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Bubble Point: The bubble point test is based on the fact that for a given fluid and pore size, with constant wetting, the pressure required to force an air bubble through the pore is inversely proportional to the size of the pore diameter.[2] This is sometimes referred to as 'Capillary Theory'. In practice, this infers that the largest pore size of a filter can be established by wetting the element with a fluid and measuring the pressure at which the first bubble stream is emitted from the upper surface of the element when air is introduced to the open end. The standard test procedure (ARP 901/ISO 4003) calls for isopropyl alcohol (IPA) as the test fluid and maintaining a 0.5 in. head of fluid over the top surface of the filter.

The point at which the first stream of bubbles emerges is the largest pore. Therefore, the bubble point value can be used to obtain a relative measure of the size of the single largest pore in a filter element.

The relationship is based on Poiseuille's law which can be simplified to:

$$P = K/d$$

Where: P= Air Pressure, in. H_2O
K = an empirical constant dependent on filter material, form and units of testing
d = pore diameter, µm

Since this constant is essentially a capillary shape factor and is related to the material being tested as well as its form, it is easy to see why bubble point is typically only a relative comparison value for a given element and/or medium.

The accepted value of K varies from manufacturer to manufacturer due to differences in materials of construction, shape of components within the medium and test differences. However, for the most part, the values range from 143 to 149 when P is in inches of water column and d is expressed in µm. On this basis, a bubble point of 8 in. H_2O would indicate the largest pore of the filter being tested to be 17.9 to 18.6 µm in size.

As stated, the bubble point is intended to determine the single largest pore in a given sample of medium or a given element. On a graphical basis, Figures 2A and 2B provide an idea of where this point lies relative to the pore size distribution curve for a typical mesh and sintered fiber medium.

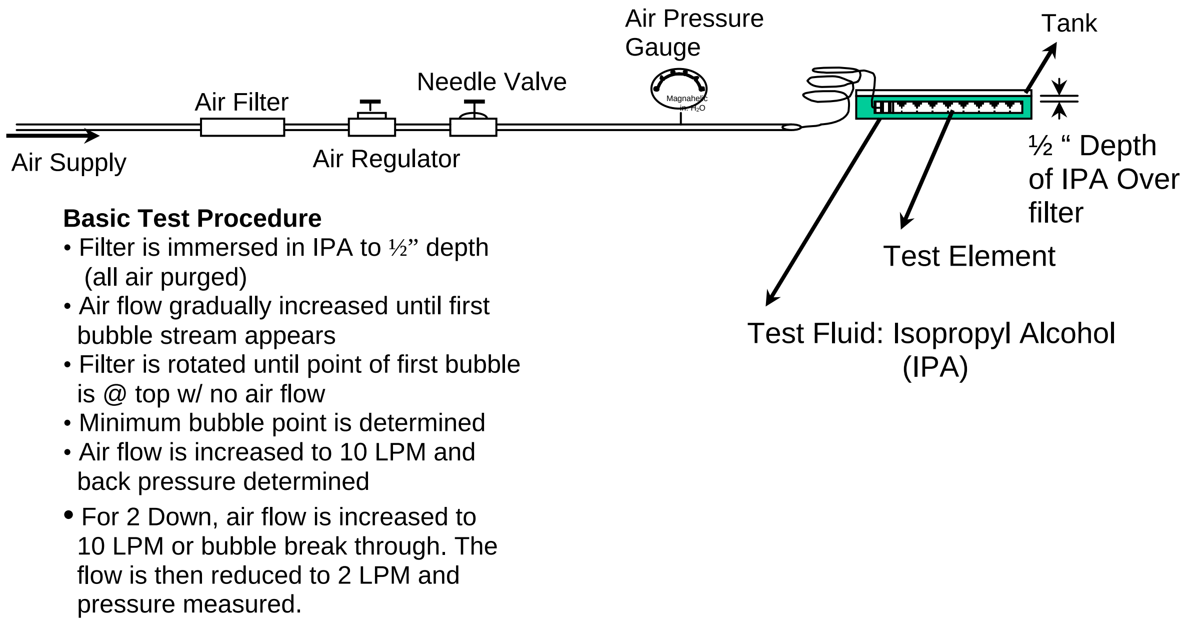

Figure 1: Bubble Point & Open Bubble Test

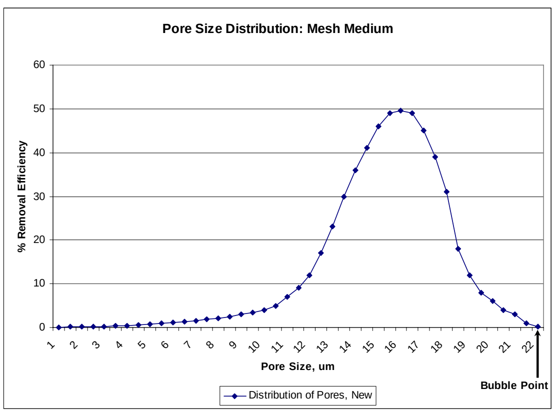

Figure 2A: Mesh Medium Pore Size Size Distribution and Bubble Point

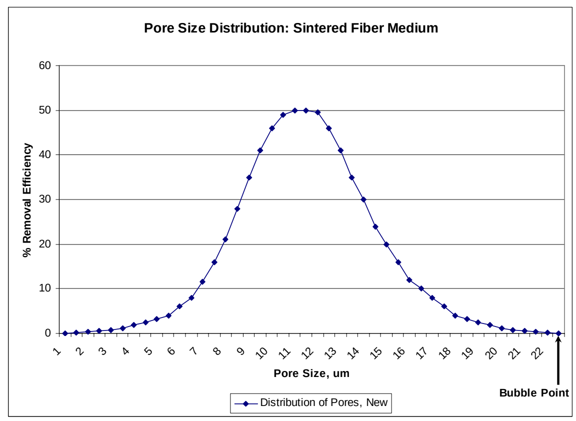

Figure 2B: Sintered Fiber Medium Pore Distribution and Bubble Point

As indicated by the two graphs, a medium has its own pore size distribution depending on composition. A mesh typically is referred to as a surface medium with a resulting narrow pore size distribution. A sintered fiber medium can be formulated to yield similar results. However, for this paper, we will assume that the sintered fiber medium has been formulated as an asymmetric depth type medium. This implies that the medium is tailored to provide course filtration on the outer surface with finer levels of filtration into the depth of the matrix. The result is a broad pore size distribution allowing larger particles to be captured on the outer surface while trapping smaller particles within the medium matrix and providing greater dirt holding capacity.[1]

If bubble point value is the sole test parameter used to qualify an element for subsequent usage, it is very likely that elements with sufficient integrity will be taken out of service. As a result, an end users may experience a significant negative impact to their operating economics. Another test that has been developed to help further qualify a filters integrity after use and subsequent cleaning is the 10 LPM or Open Bubble test. Many users now use this parameter or a combination of bubble point and 10 LPM to determine an elements fitness for reuse.

Open Bubble: The open bubble point measurement is a continuation of the bubble point test. If after the bubble point is measured, the air flow is increased until the bubbles emerge from the second largest hole, then the third and so on until a point is reached where air bubbles appear over the entire surface of the element the open bubble point is reached. This open bubble is a relatively good measure of the mean pore size of a new media[2] provided there are no other restrictions or physical limitations. Possible sources and impact of such restrictions will be discussed later in this paper. The test also gives the operator the chance to observe the physical uniformity of the media and identify any problem areas. The importance of this will be discussed later.

As an example, for an element with a standard 20 µm sintered fiber media lay up, a typical open bubble point value of around 9.5 to 10.0 in. H_2O would be the expected baseline (i.e. new condition before use) value. Compared to a bubble point value of around 7.5 to 8.0 in. H_2O. For specific media and applications, the difference between bubble and open bubble point test values can be used as a relative measure of certain characteristics (e.g. depth characteristics and tortuosity).

This test provides a somewhat broader perspective of an elements integrity as it challenges a greater number of the larger pores than does the single point Bubble Point Test. In addition, it offers the operator administering the test a better perspective of an elements condition by providing visual information about the media uniformity within the element. That is to say, if the bubbles generated are uniform and evenly distributed along the length and around the circumference, the element has an even distribution. However, if localized bubbling occurs at end welds, along seam welds or in damaged areas, the media within the element may be compromised. The extent and impact of this uneven distribution is a visual inspection limit that often comes from experience and customer feedback. It is a bit subjective but does allow identification of corrupted areas within the element configuration to be identified. Typically the operator will note large or localized bubble percolation at damaged locations and assign identification codes to designate their location.

As stated, open bubble point is intended to provide an idea of the mean pore size in a given sample of medium or a given element. On a graphical basis, Figures 3A and 3B provide an idea of where on this curve the open bubble point value lies relative to the pore size distribution for a typical mesh and sintered fiber medium.

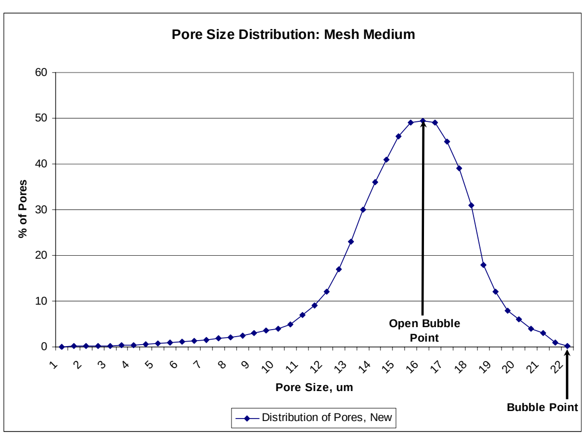

Figure 3A: Mesh Medium Pore Size

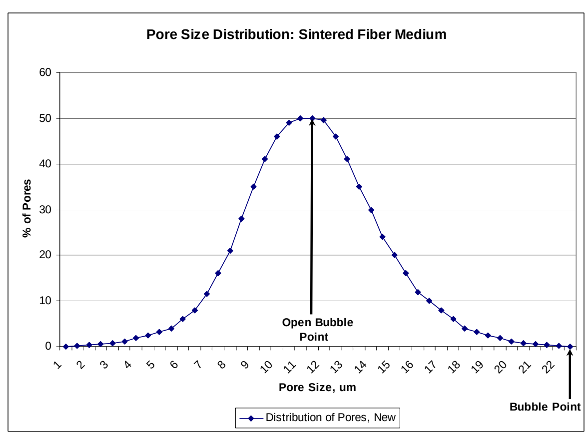

Figure 3B: Sintered Fiber Medium Pore

Distribution, Bubble and Open Bubble Point	Size Distribution, Bubble and Open Bubble Point

Summary:

It is generally accepted that the filtration integrity of an element will diminish with usage, cleaning and handling. As a result, it is important to have test methods available to predict the degree of change occurring relative to the initial filtration characteristics. The most simple and revealing tests employed today are bubble and open bubble point. While these tests cannot be used to determine precise filtration characteristics, they have been shown to provide relative information about filtration efficiency or changes in a filter when new as compared to characteristics following subsequent cleaning cycles.

The interpretation and assessment of the potential impact of changes indicated by these test results are critical to making the decision to continue using a given filter or filter set vs. its’ replacement. This decision has definite affect on the operating costs of a process or product as a result of influences on operating performance, product quality, maintenance and capital replacement costs. The potential cost risk of each contributor has to be considered in order to minimize affect of changes in filtration characteristics.