ABSTRACT
Filter media with an engineered gradient structure can optimize the filtration efficiency, pressure drop, and holding capacity of media performance. An important part of establishing these properties for a specific application is to determine the porosity of the media design. Through media characterization, liquid filtration media can be designed to fit most applications. Kimberly-Clark Corporation has designed a unique media to provide improved filtration efficiency without sacrificing dirt-holding capacity. The media is 100% polyolefin and is thermally bonded for strength. This media is chemically compatible with most liquid applications and does not contain binders that can interfere with the fluid chemistry.

This paper describes the parameters for developing a gradient structure and designing it for specific applications. The liquid filter media used in these applications clean better, clean longer and reduce end user costs.

INTRODUCTION
Choosing a filter media for a filtration process requires information regarding the specific application. What is being filtered? What is the particle size of the particulates? How many of the particulates need to be filtered or what efficiency needs to be achieved? When choosing a filter media, does the performance of the product outweigh the cost? When selecting a media, what does the rating of the media indicate? These are just a few of the questions a filter media purchaser should ask when they are searching for the right media to fit their application.

For most applications, the ideal filter media will provide a high filtration efficiency, low pressure drop and high dirt holding capacity. To accomplish all three of these attributes, the filter media must capture the desired particles, minimize the pressure loss, and require less frequent filter changes. Most filtration applications require a balance or optimization of these three attributes. Kimberly-Clark has a unique process that can manufacture media with a density gradient structure and the proper pore structure to enhance this balanced performance. The filter media thickness and pore structure are engineered using fiber diameter, fiber crimp, and fiber arrangement. An optimized pore structure traps a broad range of particle sizes; thus the media exhibits higher efficiencies and/or dirt holding capacity with minimal increase in pressure drop. Figures 1, 2, and 3 demonstrate thickness and pore structure differences within the same basis weight range.
Before presenting industry examples on the importance of media characterization and filter media design, this paper discusses the different types of filter mechanisms, the meaning of pore characterization and how these material properties affect the filter.

FILTER MEDIA DESIGN

Knowing a customer’s requirements prior to designing a filter media is imperative. As noted below, there are a variety of mechanisms and characteristics that play a role in filter performance. These unique properties must be considered when manufacturing a filter media to achieve end user satisfaction. These characteristics and mechanisms often include filter loading, particulate size, filter life and filter efficiency. The cost to performance ratio is another important consideration. The initial media cost may be more per square yard, however because the media efficiency is greater, less media is used annually. During the oral presentation of the filter press case studies, the results demonstrate increased coolant life leading to lower disposal costs, less frequent roll changes and improved efficiency in metal working applications. Below, the different characteristics and mechanisms in filtration are described.

Mechanisms

The four types of mechanisms in filtration are briefly reviewed below. The two mechanisms that work as gradient structures are depth straining and depth filtration.

Surface loading is a mechanism where the pores are smaller than the particles collected on the surface of the filter (see Figure 4). As the surface loads, the differential pressure increases.

Cake Filtration is a mechanism where a thick layer or cake of particles accumulates on top of the media. These particles are usually larger than the pores in the media (see Figure 5). This mechanism is effective in solids recovery because as the cake gets thicker, the efficiency can improve.
**Depth Straining** is a mechanism where the particles move through the media and are physically entrapped in the web structure (see Figure 6). The pore sizes are smaller than the particles retained. Particles smaller than the pore structure will penetrate through the media. This application is widely used in liquid applications and in less critical air applications.

**Depth Filtration** is a mechanism where particles smaller than the pore structure are trapped within the media. This mechanism involves several complex forces, such as impaction, interception and diffusion, which act on the particles and result in high efficiency (see Figure 7). These forces all depend on the relationship between media construction and particle size to provide high efficiency in air applications.

Depth straining and depth filtration are both mechanisms that work in gradient structure media. The pore structure is open on the face of the filter and the packing density of fibers and their diameters can change through the filter and result in more restrictive pores. This tortuous path results in improved efficiency and life with minimal pressure drop. Both of these filtration mechanisms allow greater utilization of the filter media in the z direction.

**Gradient Structure Design**
Innovations at Kimberly-Clark have provided advancement in filtration media. Filter media, in general, provide some level of efficiency, pressure drop and holding capacity. To improve the performance in one area, the functionality of the filter is usually compromised in another area. Kimberly-Clark Filtration Products uses a proprietary process that can control the fiber forming process to balance these three attributes for optimum filter media performance. The process can customize fiber diameter and fiber
arrangement to create gradient structures. These structures are beneficial in both liquid and air filtration applications.

The fibers in POWERLOFT® Media are 100% polyolefin, specifically polypropylene and polyethylene. The dual polymer construction of the fiber allows the manufacturing process to be adjusted to control fiber diameter, fiber density, fiber crimp and bond strength between fibers. With control over these fiber properties, the construction of filter media can be designed with a pore structure to meet desired filtration requirements. Depending on the size of the particles to be removed, the pore structure is built to filter these particles with the optimum balance between filtration efficiency, holding capacity, and pressure drop. The following sections discuss how pore characterization is used to characterize and design media to fit the needs stated above.

**DESIGN AND CHARACTERIZATION OF A POROUS MEDIUM**

Accurate pore size determination is critical in determining how effective a material will perform in its final application. Knowing the rating of a filter media and understanding what this rating means is necessary for selecting the correct media for an application. If the product is labeled as a five-micron nominal product, does this mean it will filter out 100% of the particles five-microns and larger? Or is it stating that it will remove most of the particles close to five-microns? How did the filter manufacturer arrive at this rating? Does it perform the same as any other five-micron media? Currently, there is not a standard pore characterization test method in the liquid filtration industry that is followed by all industry participants. Businesses use a variety of methods from the Frazier Permeability test to the bubble point test to establish a micron rating for their products. With such a wide number of test methods, decisions about media performance and which media may work best in an application are difficult.

For the reasons stated above, the Kimberly-Clark Corporation does not label its filtration products with specific micron ratings. Instead, the liquid filtration team tests and performs a complete media characterization. The results are used to guide the design of filtration media to meet or exceed customer expectations.

**Pore Characterization**

When choosing a filtration product, it is necessary to recognize the importance of the media characteristics. The micron rating alone does not provide the end user with enough information on how a media will perform. Frazier Permeability and the bubble point provide some performance expectation. The pore distribution and the mean flow pore (MFP), or the average pore size where flow occurs, are additional media characteristics that are of value. In the case where only the bubble point is considered, the size of the particles that will be filtered can be determined. Typically, any particles larger than the bubble point will not filter through the media. But, what if the bubble point is only a small portion of the total pore distribution? In this case, the bubble point may not be relevant. A more relevant number would be the pore size that is prevalently found in the media. This pore size would be the most important value used to design or select a media. Thus, the cumulative data provided from all these media characterizations are properties
to consider when designing a media. Each characteristic is a part of the total filter media performance and enables the user the opportunity to determine what filter performance to expect.

Figure 8 is a Sample Pore Characteristic Curve. It graphically shows the location of the bubble point, the mean flow pore and the pore distribution. To obtain this information a sample is wet with wetting fluid, which acts like a plug. As pressure is applied to the sample, a point is reached where the wetting fluid is pushed out of the largest pore. This is termed the bubble point. As the pressure continues to increase, the flow through the open pores increases as the pores continue to release their wetting fluid. This continues until all of the pores are open. The information collected is used to graph the wet curve described in Figure 8.

The path of the wet curve tells a lot about the pore distribution. A curve that is vertical symbolizes a narrow pore distribution. Conversely, a wet curve that moves from vertical to horizontal, represents a widening of the pore distribution and finer particle filtration. Depending on the application, either media may be beneficial. Recall Figures 1 through 3. Figure 1 represents a low loft media as compared to Figure 3, a high loft media. Figure 3 has a longer life and a greater efficiency. If the wet curves of each of the figures are compared, Figure 1 would be the most vertical followed by Figure 2 and Figure 3. As the curves move to a horizontal position, the life and efficiency of the media increase for finer particle filtration.

**Pore Characterization Sample**
Figure 9 compares the pore characteristics of two media. From the graph, it can be seen that Media Two does not match Media One because the bubble points and the pore
distributions are not equivalent. Keep in mind the pore size is inversely proportional to the pressure. The bubble point for Media Two is smaller, therefore Media Two will remove smaller particles. Also, the pore distribution of Media Two lies to the right of Media One. As we have already discussed, the distribution that lies horizontally is a media with a wide distribution of micron sizes and the capability to filter smaller particles. Therefore, Figure 9 signifies that, overall, Media Two will filter out smaller particles than Media One with a higher efficiency. Figure 10 represents the cumulative filter flow percent or inefficiency of the media versus the pore diameter. As expected, Media Two is more efficient than Media One. For example, at ten microns Media Two’s efficiency is 62% (100-cumulative filter flow %) compared to Media One’s efficiency of 43%. Thus, Media Two will filter out particles at ten microns and larger 62% of the time, where the Media One will only filter the same particles 43% of the time.
FIELD STUDY PROCEDURE
The process to qualify a gradient medium for a plant is similar at every location. A qualification plan must identify the amount and size of the dirt, index frequency, coolant chemistry and the process conditions of the system. A field study establishes the debris concentration (parts per million) in the coolant, the annual media usage, and the relative costs. These evaluations take place over a period of one to six weeks, depending on the application and the regularity of the filter press operation. Data collection begins on the existing filter medium and includes coolant sampling above and below the filter and the time of each index. The coolant is analyzed for the amount and size of the dirt in the system. Once the filter operating parameters are measured, a POWERLOFT Medium is placed on the filter press. The system is allowed to equilibrate and comparative measurements begin. The objective of each trial is to improve filter performance and possibly lower end user costs.

Case 1: Cast Iron Grinding Operation Utilizing A Vacuum Filter Press In The U.K.
The objective of this plant trial was to cut costs and provide the same or better performance using POWERLOFT Media. The felt medium indexed every 2 hours and media usage averaged 8 meters per day. The debris concentration ranged from 40 to 58 ppm over the four-day period during which samples were collected. POWERLOFT 3.0 osy ML Medium was selected to provide similar performance to the existing felt. Once the medium indexed through the system the data collection began. The media usage for POWERLOFT averaged 2.74 meters per day and indexed every 6 hours. The debris concentration down stream of the filter ranged from 14 to 34 ppm over the four-day period during which samples were collected.

Charts 1 and 2 show that POWERLOFT 3.0 osy ML Medium reduced the media usage 66%, and reduced the dirt concentration in the coolant 46%. The medium offered an annual projected saving of £750, a 33% reduction in media cost, as shown in Chart 3.
Case 1: Cast Iron Grinding Operation

Chart 1: Media Usage

<table>
<thead>
<tr>
<th>Media Usage (m/day)</th>
<th>Felt</th>
<th>POWERLOFT 3.0 HL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 hr index</td>
<td>8.23</td>
<td>2.74</td>
</tr>
<tr>
<td>6 hr index</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chart 2: Debris Concentration in Coolant

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Felt</th>
<th>POWERLOFT 3.0 ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-Sept</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>10-Sept</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>11-Sept</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>12-Sept</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>13-Sept</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>14-Sept</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15-Sept</td>
<td>32</td>
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<tr>
<td>16-Sept</td>
<td>34</td>
<td></td>
</tr>
</tbody>
</table>

Chart 3: Projected Annual Cost

<table>
<thead>
<tr>
<th>Annual Cost (£)</th>
<th>Felt</th>
<th>POWERLOFT 3.0 ML</th>
</tr>
</thead>
<tbody>
<tr>
<td>£ 2253</td>
<td></td>
<td></td>
</tr>
<tr>
<td>£ 1500</td>
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</tbody>
</table>

Case 2: Cast Iron Broaching On A Vacuum Filter Press In The U.S.
The objective of this field study was to improve the filter media performance in this engine plant. The medium on the filter press was a multi-layered spunbond laminate.
ranging in basis weight from 1.8 to 2.5 osy. The medium usage over a two-week period averaged 38.4 feet per day collecting 7.24 ounces per square yard of ash. The system contamination level, during a 30 day period, ranged from 4 to 36 parts per million and averaged 16 ppm. The history indicated the operation ran five days a week at 20 hours per day. POWERLOFT 3.0 osy HL Medium ran seven days on the filter press. During that period, POWERLOFT usage dropped media consumption 72%, increased ash collection 500% per square yard, and reduced system contamination 62%. Charts 4, 5, and 6 show the improved performance POWERLOFT Media provided in this manufacturing application.
Case 2: Cast Iron Broaching Operation

Chart 4: Media Usage

<table>
<thead>
<tr>
<th>SB Laminate</th>
<th>POWERLOFT 3.0 HL</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.66</td>
<td>38.4</td>
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</table>

Chart 5: Ash Retained

<table>
<thead>
<tr>
<th>SB Laminate</th>
<th>POWERLOFT 3.0 HL</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.24</td>
<td>27.24</td>
</tr>
<tr>
<td>25.66</td>
<td>37.09</td>
</tr>
</tbody>
</table>

Chart 6: System Contamination

<table>
<thead>
<tr>
<th>SB Laminate</th>
<th>POWERLOFT 3.0 HL</th>
</tr>
</thead>
</table>
CONCLUSION
The importance of utilizing media characterization during design is presented. Each
characteristic is a part of the total filter media performance and enables the user the
opportunity to determine what filter performance to expect. The attributes best indicating
performance can be engineered to achieve optimal performance. A complete media
characterization is best used to design media to meet the customer requirements. Field
study examples are shared to demonstrate the results with the end user. Kimberly-Clark
uses proprietary technology to develop these structures, control the stated attributes and
produce them to meet the criteria for specific applications. Kimberly-Clark’s Powerloft®
Media is one example of an engineered gradient structure for liquid filtration applications.

FOOTNOTES

1 Medium is used to describe the amount of loft in the media and is stated as such.
Therefore, media is used to describe both singular and plural uses.
2 Laboratory Photographs From Crystal Filtration Company, 1998 (used with
permission from Crystal Filtration Company).
4 Ehlers, S. “The Selection of Filter Fabrics Re-Examined”, Industrial Engineering
5 Rushton, A. & Griffiths, Chapter 3, “Filter Media” in Filtration Principles and

REFERENCES
Purchas, Derek, Handbook of Filter Media, Elsevier Science LTD, 1996.