penetration measuring stands because the low face velocities frequently involve flow rates at the measurement limit of the equipment, and because the particle count rates require longer and longer sample times for statistical confidence. It would be desirable to measure penetration performance at higher face velocities and be able to extrapolate to the lower face velocities of interest. Thus the second objective of this study was the establishment of a correlation between MPPS penetration and face velocity which might be used for such an extrapolation.

2. Experimental

Two different flat sheet test stands were used for this study. The more sophisticated is the TSI CertiTest 8160[3] which is shown schematically in Figure 1. A fine particle aerosol of dioctylphthalate (DOP) is generated by atomization and evaporation of a dilute solution of DOP in isopropyl alcohol. This aerosol then encounters an electrostatic classifier, which permits only a tunable monodisperse aerosol of the desired particle size to proceed to challenge the test media. Samples of aerosol are withdrawn upstream and downstream of the test media and fed to

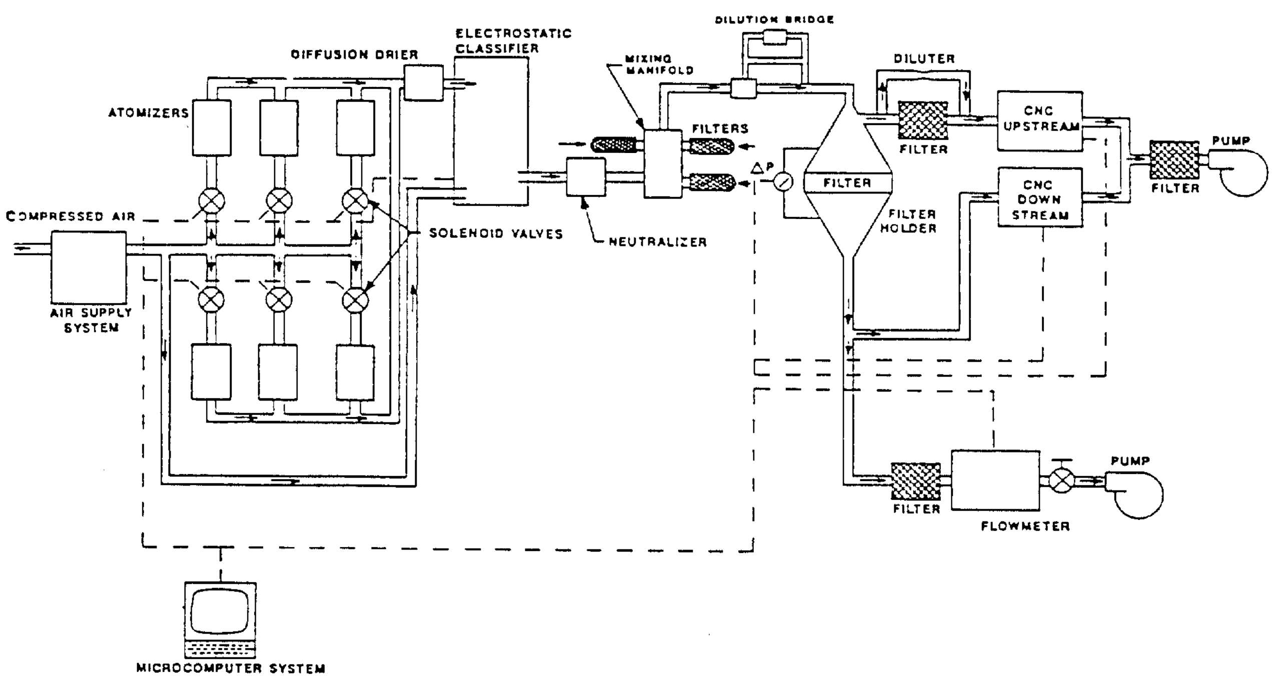


Figure 1.
Schematic of TSI Model 8160 Automated Filter Tester

separate CNC's for determination of the penetration for that particle size. To obtain a full curve of penetration for a range of particle sizes encompassing the maximum penetration, a series of particle sizes is selected and the individual penetration measurements are determined sequentially. With this equipment penetration can be reported to a precision of 10^{-8} percent over a particle size range from 0.015 to 0.40 micrometers at flow rates from 5 to 100 liters per minute.

The less sophisticated test stand is the TSI Model 8140, which is shown schematically in Figure 2[4]. This instrument generates a polydisperse aerosol of DOP by atomization. This aerosol then passes through a coarse fibrous prefilter intended to narrow the particle size distribution. The aerosol then proceeds to challenge the test media. Samples of the aerosol are withdrawn upstream and downstream of the test media and fed to CNC's for determination of penetration. With this equipment penetration can be reported to a precision of 10^{-7} percent at flow rates from 15 to 100 liters per minute.

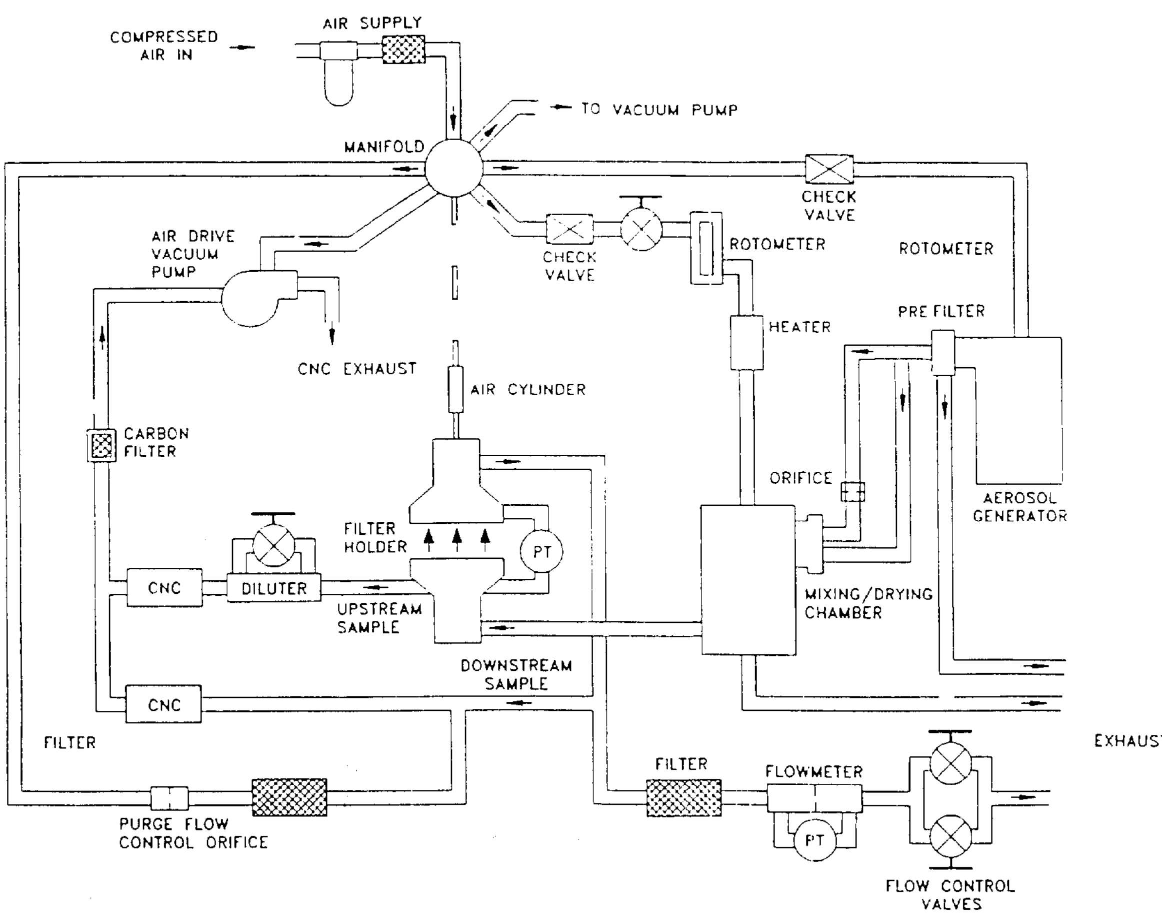


Figure 2.
Schematic of TSI Model 8140 Automated Filter Tester

With both instruments it is necessary to use purge times long enough to guarantee achievement of steady state, and sampling times long enough to provide satisfactory counting statistics. The normal sample area for both instruments is 100 cm^2, but on the 8140 we use a 333 cm^2 sample area for face velocities below 1.8 cm/sec in order to maintain flow rate accuracy.

Multiple samples of ULPA, HEPA, Sub-HEPA, and 95% DOP efficiency media were obtained. These were first tested in the 8160 using face velocities of 1.0, 1.2, 1.8, 2.5, 3.5, and 5.35 cm/sec for 0.075, 0.10, 0.12, 0.15, 0.18, 0.22, 0.26, 0.30, and 0.35 micrometer particle diameters. The same area of each sample was then retested at the same velocities using the 8140 tester Each 8160 data set was subjected to regression analysis to fit the data to the model:

$$\ln(Pen) = A(\ln D)^2 + B(\ln D) + C \qquad (1)$$

Where Pen = Penetration fraction

and D = Particle diameter

The MPPS is then easily determined by setting the derivative equal to zero, so that:

$$\ln(MPPS) = -B/2A \qquad (2)$$

where MPPS = Most penetrating particle size

and substituting back into the model we get:

$$\ln(Pen_{MPPS}) = C-(B^2/4A) \qquad (3)$$

3. Results and Discussion

Figures 3, 4, 5, and 6 are typical 8160 curves for the ULPA, HEPA, Sub-HEPA and 95% DOP efficiency media along with the 8140 results for the same samples. In general the quality of the fit to this simple model is quite good, with an average R^2 value of 0.98 for roughly 72 data sets of six points apiece. Thus the model provides a simple objective way of treating such a data set in order to abstract an MPPS value and a Pen_{MPPS} value.

It is clear from these graphs that the curves are tangent to or just below the 8140 lines shown. It is noted that at the lower test velocities the 8140 values tend to overpredict the 8160 MPPS values by an appreciable percentage. Since the particle size distribution in the 8140 is certainly not monodisperse, one would expect that the 8140 should give penetration values somewhat below the Pen_{MPPS}, but our experimental results do not confirm this. From a media specification point of view, however, the 8140 penetration is a conservative estimate of the MPPS penetration. Areas we suspect to be possible causes for these results are diluter

FIGURE 3
PENETRATION CURVES OF ULPA MEDIA

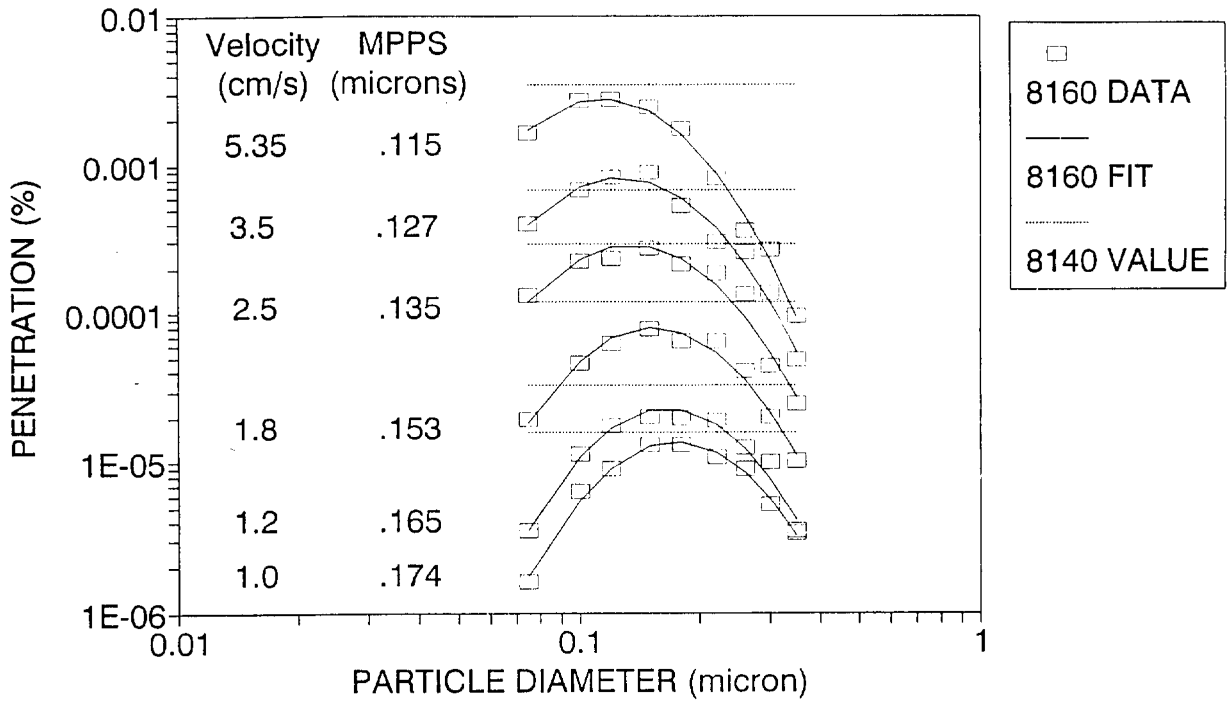


FIGURE 4
PENETRATION CURVES OF HEPA MEDIA

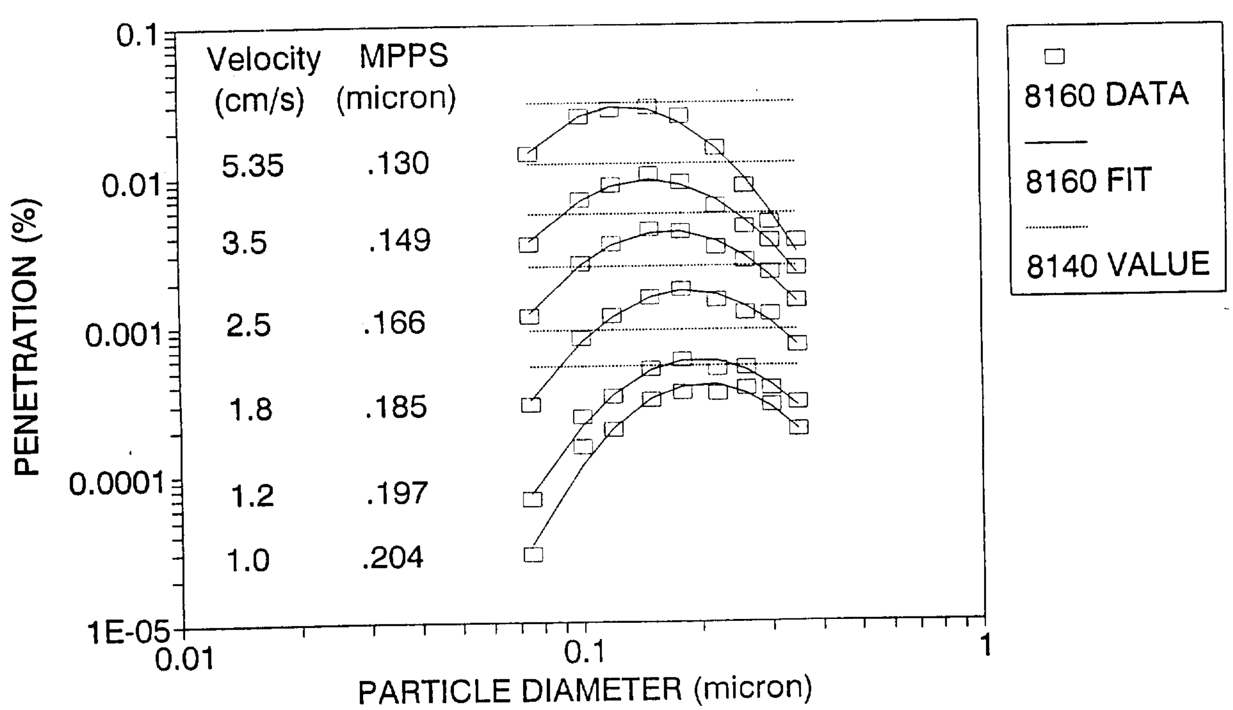


FIGURE 5
PENETRATION CURVES OF SUB-HEPA MEDIA

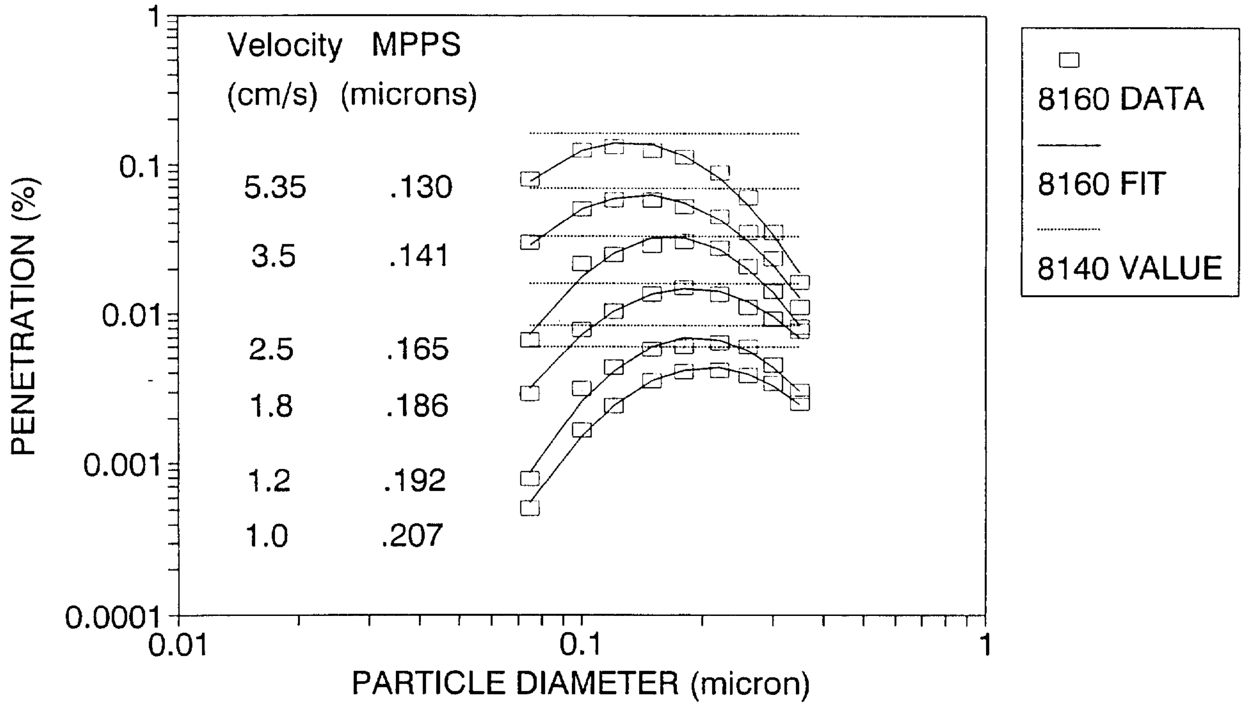
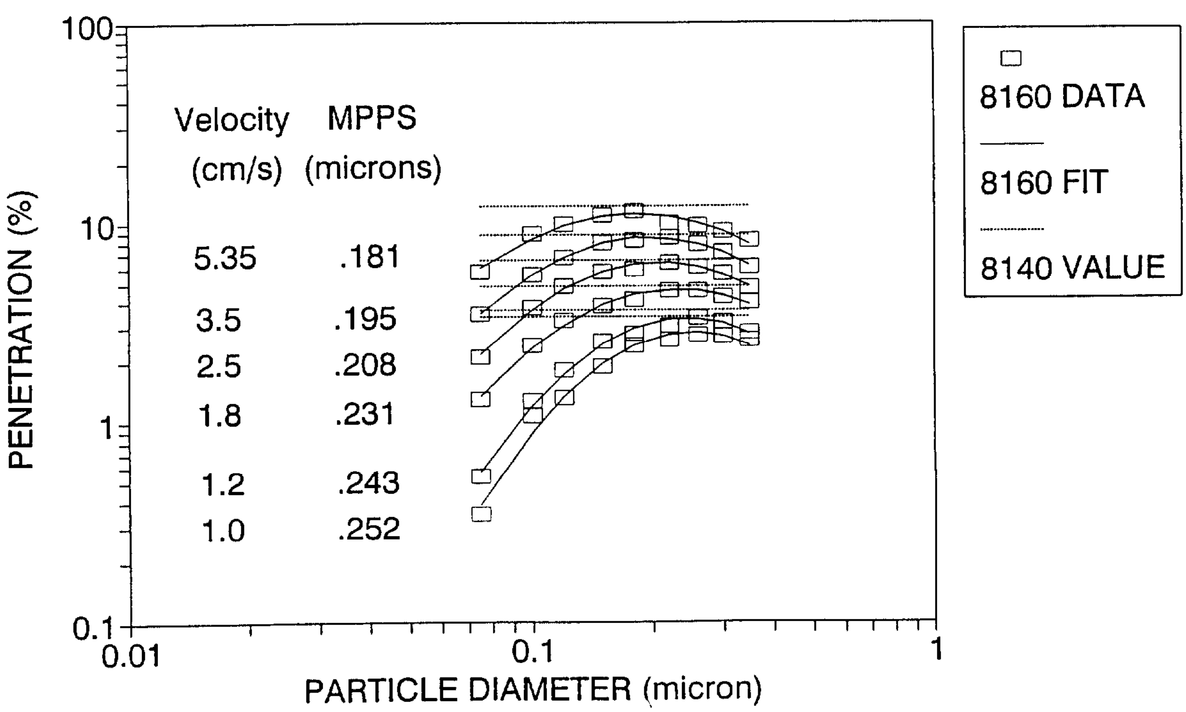


FIGURE 6
PENETRATION CURVES OF 95% DOP MEDIA



differences between the instruments, individual CNC response differences, adequate purge time at low velocity, and flow measurement precision at low velocity.

Figure 7 is a plot of Pen_{8140} values against Pen_{MPPS} values obtained from the fits to the 8160 data. Over seven orders of magnitude the two measures of penetration agree very well.

Since the 8140 gives penetration values that correlate so well with the MPPS penetration, a correlation of 8140 penetration with velocity would be useful. The 8140 data for each sample was fit to the power model for filter media penetration previously presented at this conference[5]:

$$\ln Pen = \ln Pen_r (V/V_r)^N \quad (4)$$

Where Pen = Penetration fraction at face velocity, V

and Pen_r = Penetration fraction on the same sample at the reference velocity, V_r

The R^2 values obtained from these regressions were all above 0.98. Figure 8 is a graph showing the velocity dependence of 8140 penetration for the typical media samples shown earlier. The ULPA, HEPA, and Sub-HEPA curves are parallel having N values equal to -0.24. The 95% DOP media is different, however, having a slope of -0.28.

The determination of the N value for a filter medium or filter media family allows for measurement of penetration at a reference velocity within reasonable operating parameters of the test equipment and estimation of the penetration at the low application velocities which will be encountered.

Conclusions

A comparison of the penetration performance values between the TSI CertiTest 8160 and the TSI Model 8140 has shown that the penetration value obtained from the 8140 correlates very well to the MPPS penetration obtained from the 8160 penetration curve for penetrations spanning several orders of magnitude.

The 8140 penetration is related to face velocity by a power law model. This can be a useful tool for specifying media penetration performance at reasonable test equipment operating parameters.

FIGURE 7
8140 PENETRATION VS MPPS PENETRATION

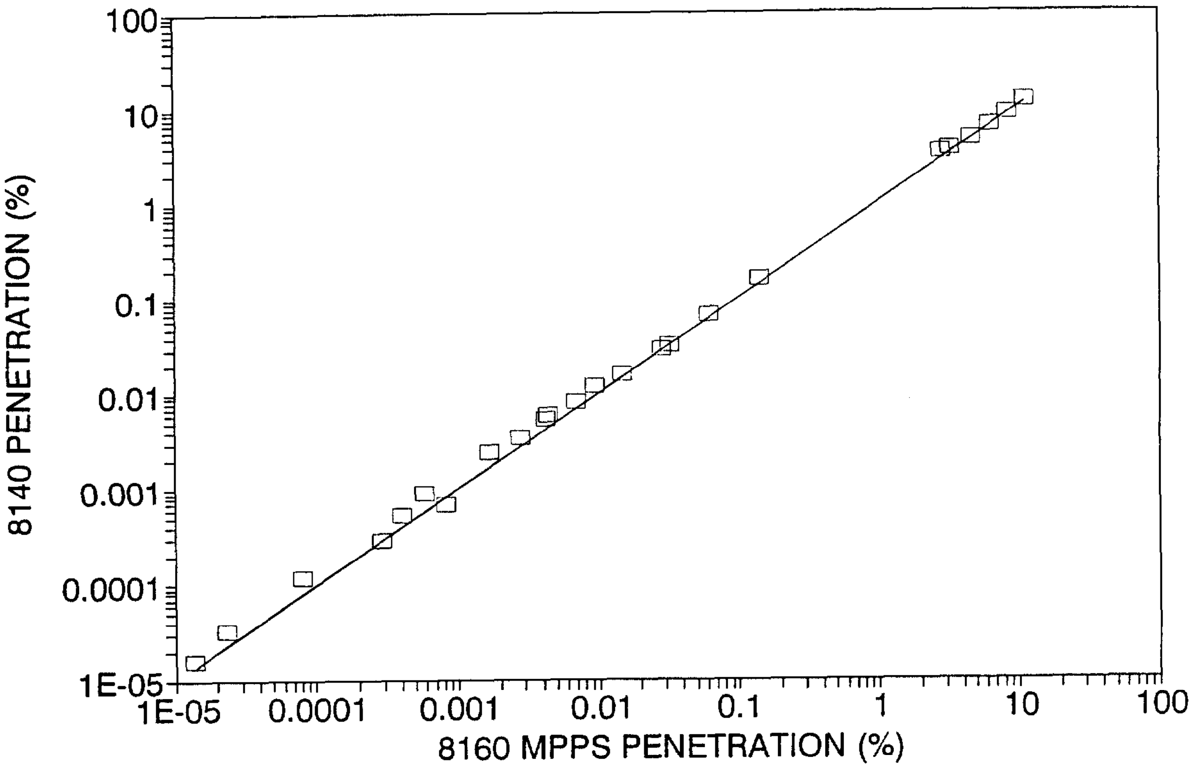
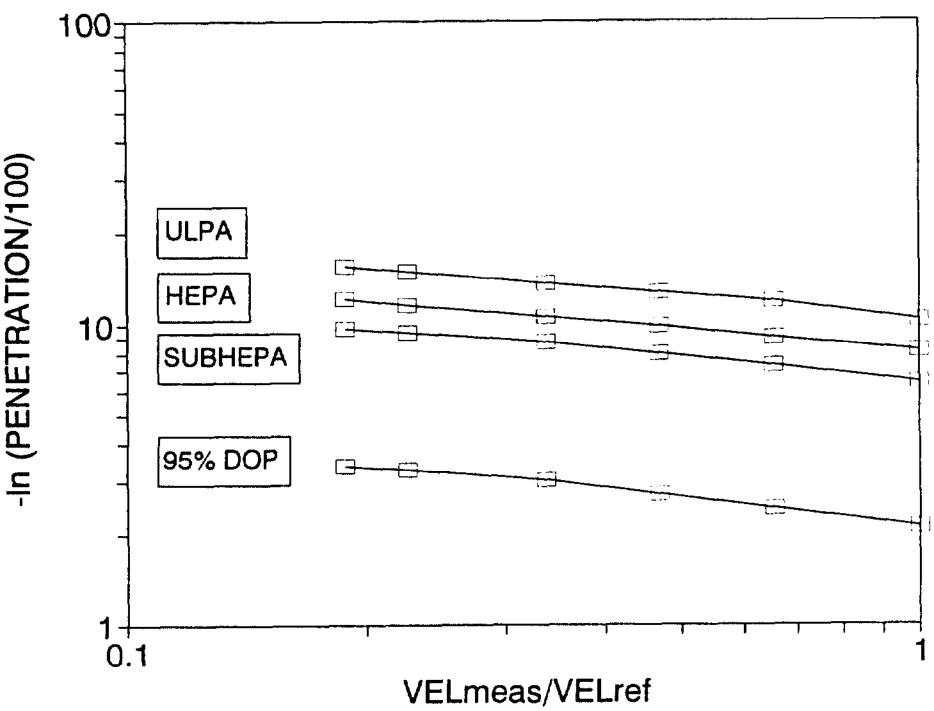


FIGURE 8
EFFECT OF VELOCITY ON PENETRATION



24th DOE/NRC NUCLEAR AIR CLEANING AND TREATMENT CONFERENCE

Bibliography

(1) IES-RP-CC021.1, "Testing HEPA and ULPA Filter Media", 1993. Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056.

(2) CEN/TC 195/WG 1/N 023, "Final Draft Specifications for Particulate Air Filters for General Ventilation", 1991. Institute Belge de Normalisation, C/o INIEX-ISSeP - Division de Colfontaine, Sec. of CEN/TC 195/WG-1 - rue Grande, 60 - B-7340 Colfontaine, Belgium.

(3) TSI Incorporated, 500 Cardigan Road, St. Paul, MN, "CertiTest Model 8160 Automated Filter Tester Operation and Service Manual", 1993.

(4) TSI Incorporated, 500 Cardigan Road, St. Paul, MN, "Model 8140 Automated Filter Tester Operation and Service Manual", 1992.

(5) Pierce, M., Guimond, R., Lifshutz, N. "A General Correlation of DOP Penetration With Face Velocity as a Function of Particle Size Using the FTS-200", CONF-880822, pp. 973-982, Proceedings of the 20th DOE/NRC Nuclear Air Cleaning Conference, Boston, MA (1988).

DISCUSSION

SCRIPSICK: How does the particle size at maximum penetration and the penetration curve compare to theory? Did you look at that? We have seen that theory predicts much greater slope values than measurements on filters.

PIERCE: We have not compared our laboratory flat sheet results to any computer models of what the theoretical penetration would be. As a general comment, we have observed that the theoretical penetration curves tend to have steeper slopes on either side of the most penetrating particle size than test data.

DYMENT: Please comment on the relationship between the MPPS and efficiency of the different media which you chose to use.

PIERCE: Theory dictates that as face velocity is decreased, penetration will increase and the most penetrating particle size will increase. I believe this is because diffusional effects are more pronounced and inertial effects are less pronounced at lower and lower velocities, so that larger particles become more penetrating. Also, it is generally observed that as efficiency between media samples is reduced, effectively increasing the mean fiber diameter within the media samples, the MPPS increases.