Pore Size Distribution Analysis In Critical Filter Applications

A Question Of Definition

The important criterion in specifying a filter medium is usually it's cut point – will it remove or trap the particles in question? However, having the correct 'maximum' pore size is only part of the solution.

As particles build up on, or within the filter, a secondary filtration process can often occur where the effectiveness of the filter system as a whole depends on a combination of the filter medium and the product being filtered. In such situations the pore size distribution as well as just the 'maximum' pore size is an important parameter in understanding the filtration process. In certain applications where a filter cake has to be removed, it may be a disadvantage to have a broad pore size distribution, which can prevent clean or efficient product release. The reason for putting quotes around the word 'maximum' is that it is probably the most abused parameter in filtration. 'Absolute' maximum pore size is often specified without having an understanding of the uncertainty surrounding the term. The 'absolute' maximum pore size can only be found in a 100% examination of all the pores in the final assembled filter system (the filter medium and housing), which is clearly impractical for most applications. Even though the filter medium may be manufactured to specification, welding or other errors in the filter assembly could introduce flaws that totally eclipse any attempt at measuring the 'absolute' maximum pore size in the filter medium. To try to estimate the absolute maximum pore size pore from a small part of a larger filter cloth can also lead to uncertainties so large that the measurement is too unreliable to be of any use.

The reliability of the maximum pore size is therefore a function the homogeneity of the filter media as a whole and the ability to take a representative sub-sample for analysis. Assuming that a representative sample can be taken, the confidence in the maximum pore size is dependent on the number of pores examined. There is less uncertainty in finding and measuring 1 in a 100 pores (P99%) than in finding and measuring 1 in 10 million (P99.99999999%). Meas-uring a maximum pore size of P97% where there are 3 in 100 or 30 in 1000 pores is far more certain and repeatable (fig 1). Pore size defined as P97% is therefore considered the most statistically robust method of determining the maximum pore size.

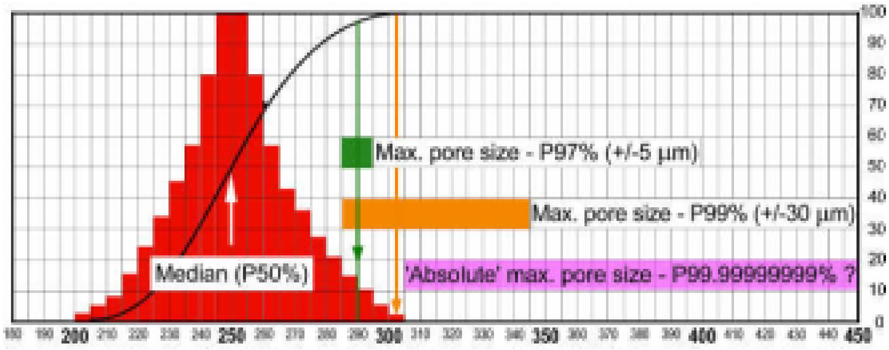

Fig. 1: Three definitions of 'maximum' pore size and the associated uncertainty

Fig. 2: Near mesh challenge particle trapped in a square mesh filter

Critical Applications Of Filter Media

In certain filter applications a knowledge of 'absolute' maximum pore size is critical to the point of being a life or death definition, for example, the ability of a filter to screen out certain toxins or viruses in medical applications.

In other applications, there may be a huge cost penalty to pay for incorrect specification of a filter system. For example 14 oil wells in the South China Sea recently 'plugged' because the wrong sand screens were used in the pipeline to the surface. To move the oilrigs and re-drill to the oil seam, sometimes up to 10,000 metres below, incurred a total cost of $300 million.

Pore Size Distribution From The Challenge Test

It has been known for some time that a test sieve can be calibrated using a near mesh method. This process involves challenging the test with a range of particles, which cover the anticipated range of apertures. Microspheres are the ideal challenging material because there is no shape implication. After shaking the microspheres over the surface of the sieve, oversize particles are removed by inverting the sieve and gently tapping. The tightly wedged microspheres between the wires are then released by gentle brushing and analysed by microscopy (Fig 2). The theory is that these 'near mesh'

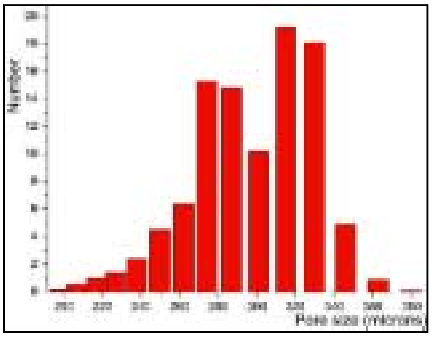

Fig.3: Challenge testing reveals detailed pore structure in a sand screen

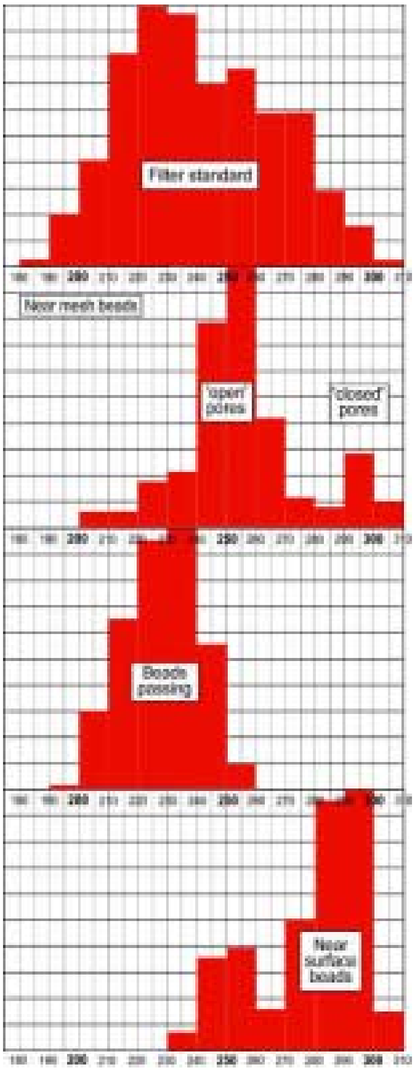

Fig.4: The fractionation of a filter standard during Sonic testing reveals 'open' and 'closed' pores.

microspheres replicate the range of apertures in the sieve [1].

This technique has been developed by Whitehouse Scientific to measure the pore size distribution of more complex 3-dimensional woven filters such as Dutch and twilled weaves used in sand screens whose internal pore sizes cannot be accurately determined by any other means. In sand screens for the oil industry, complex multi layered stainless steel meshes are used that are opaque to light so cannot be measured by microscopy as in the case of test sieves. However, using a Sonic filter tester, the structure can be penetrated with calibrating microspheres, which when released and measured give fine detail of the internal pore structure (Fig 3).

Identifying Open And Closed Pores

In the Sonic challenge tester the microspheres of the filter standard are acoustically energised through the depth of the filter. In the process, beads are trapped according to the widths of the pores in the filter. The maximum pore size can be determined from both the beads passing and those trapped within the filter.

If the two analyses correlate well, then the pore diameters are uniform through the depth of the filter (Table 1). However if the maximum pore size measured from beads recovered from within the filter is greater than that measured from the beads passing the filter, then the diameter at the point of entry is not sustained to the point of exit. Such a wedge shape pore is known as a 'closed' pore in woven filter media.

Fig. 4 shows the fractionation of a filter standard resulting from a Sonic pore size measurement. It can be seen that the maximum size of the beads trapped in the mesh are greater than the maximum size of the beads passing the mesh, indicating the presence of closed pores. In this case there is a discrete second peak showing that the weaving process produces a uniform set of larger pores in the filter structure, but these pores do not exit on the undersize.

A High Level Of Confidence

It can be seen from Fig. 4 that the particle size distribution of filter standards is quite narrow; the width of the distribution of each grade is designed to cover the expected range or pore sizes in the filter. The particles used are also spherical. The combination of these two factors result in highly reproducible results and many industries, particularly in critical applications, now specify Sonic challenge testing as the preferred method of pore size determination.

Sonic challenge test (beads passing)		**Near mesh challenge test (beads trapped)**		
Cut point (µm)	Projected Max pore D97 (µm)	Minimum pore size P3 (µm)	Average pore size P50 (µm)	Maximum pore size P97 (µm)
212	**233**	**182**	**209**	**233**

Table 1: Maximum pore size from Sonic and 'near mesh' methods

References:

[1] G Rideal, Particles and particle Characterisation Systems, 17, 1-7, Wiley, 2000

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