HOMOGENEITY OF PORE STRUCTURE OF FILTRATION MEDIA

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ABSTRACT

Homogeneous pore structure of filtration media results in consistent performance. Evaluation of honogeneity requires multiple testing on many areas without damaging the filtration media in any way. The PMI on-line porometer was used for such tests on a number of filtration media. The results show considerable inhomogeneity. Some media show different pore characteristics on different areas of the filter material. These results suggest that homogeneity evaluation of filtration media is important.

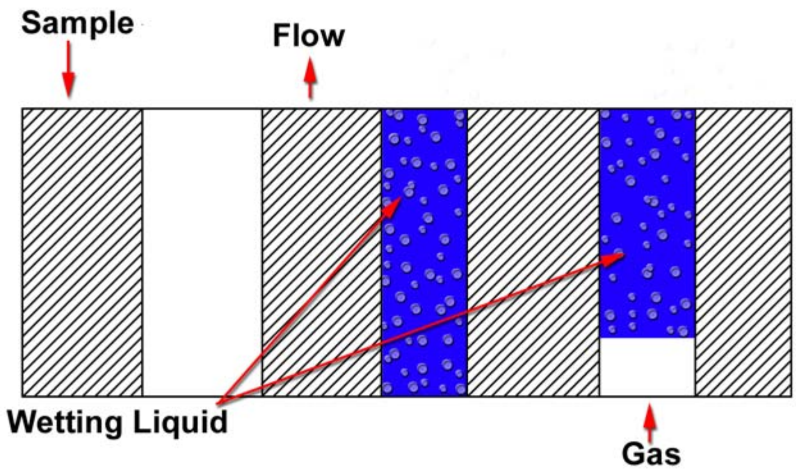
INTRODUCTION

The performance of filtration media depends primarily upon the characteristics of their pore structure. However, pore structure of filtration media may not be homogeneous. Pore size and pore distribution often differ from location to location. If the variation is appreciable, performance of filters would not be consistent. It is, therefore, important to monitor the structural homogeneity of filtration media. Defects in filtration media that cause inhomogeneity may be randomly present in the material requiring testing random locations on filtration media. Often, the manufacturing process itself introduces defects on specific locations. Structural characteristics of these locations need to be evaluated. Thus, many locations need to be tested for their pore characteristics. Test techniques are available for pore structure characterization. However, all of these techniques require samples to be cut from the filtration media, which may result in damage and unusable waste of material. This problem can be avoided and a large number of tests on filtration media may be performed without damaging the material in any way by the use of on-line porometer. In this investigation a number of commercial filtration media were investigated using the on-line capillary flow porometer. The results show considerable inhomogeneity of pore structure of filtration media and suggest a strong need for testing of homogeneity of filtration media.

THE ON-LINE POROMETER

PRINCIPLE

The pores of material to be tested are filled with a wetting liquid and pressure of a non-reacting gas on one side of the sample is increased to displace liquid from pores and permit gas flow (Figure 1).



The pressure required to displace liquid from a pore is given by [1]:

$$P = 4 \gamma \cos \theta / D \quad (1)$$

Where, p is the differential pressure across the pore of diameter D, γ is the surface tension of the wetting liquid and θ is the contact angle of the wetting liquid on the filtration medium in contact with air. For small surface tension wetting liquids the contact angle may be taken as zero [2]. The diameter of a pore computed from the pressure is its diameter at its most constricted part [3]. The constricted pore diameter determines the barrier characteristics of a pore.

The pressure of gas and flow rate of gas through dry and wet samples yield constricted pore diameters, the largest pore diameter, the mean flow pore diameter, the flow distribution and gas permeability as illustrated in Figure 2.

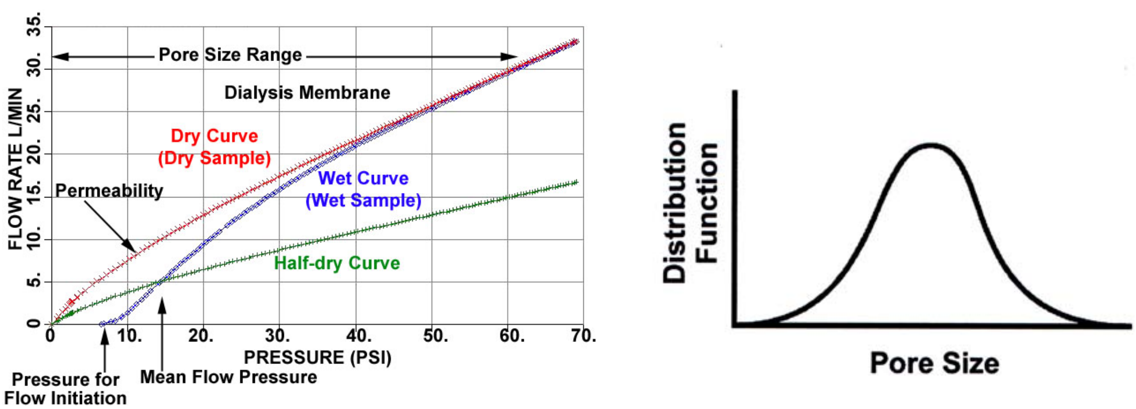


Figure 2. Characteristics measurable by on-line porometer.

INSTRUMENT

The unique feature of the on-line porometer is its sample chamber. The sample holder connected to the instrument by flexible tubes can be clamped on any wetted location for the instrument to measure pressure and flow characteristics at the location and evaluate the pore properties. Two models of the instrument were used in this study. In one model the mobile sample chamber is taken to any desired location on filtration media and clamped on for testing. In the second model the filtration media simply slides through the sample camber for testing. Figure 3 shows the instrument.

Figure 3. The PMI On-Line]

The instrument was fully automated. Windows based operation was simple. After the area to be tested was wetted and the sample chamber was clamped, the instrument automatically performed the test, acquired data, stored data and plotted data. The results were repeatable and reliable.

RESULTS AND DISCUSSION

MATERIAL
Seven commercial filter materials designated #1, #2, #3, #4, #5, #6 & #7were investigated. The first six materials were tested at random locations and #7 was tested at specific areas of the product.

REPRODUCIBILITY OF MEASUREMENT

Bubble points measured at a number of locations were repeated several times and repeatability of measurements were calculated in terms of standard deviation. For example, four repeat measurements at one location yielded pore diameters of 1.2958, 1.2876, 1,2540 & 1.2590 microns. Thus, the average value had a standard deviation of 1.4%. All the repeat measurements showed standard deviations less than 1.4 %. Thus, the instrument uncertainty was less than 1.4 %.

MEASUREMENT AT RANDOM LOCATIONS ON FILTER MATERIAL

Figure 4 illustrates the random locations at which tests were carried out on the six filters, #1 to #6. For a given filter, at least two repeat measurements were made at each location and the average value was taken as the pore diameter at that location. The average pore diameter of the filter was calculated as the average of the pore diameters at various locations. The deviation of the pore diameter at each location from the average pore diameter of the filter was computed. The deviation represented inhomogeneity of the filter material.

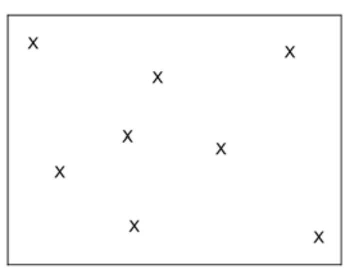


Figure 4. Random test locations.

BUBBLE POINT: The bubble points of the filter materials #1 to #6 are shown in Figure 5. Thus, the filters investigated had bubble points over a wide range between 120 and 25 microns.

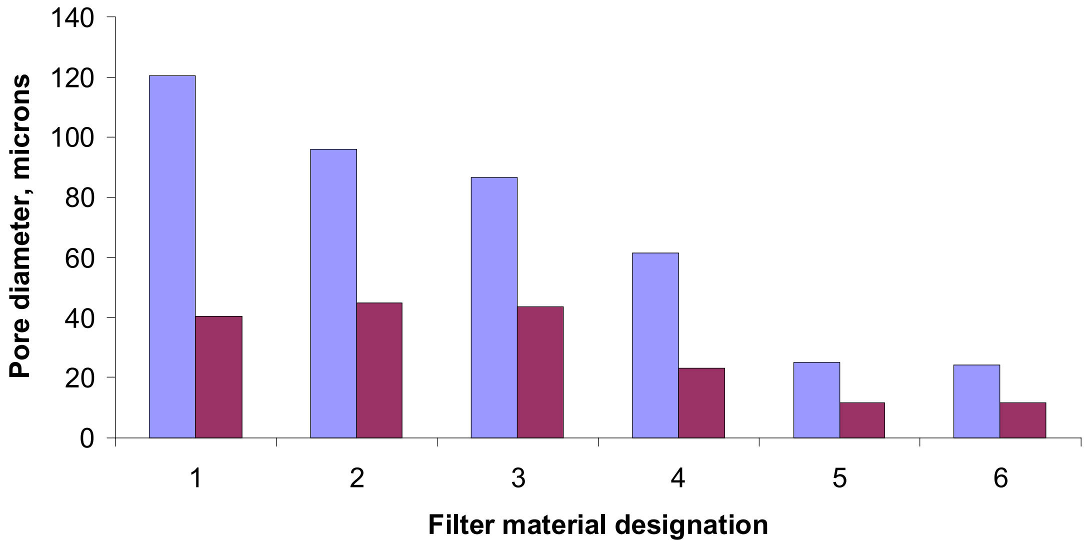


Figure 5. Bubble point and mean flow pore diameter in filter materials, #1 to #6.

The scatter in the bubble point values obtained at various locations of the same filter material is shown in Figure 6. The uncertainty of measurement (1.4 %) is also shown as error bars. It is clear that the variation from location to location is considerably more than the uncertainty in measurement. Some of the filters were highly inhomogeneous with scatter as high as 16 to 21 %, although one filter was homogeneous with a scatter of only 3.2 %. Others had scatters of about 6 to 9 %. The filter with a large bubble point, 86.54 microns had the minimum scatter of 3.2 %, where as the filter with a bubble point of 61.53 microns had a scatter of 15.6 %. Thus, there appears to be no correlation between pore diameter and scatter. This is demonstrated in Figure 7.

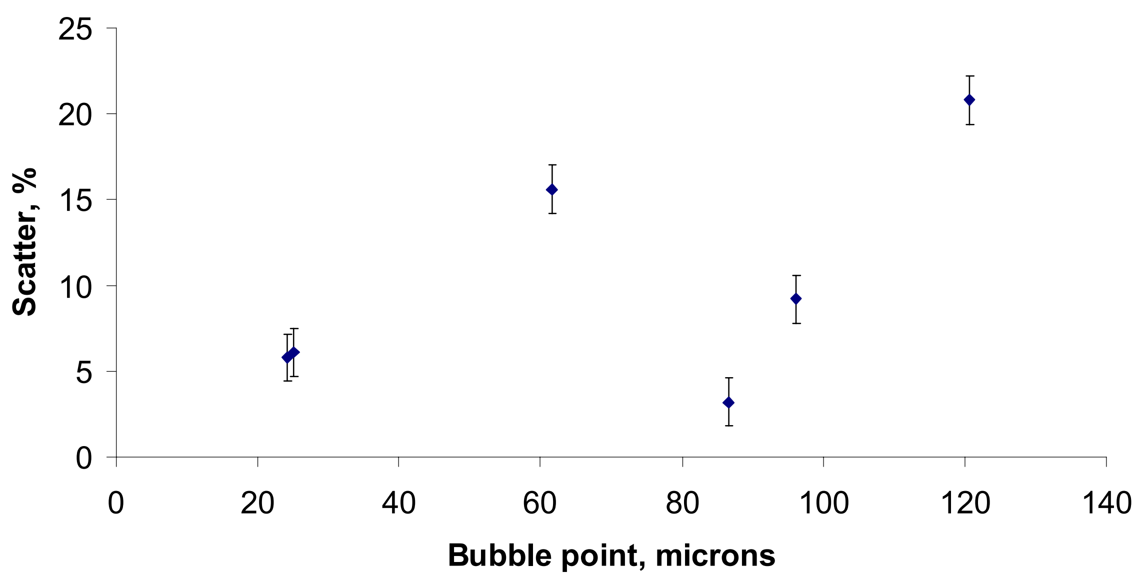


Figure 6. Scatter in the bubble point values measured at different locations of the same filter.
The uncertainty in measurement at each location is shown as error bars.

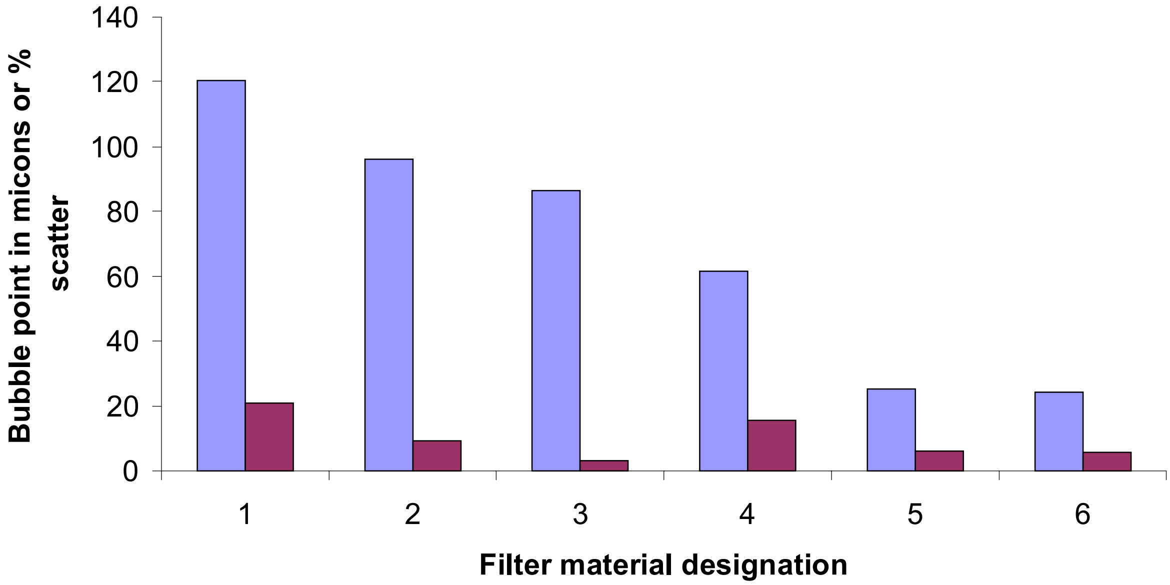


Figure 7. Bubble point pore diameter and scatter.

MEAN FLOW PORE DIAMETER: The mean flow pore diameters of filter materials are shown in Figure 5 along with the bubble points. The filters have a wide range of mean flow pore diameters between 12 and 45 microns. The scatter in the mean flow pore diameters measured at various locations in a filter is shown in Figure 8. The error bars in the data are the uncertainties in measurement at each site. The scatter is much larger than the uncertainty. The variation of 3.8 % in one filter material is very small, although the variation in other materials can be as high as 9.4 %. There is no correlation between mean flow pore diameters and the scatters as seen in Figure 9. Comparison of scatter in the bubble point and mean flow pore diameter shows that there is no correlation between the two scatters (Figure 10). The filter showing 20.8% scatter in the bubble point has only 4.8% scatter in the mean flow pore diameter.

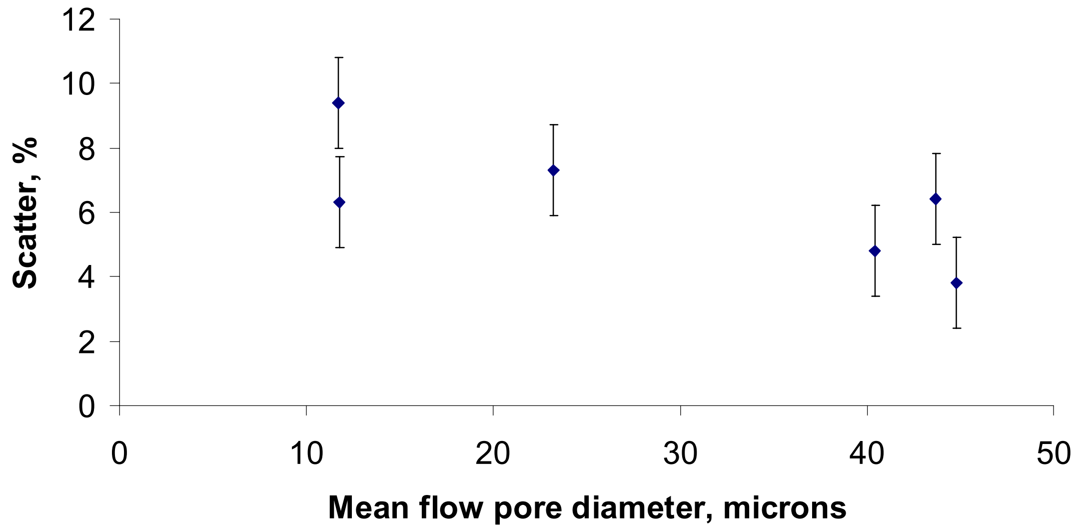


Figure 8. Scatter in the mean flow pore diameters measured at random locations in the filter. The uncertainty in each measurement is shown as an error bar.

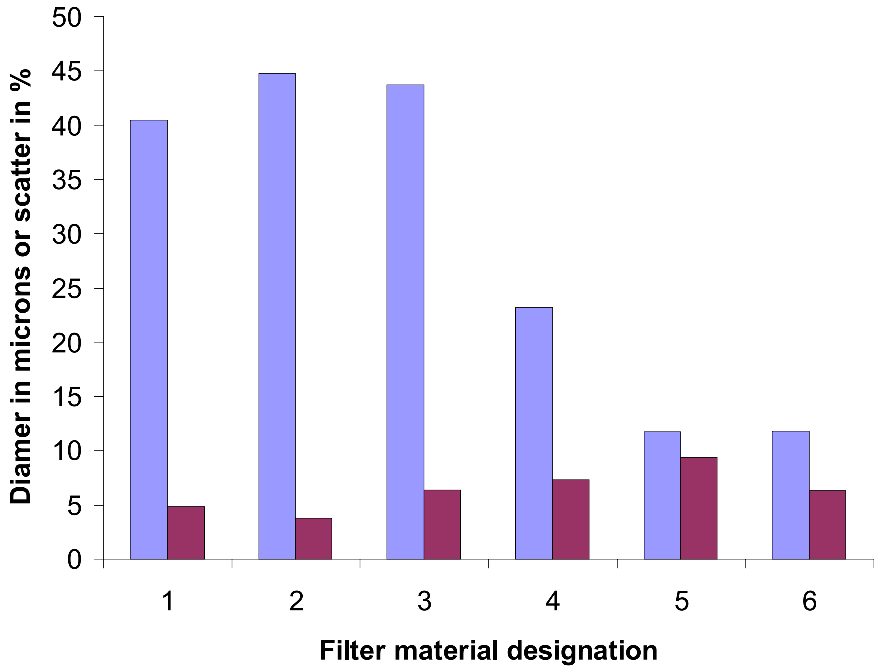


Figure 9. Mean flow pore diameter and scatter

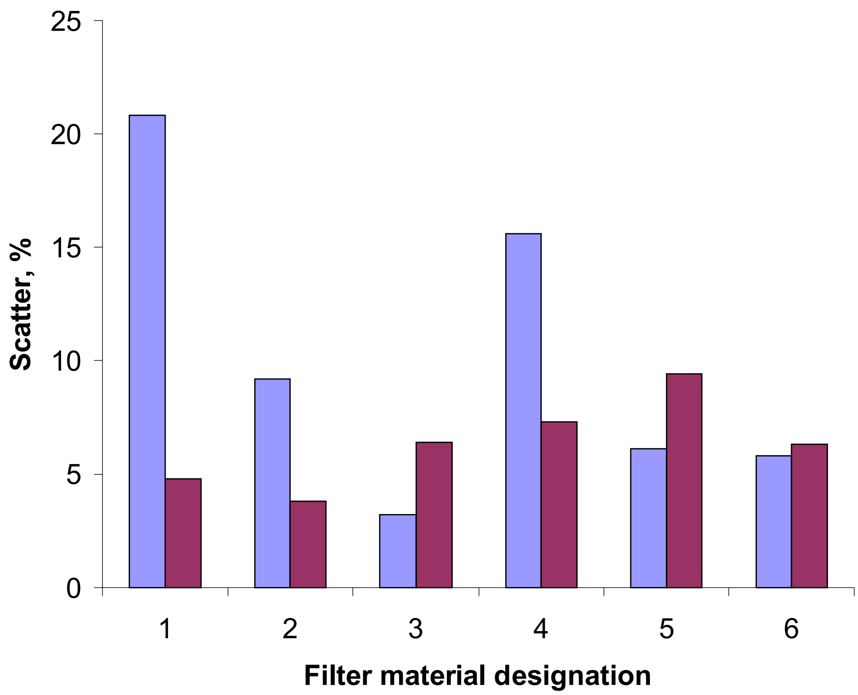


Figure 10. Scatters in bubble points and mean flow pore diameters measured at random locations in the filter.

MEASUREMENTS AT SPECIFIED AREAS OF FILTER MATERIAL

The manufacturing process often introduces defects in filter material in certain areas. These areas are likely to produce inhomogeneity. In one such filter material, three areas were tested as illustrated in Figure 11. The bubble points and mean flow pore diameters measured in any one of these three areas suggested homogeneous structure.

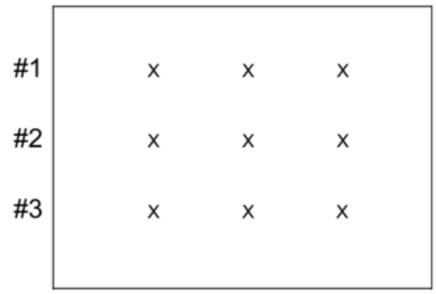


Figure 11. Measurements in specified areas.

Variations in pore diameters measured in different areas were appreciable. The average of measured values in all areas was calculated and deviation of the pore diameter of a given area from the average was calculated. The deviation from the average is plotted in Figure 12. The result shows that the bubble point at the three locations were identical as demonstrated by very little deviation of the bubble points from the average value. However, the mean flow pore diameters were considerably different from location to location. The deviations were as much as 16.3 % for area #1, 10.7 % for area #2 and 5.5 % for area #3.The position of the pore distribution peak also showed similar scatter. However, area #1 gave values less than the average, area #2 gave values higher than the average and area #3 gave values closest to the average.

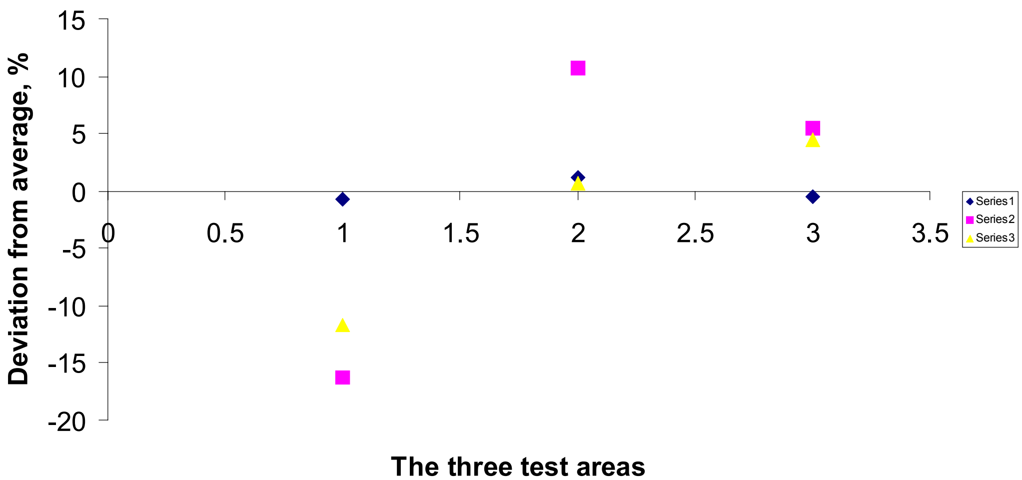


Figure 12. Deviation of pore diameters from the average at three different areas. Bubble point pore diameter (series 1), mean flow pore diameter (series 2) and peak diameter of the distribution peak (series 3) are included in the figure.

CONCLUSION

1. On-Line Porometer permitted testing of filter material at many locations without damaging the material in any way. This technique was used to investigate homogeneity of pore structure of a number of filter materials.
2. Six filter materials were tested at random locations. The instrument reproducibility was 1.4% at a given location. The bubble points and mean flow pore diameters were in the wide ranges of 121-25 and 45-12 microns respectively.
3. Several filter materials were considerably inhomogeneous with variations in bubble point from location to location of about 15.6- 20.8 %, although one of the filter materials was quite homogeneous with a variation of only 3.2 %. There was no correlation between bubble point and inhomogeneity.

4. Mean flow pore diameter showed variation between 3.8 and 9.4 %. These are much smaller than the variations in the bubble points. There was no correlation between mean flow pore diameter and variation.
5. One filter was tested in three different areas. Although each area was homogeneous, variation in pore characteristics of different areas was considerable.
6. Filter materials could be considerably inhomogeneous leading to inconsistent performance. It is, therefore, important to evaluate homogeneity of pore structure of filter materials.

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