A NEW SONIC CHALLENGE TEST FOR THE PORE SIZE MEASUREMENT OF SAND SCREENS

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Summary

This report describes the development of a new method for the direct and unambiguous measurement of the pore size of sand screens. The calibration procedure utilizes a sonic sieving device that energises glass microsphere standards to efficiently transport them through the filter mesh. From the percentage passing, a calibration graph is used to determine the filter cut point, which is traceable to international standards of length. The definition of a cut point and its relation to the maximum pore size is also discussed. The repeatability of the method at all stages from single 90mm discs through the production process to the final assembled sand screens for the pipeline is rigorously investigated. The Sonic challenge test as it is known is compared to the Porometer method based on the bubble point test.

Note. This is the first version of a working document that will be regularly updated in line with the latest technical developments.
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ILLUSTRATED SUMMARY

Pore Size Measurement of Sand Screens Using Calibration Beads

1. **Precision Glass Microspheres**

   Prepare 20 narrow size range standards from 20 – 600 microns.

2. **Accurately subdivided**

   Identical sub-samples are prepared for each sand screen test.

3. **NIST Traceable certification**

   Electroformed sieve  Woven wire sieve

   NIST traceable
   Certified to NIST using calibrated precision electroformed sieves.

4. **Precision measurements**

   Good subdivision ensures highly repeatable certification.

5. **Calibration graph**

   The cut point is determined from the % of beads passing the screen.

6. **Screen sampling**

   Cut out 6 x 3½" discs from the length of the sand screen element.

7. **The beads in action**

   Fully automatic sand screen tester gives highly repeatable results.

8. **Pore size definition**

   The cut point is the size above which 97% of the particles are trapped by the filter, and is within 10% of the maximum pore size in the filter.

9. **A typical set of results from a test certificate**

<table>
<thead>
<tr>
<th>Initial Weight</th>
<th>Weight Retained</th>
<th>% Cut</th>
<th>Passing point</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.349g</td>
<td>0.279g</td>
<td>20%</td>
<td>135µm</td>
</tr>
<tr>
<td>0.341g</td>
<td>0.242g</td>
<td>29%</td>
<td>139µm</td>
</tr>
<tr>
<td>0.364g</td>
<td>0.267g</td>
<td>27%</td>
<td>138µm</td>
</tr>
<tr>
<td>0.375g</td>
<td>0.293g</td>
<td>22%</td>
<td>135µm</td>
</tr>
<tr>
<td>0.342g</td>
<td>0.260g</td>
<td>24%</td>
<td>136µm</td>
</tr>
<tr>
<td>0.361g</td>
<td>0.281g</td>
<td>22%</td>
<td>135µm</td>
</tr>
</tbody>
</table>

This latest technology offers unprecedented precision and confidence in the final performance.

**DEFINING PORE SIZE**
An idealised form of a filter is an electron etched foil where the apertures are circular and have the same size. Only in this case can pore size be described by a single parameter – pore diameter. All other filter media are irregular 3-dimensional structures whose pore size, shape, depth and size distribution is not so easily described, figure 1. Although complex mathematical modelling can give insight into pore structure, it is important not to lose sight of the function of a filter, which is to clarify a liquid or gaseous suspension of particles.

Notwithstanding pore size definition, the two most common specifications of a filter are mean or median size (sometimes called the nominal rating) and the maximum pore size. Mean or median sizes are conceptually easy to understand in that they are simply averages of all the pore sizes, however the relationship to the performance of a filter is a much debated issue.

Maximum pore size has more relevance to the ability of a filter medium to clarify a suspension and may be the foremost parameter sought in a filter but without qualification the term can be very confusing. For example, ‘absolute’ maximum pore size is the single largest detected pore, but how far must one look to find the pore?

The ‘absolute’ maximum pore size can only be found in a 100% examination of all the pores in the final assembled filter system constructed from the filter medium, which is clearly impractical for most applications. Furthermore, welding or other assembly errors in the filter system could introduce flaws that totally eclipse any attempt at measuring the ‘absolute’ maximum pore size. To try to estimate the absolute maximum pore size pore from a small part of a filter can 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%) while there is most confidence in measuring a maximum pore size of P97% where there are 3 in 100 or 30 in 1000 pores, figure 2.

Pore size defined as P97% is therefore considered the most statistically robust method of determining the maximum pore size.

In applications where the minimum pore size is also important, exactly the same statistical considerations apply as in the case of maximum pore size.

**THE CHALLENGE TEST PRINCIPLE**

Although defining pore size distribution of a filter medium is very useful in terms of its specification for a purpose, a practical assessment of performance should be the ultimate goal; will it retain the target particles?

Defining a filter medium by a more performance related criterion such as cut point may be more helpful. Cut point is measured by challenging the filter with real particles and measuring the maximum particle sizes passing. For the most unambiguous results, the challenging particles should be spherical and have a narrow particle size distribution, figure 3.

**PORE SIZE RANGES OF THE FILTER CALIBRATION MICROSPHERES**
In this work over 20 narrow particle size distribution glass microspheres standards have been prepared to cover pore sizes from 16 – 700 microns, table 1.

**Table 1:** Band Widths of Filter Standards (µm)

<table>
<thead>
<tr>
<th></th>
<th>16-25</th>
<th>20-34</th>
<th>26-36</th>
<th>31-46</th>
<th>36-55</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-62</td>
<td>53-73</td>
<td>63-86</td>
<td>75-103</td>
<td>80-123</td>
<td></td>
</tr>
<tr>
<td>106-147</td>
<td>127-175</td>
<td>151-209</td>
<td>180-248</td>
<td>214-295</td>
<td></td>
</tr>
<tr>
<td>252-346</td>
<td>304-417</td>
<td>360-498</td>
<td>383-591</td>
<td>484-700</td>
<td></td>
</tr>
</tbody>
</table>

By accurately measuring the particle size distribution both by microscopy and a precision electroformed sieving method, it is possible to construct a calibration graph for the microspheres where the percentage of the beads passing an unknown mesh can be used to calculate the filter cut point, figure 4.

As the results are traceable to international standards such as the National Institute of Standards and Technology (NIST), the derived filter cut points are also NIST traceable.

**PREPARING IDENTICAL SAMPLES FOR THE CHALLENGE TEST**

One of the most difficult and often overlooked aspects of calibration standards is in the preparation of identical sub samples from a master batch of powder. Unless the powder has an ultra-narrow particle size distribution there is always the possibility that some settling or segregation of particles of different sizes can take place. A consequence is that, not only is the small sample extracted not representative, but the remaining powder in the larger bottle has also been changed.

To overcome sampling problems it is essential that sub samples are taken in a representative way. The most effective method of subdivision is a spinning riffler where a carousel of bottles is rotated beneath a flow of powder from the master batch. Depending on the number of revolutions, each bottle can contain several hundred portions from the main sample, making each sub sample an identical fraction of the master batch, figures 5 and 6.
THE CHALLENGE TEST INSTRUMENT

Having a precision range of traceable microspheres is only the first stage in measuring filter cut points. There must also be an accurate and repeatable way of presenting (challenging) the filter medium with the standards.

The Gilsonic Autosiever, figure 7, is a unique system that uses intense sonic energy to produce an oscillating column of air, which flows through the body of the mesh. A tapping action helps to clear trapped particles within the mesh. This process energises the individual microspheres at rates of 3600 cycles per minute rather than mechanically shaking the mesh as in a conventional shaking process, figure 8.
An on-board computer programmes the entire test sequence thus eliminating any operator bias. Woven sand screens can be measured in a few minutes using the Sonic sifting device.

**MEASURING A FILTER CUT POINT**

To measure the cut point of a mesh, a 90mm diameter circle is cleaned in an ultrasonic bath for 5 minutes before being sealed onto a clear plastic ring to make a small sieve, figure 7. The assembled sieve mesh is weighed to 1mg on an analytical balance.

Between 0.2 and 0.5g (depending on filter rating) of the calibrating microspheres are weighed onto the mesh. The assembled mesh with the microsphere standard is then loaded onto the filter tester and a test run performed to determine the minimum amplitude of oscillation required to fluidize the microspheres evenly over the surface of the mesh. Ramp up and ramp down values refer to the time taken to reach the maximum set amplitude and then to reduce to zero again.

A typical test sequence is as follows: Ramp up: 0.1 minute, maximum amplitude: 30, run time: 1 minute, ramp down: 0.1 minute.

The end point of the test is when the weight of microspheres passing the filter no longer has an effect on the cut point, figure 9.

On completion of a test, the mesh and frame are removed and re-weighed to determine the percentage of microspheres passing. The cut point of the sand screen can then be found from the calibration graph supplied with the test certificate, see figure 4.
DEFINING THE FILTER CUT POINT

The particle size distribution of the filter standards is so narrow that more than a 5% change in weight is required to have a significant impact on the cut point (see figure 4 where an increase in percent passing from 80 to 85% corresponds to less than a 2 micron difference in cut point).

However, if the experiment was continued to 5 minutes or even to 5 hours there would be an increasing probability that the calibrating particles would find and pass through the largest single aperture present in the filter. So, although very close, the cut point does not represent the maximum pore size of a filter.

To understand the cut point more precisely, one must analyse the particle size distribution of the standard after it has passed the filter and compare it to the cut point, figure 10.

![Figure 10. Microscope analysis of the beads passing compared to the sonic test result](image)

In figure 10, 29% of the standard passed the sand screen, which corresponded to a cut point of 140 microns. When the microscope analysis (by volume) of the standard passing the filter was superimposed on the calibration graph, the cumulative percent undersize at 140 microns corresponded to a percentage of approximately 97%. This suggests that the filter would be 97% efficient in trapping particles above 140 microns.

To check the validity of this claim, the cut point was compared to the particle size at the 97% cumulative size distribution (D97%) for a wide range of sand screens from a nominal size of 85 microns up to 250 microns. In this case the microscope analysis was by number, which is more representative of the number of pores in the sand screen. The results in table 2 show an excellent correlation between the cut point and the D97% of the beads passing.
Table 2. Comparison of filter cut points with analysis of the beads passing

<table>
<thead>
<tr>
<th>Nominal Size (µm)</th>
<th>85</th>
<th>115</th>
<th>175</th>
<th>200</th>
<th>250</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter standard used</td>
<td>75-103</td>
<td>106-147</td>
<td>180-248</td>
<td>214-295</td>
<td>252-346</td>
</tr>
<tr>
<td>Filter cut point</td>
<td>90</td>
<td>137</td>
<td>202</td>
<td>243</td>
<td>296</td>
</tr>
<tr>
<td>Beads passing (D97%)</td>
<td>98</td>
<td>129</td>
<td>209</td>
<td>247</td>
<td>299</td>
</tr>
</tbody>
</table>

To check the repeatability of both the Sonic challenge test and the microscope analysis of the beads passing, the 200 micron sand screen was tested 3 times and the two methods of analysis compared. The 90mm disc was thoroughly cleaned between each test. The results are shown in figure 11 and table 3.

![Figure 11.](image)

Repeatability of the microscope analysis. 3 tests on beads passing the same 90mm diameter disc.
Although the average values in Table 3 show an increase in particle size of the beads from the D90% to D97% of 6 microns (2.5%), this is within experimental error and is therefore not considered to be significant.

**Table 3.** Comparison of cut point with the size of the beads passing

<table>
<thead>
<tr>
<th>Sand screen*</th>
<th>Filter calibration standard used: 214 - 295µm</th>
<th>Size of beads passing at stated percentile µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>Cut point µm</td>
<td>90% &lt;</td>
</tr>
<tr>
<td>Test 2</td>
<td>243</td>
<td>243</td>
</tr>
<tr>
<td>Test 3</td>
<td>243</td>
<td>244</td>
</tr>
<tr>
<td>Average</td>
<td>243</td>
<td>243</td>
</tr>
</tbody>
</table>

* The same test disc was used each time after thorough cleaning

The overall results show excellent correlation between the cut point and the D97% of the beads passing and underlines the importance of using narrow particle size distribution filter standards. The cut point by the sonic challenge test is therefore defined as follows:

**FILTER CUT POINT**

The size above which there is a 97% chance of particle capture

**THE RELATIONSHIP BETWEEN FILTER CUT POINT AND MAXIMUM PORE SIZE**

To obtain a more accurate assessment of the relationship between cut point and maximum pore size, the same 200 micron sand screen mesh was challenged with two very narrow particle size distribution particle size standards, figure 12 (the blue bands represent the uncertainty of measurement from the test certificates).
The first has a peak at 236 microns with 90% of the beads between 224 and 246 microns. 90% by weight of the 0.5g passed the sand screen indicating a maximum pore size in excess of 245 microns, which was consistent with the results obtained in table 3.

The second monodisperse standard had a peak at 259 microns with 90% of the beads between 251 and 265 microns. Only about 2% of 0.6g of the standard passed, which puts the maximum pore size below 250 microns, but allowing for the error bar, this could increase to 255 microns.

However in the 2% of beads that did pass, 2 or 3 particles up to 264 microns were detected, which is 9% above the cut point. The Sonic challenge test therefore provides the following information:

<table>
<thead>
<tr>
<th>Filter standard Initial wt g</th>
<th>Retained wt. g</th>
<th>Wt passing g</th>
<th>% passing</th>
<th>Filter cut point</th>
</tr>
</thead>
<tbody>
<tr>
<td>127-175</td>
<td>0.341</td>
<td>0.306</td>
<td>0.035</td>
<td>10</td>
</tr>
<tr>
<td>106-147</td>
<td>0.325</td>
<td>0.073</td>
<td>0.253</td>
<td>78</td>
</tr>
</tbody>
</table>

Note: This relationship only applies to Hollander weave sand screens. Non woven and other types of sand screen may have a different relationship between cut point and maximum measurable pore size. This is the subject of ongoing research.

### SELECTING A FILTER CALIBRATION STANDARD

It can be seen from table 1 that there is an overlap of sizes between adjacent grades. In selecting a standard, optimum results are obtained between 80 and 20% passing. Where two grades are suitable for a particular analysis, it is better to use the larger size because it will be more sensitive to the larger pores (provided it falls within the 20 – 80% band).

Table 4 shows a comparison of two standards for the same nominal mesh of 115 micron. Although the results are very similar, in this instance it is better to use the smaller particle size grade because it is closer to the 20 – 80% band.

It is worth noting that the filter standard selection also depends on the description of the filter by the manufacturer. If the sand screen is labelled according to its nominal (mean) pore size, a larger size standard will be required to determine the cut point because the cut point measures a pore size closer to the maximum size rather than the mean pore size (see above).

### MEASURING THE WEAVING PRECISION IN A SAND SCREEN

#### a) Establishing the repeatability of cut point testing

The calibration of the filter standards using highly accurate electroformed test sieves has been shown to be exceptionally repeatable with variations below 1% across the entire width of the size distribution (note the extremely narrow uncertainty band in figure 4).
It was also shown above that when the same disc is tested several times using the precision microspheres, there is a similar excellent repeatability, table 3. Any variations within a sand screen roll is therefore most likely to come from the weaving process rather than any inherent variation in the Sonic testing method.

In the second repeatability experiment, three 90mm discs were cut close together from a stainless steel sand screen of nominal aperture size 100\(\mu\)m and tested using a 106-147\(\mu\)m calibration standard. The results in table 5 show that the cut points were indistinguishable.

Table 5. Close proximity testing of a sand screen discs

<table>
<thead>
<tr>
<th>Sand screen test</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut point ((\mu)m)</td>
<td>121</td>
<td>120</td>
<td>119</td>
</tr>
</tbody>
</table>

b) Assessing weaving tolerances in a sand screen roll
The next experiment investigated the variation of the cut point with respect to the sampling position on a 3 metre length of a sand screen roll. The nominal 200\(\mu\)m rating sand screen required a 214-295\(\mu\)m filter calibration standard.

Two adjacent 90mm diameter discs were cut from the edge of a 3 metre long section of mesh and as expected were very close. Samples were then taken across the width of the roll and at 2 and 3 metre intervals down the length of the roll, figure 13.

Although larger variations were seen when sampling over a wider area, the results were nevertheless very good for a weaving process and compare very well to the best technology offered by test sieve mesh manufacturers.

c) Replicate testing from roll to roll
In the final series of repeatability testing, pairs of adjacent samples were cut from positions across three different sand screen rolls of nominal rating 115 microns.

The results in table 6 show that, when samples are taken which are physically close together on the roll, the maximum difference in aperture size observed was approximately 5%. Thus, the repeatability of this method is usually less than 5%.
d) Quality assurance checking during sand screen weaving

Because the cut point of a filter can be carried out so quickly using the Sonic challenge test, it is possible to accurately monitor quality control during the production of sand screen meshes. Having established that the size variation on a single roll was approximately 5%, the next phase of the work was to examine the overall uncertainty from roll to roll by taking much larger samples. 25 random samples were taken from several rolls of sand screen meshes having target cut points 270µm, 230µm and 150µm. The results in figure 14 show excellent consistency over a prolonged period and illustrate the precision that can be achieved in the weaving process.

A statistical analysis of the results confirms that both the production process and the Sonic challenge test method of analysis are extremely accurate, table 7.

![Figure 14. Cut point variations of sand screen meshes during production using the Sonic Challenge test](image)

Table 7. Cut point variations during sand screen production

<table>
<thead>
<tr>
<th>Target Cut point µm</th>
<th>Measured Range (25 tests) µm</th>
<th>Uncertainty µm (2 x SD*)</th>
<th>Final Size µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>270</td>
<td>263 – 283</td>
<td>12.4</td>
<td>272 +/-12.4 (4.6%)</td>
</tr>
<tr>
<td>230</td>
<td>225 – 240</td>
<td>6.8</td>
<td>231 +/-6.8 (2.9%)</td>
</tr>
<tr>
<td>150</td>
<td>143 – 154</td>
<td>6.0</td>
<td>147 +/-6.0 (4.1%)</td>
</tr>
</tbody>
</table>

* SD = Standard Deviation
The calculated uncertainty means that there is a confidence level exceeding 95% that the cut point achieved during production will fall within the stated range. The production tolerance for every grade is therefore below than 5%.

e) Quality assurance in the final fabricated sand screen

Once a validation procedure has been established in the manufacture of woven sand screen meshes, the last test on the quality assurance route is to check the performance of the fabricated filter element.

There are two possible sources of error. The first is that the wrong sand screen mesh has been fitted. As the challenge test is a destructive method, it is not possible to measure the cut point of every sand screen tube, otherwise there would be none left to put underground.

It is therefore recommended that a given roll number is first tested to establish weaving consistency as described in ‘Assessing weaving tolerances in a sand screen roll’ above. A test certificate for the roll would then be sufficient to accompany any part of the roll for fabrication into the final form, figure 15.

In checking the final fabricated sand screen, it is recommended that six 90mm discs are cut from random positions. The results of such a test are shown in table 8.

<table>
<thead>
<tr>
<th>Sample #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>% passing</td>
<td>27</td>
<td>28</td>
<td>27</td>
<td>31</td>
<td>26</td>
<td>28</td>
</tr>
<tr>
<td>Cut point (µm)</td>
<td>138</td>
<td>139</td>
<td>138</td>
<td>140</td>
<td>138</td>
<td>139</td>
</tr>
<tr>
<td>Filter standard used 127-175 µm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The second source of error is in the welding of the mesh layers into the tube itself, figure 15, but this is beyond the scope of this report. A visual inspection is probably sufficient as the open area involved should be minimal compared with the area of the pores.
FILTER CALIBRATION SERVICE

Because of the enormous financial consequences of inserting an incorrect sand screen down an oil well, calibration of the meshes is undertaken directly at the Whitehouse Scientific laboratories. The validity and repeatability of the results are recognised by some of the leading oil exploration companies, some of whom will only approve a sand screen that has a Whitehouse Scientific test certificate. A rapid turnaround service is offered giving clients results within 48 hours of receiving the samples.

Where more rapid feedback is required, for example, in the process control of the weaving, Whitehouse Scientific offer a satellite facility where the necessary equipment is supplied and staff are trained and authorized to issue test certificates on behalf of Whitehouse Scientific.
1. **Filter Reference:** XXX
2. **Client:** XXX

**Calibration Method:**
Clamp a disc of the filter to be tested in the Perspex filter holder of the Automatic Sonic Filter Tester. Tare and add approximately 0.3g of the calibrating microspheres. Record the weight of microspheres before transferring to the test machine. Run under the conditions specified below and reweigh to calculate the percentage of microspheres passing the filter. From the percentage passing, use the graph or equation below to determine the pore size of the filter under test.

3. **Test Conditions:**
   a) Microsphere Size Range: 127 - 175µm
   b) Filter Tester Settings: ramp up time 0.1 minute, amplitude 30, run time 1 minute, ramp down 0.1 minute

4. **Microsphere Calibration Graph:**

![Graph of Microsphere Calibration](image)

5. **Microsphere Calibration Equation:**
   \[ \text{Filter Cut Point} = 124.63 + 0.527 \times - 0.00115 \times^2 + 0.0000142 \times^3 \]
   where \( \times = \% \text{ passing} \)

6. **Analysis Results:**
   Initial Wt: 0.342g, Wt Retained: 0.239g, Percent Passing: 30%, **Filter Cut Point: 139µm**

**Authorised by:** Dr G R Rideal - Senior Analyst

**Notes:**
1. Filter cut point is the size above which there is a 97% chance of particle capture.
2. The electroformed sieves used to measure the particle size of the microspheres were calibrated by optical microscopy using reference graticules from NIST (821/263573-00) and NPL (086038/970127/106-66). For full details of see web site [www.whitehousescientific.com](http://www.whitehousescientific.com).
3. Whitehouse Scientific Ltd does not accept responsibility for losses, financial or otherwise which may occur as a result of the interpretation or use of the information contained within this certificate.
4. Whitehouse Scientific is the leading European particle size certification laboratory for the Community Bureau of Reference (BCR), Brussels (Laboratory News - August 1996).
PORE SIZE MEASUREMENTS USING POROMETERS

The earliest form of ranking the performance of filter media was through permeability testing, using air or water, but these methods were not able to determine pore sizes. Later bubble point testing was developed to detect the largest pore.

In this technique a wetted filter medium is subjected to increasing air pressures until a bubble breaks through the surface, a technique akin to leak testing welds in steel containers. Very soon a relationship between the pressure applied and the size of the pore was developed but it was a theoretical relationship assuming cylindrical pores.

To estimate the range of pore sizes, the flow rates of air through a dry filter at increasing pressures is first measured, a ‘dry run’. The filter is then wetted and the process repeated. Initially there is no air flow because all the pores are blocked by the liquid, but at a critical pressure, the bubble point, the largest pores offer the least resistance and air is forced through.

At increasing pressures smaller pores are cleared until at the highest pressure even the smallest pores are emptied of liquid. At this point the flow rate returns to that of the dry filter medium. The mean pore size is estimated to correspond to the pressure at half the maximum flow rate. The pressure range therefore relates to the pore size range. The method is called Porometry and is summarised in figure 16.

COMPARISON OF SONIC CHALLENGE TEST AND POROMETRY

The pore size of a range of woven polymer filter media supplied by Madison Filter were measured by both the Sonic challenge test and two Porometers - the Coulter I and the PMI-1100. A side view of the construction of the filter is shown in figure 17. It can be seen that there are two interwoven layers, a top layer responsible for the filtration and a lower layer providing mechanical strength. In this regard it is similar to some of the multiplayer sintered
woven filter media used in sand screens and therefore provides a useful model for comparing pore size measurement methods.

The cut point from the Sonic challenge test was used to determine the maximum pore size, which was then compared to the maximum pore size obtained from the bubble point methods. The mean pore sizes were also measured by the Porimeters. The results are summarised in table 9.

<table>
<thead>
<tr>
<th>Filter</th>
<th>Sonic challenge test</th>
<th>Coulter-I (µm)</th>
<th>PMI-1100 (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mfg's Rating (µm)</td>
<td>Cut point (µm)</td>
<td>Max pore (µm)</td>
<td>Max pore (bubble pt.) (µm)</td>
</tr>
<tr>
<td>20</td>
<td>21</td>
<td>23</td>
<td>36</td>
</tr>
<tr>
<td>40</td>
<td>36</td>
<td>40</td>
<td>56</td>
</tr>
<tr>
<td>50</td>
<td>48</td>
<td>53</td>
<td>90</td>
</tr>
<tr>
<td>70</td>
<td>75</td>
<td>83</td>
<td>180</td>
</tr>
<tr>
<td>100</td>
<td>95</td>
<td>105</td>
<td>160</td>
</tr>
<tr>
<td>140</td>
<td>140</td>
<td>156</td>
<td>230</td>
</tr>
<tr>
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It can be seen from the Sonic challenge test that the cut points are in line with the expectations of the manufacturer. However there are large differences in the maximum pore size when comparing the two Porometers.

There are three possible explanations for these observations; firstly, the sample disc used in measurement is only 25mm in diameter so there could be problems in obtaining a representative sample for analysis. Secondly, the maximum pore size measured by the bubble point may be closer to the ‘absolute’ maximum so giving rise to a wide band of uncertainty as illustrated in figure 2. Finally, as can be seen from the section in figure 20, the cylinder model of a pore used to convert flow rates to pore sizes is not a good simulation of the actual pores and may need to be corrected for this application.

The mean pore sizes are much more consistent, which is to be expected because they form the majority of the pores. However the 70 micron and 170 micron samples had...
disproportionately high mean pore sizes. These were found to result from the high air and water permeabilities of these samples, which seems to affect Porometer results.

Full details of this research was published at the World Filtration Congress (WFC9) in New Orleans, April 2004, see the Library section in www.WhitehouseScientific.com for the full paper.
CONCLUSIONS

1. The narrow particle size distribution glass microspheres used in the sonic challenge test produce a pore size defined in terms of the equivalent spherical diameter.
2. Sonic challenge testing is a highly accurate and rapid method for the certification of sand screens.
3. The results are unique in that they are traceable to NIST (the National Institute of Standards and Technology, USA).
4. The ‘cut point’ measured by the test is the size above which 97% of particles are trapped by the filter.
5. The maximum measurable pore size is approximately 10% above the cut point for Hollander weave sand screens.
6. Repeat measurements on the same sample disc were within 1%.
7. Cut point differences in a roll of sand screen were less than 5%.
8. In a prolonged quality control experiment during production, 25 tests on 3 different grades showed a variation of less than 5%.
9. When a fabricated sand screen tube was cut up and analysed, the 6 discs had cut points within 1%.
10. Sand screens should be specified according to their cut points, which can be readily measured, rather than a nominal or average pore size, which cannot be accurately measured and does not reflect the efficiency of the sand screen.
11. The uncertainty of the results from Porometers make them unsuitable for the reliable determination of pore sizes in sand screens.