Sawyer Hollow Fiber Filter Strength Test

Calvin College conducted a study on the fibers used in various brands of Hollow Fiber Membrane water filters. They carefully dissected the filters to measure the fiber diameters and wall thickness using a Lecia dissecting microscope. From these measurements they were able to calculate "hoop stress" of the fibers to determine the stress the fibers can withstand. Using their calculations and the design characteristics of the way the fibers are used, Sawyer can confidently state that Sawyer fibers are 75% stronger than the other filter fibers that were tested. This means the Sawyer fibers can be backwashed more vigorously, insuring longer life of the filter.

Evaluation of Hollow Fiber Membrane Cross-sectional Geometry for Various Point-of-Use Water Filters

MATERIALS AND METHODS

For each filter model, duplicate samples were ordered from on-line suppliers. Once received, the hollow fiber assembly was removed from the housing for each filter, keeping the interior portion intact. Each filter assembly was assigned a number and placed in a separate bag until measured during later stages of analysis. The measurement of fiber wall thickness was completed by an expert who was not involved with ordering, processing, or numbering the filter assemblies.

Filter tubes were trimmed to have an even base and then were visualized at 40X magnification with a Leica dissecting microscope illuminated by a fiber optic light source. Prior to imaging each filter, a calibration slide from the National Institute of Standards and Technology was used to calibrate the software measurements. Images were captured using an Amscope MU1000 10MP digital microscope camera and subsequently processed using Amscope 3.7 software. Briefly, at high resolution each image was examined systematically. For the evaluation of both inner diameter and wall thickness, a measurement was made by drawing a measurement line at the smallest diameter (determined visually and/or experimentally) to avoid distortion from varying cut angles when the filters were assembled. One measurement for inner diameter and wall thickness, each, was made for each tube that was in focus in the examined image. For each dimension, thirty measurements were taken, using multiple images, for each filter. Representative photos of *best case* and *worst case* images are provided in Figures 1 and 2).

Based on hypothetical operational information (provided by Sawyer Products) relating to pressure ranges across fiber walls, the *hoop stress* for each POU filter was calculated.

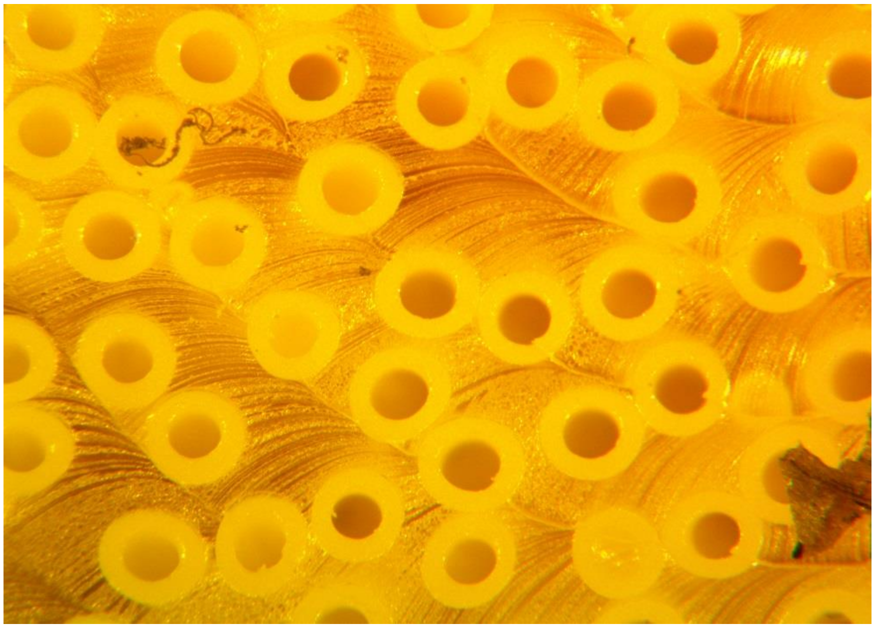

Figure 1. Representative *Best Case* Image (example)

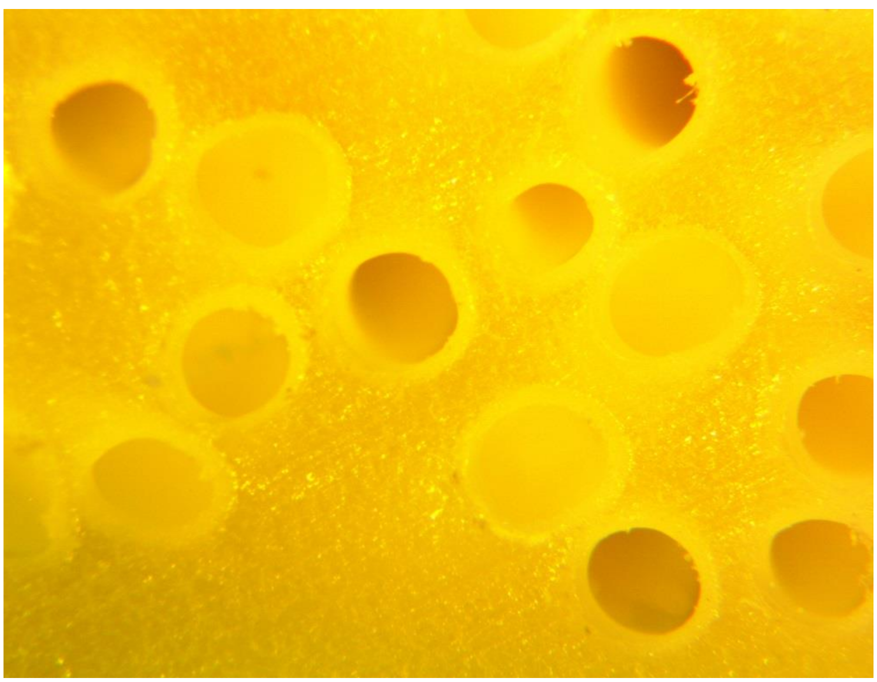

Figure 2. Representative *Worst Case* Image (example)

RESULTS

Geometry

The results of dimensional evaluation, including relatively simple statistical analysis of the measurement data are provided below for wall thickness (Table 1) and inner diameter (Table 2).

Table 1. Results and Statistical Analyses of Wall Thickness Measurements

Filter Name	duplicate	mean wall thickness, µm (95% C.I)	standard deviation
Katadyn BeFree	1	72.72 +/- 1.64	4.58
	2	72.52 +/- 1.60	4.48
Lifestraw Personal	1	68.49 +/- 3.73	10.43
	2	61.56 +/- 2.80	7.84
LifeStraw Universal	1	85.09 +/- 1.35	3.77
	2	86.08 +/- 2.03	5.68
MSR Trailshot	1	74.67 +/- 1.27	3.54
	2	74.12 +/- 1.60	4.48
Platypus GravityWorks	1	75.92 +/- 2.39	6.67
	2	76.17 +/- 1.32	3.68
Sawyer Microsqueeze	1	86.37 +/- 1.20	3.37
	2	88.02 +/- 1.19	3.33
Sawyer Mini	1	87.23 +/- 1.01	2.82
	2	86.75 +/- 0.87	2.44
Sawyer Squeeze	1	86.66 +/- 1.04	2.90
	2	87.23 +/- 1.28	3.57

Table 2. Results and Statistical Analyses of Inner Diameter Measurements

Filter Name	duplicate	mean inner diameter, µm (95% C.I)	standard deviation
Katadyn BeFree	1	310.49 +/- 2.44	6.82
	2	317.94 +/- 3.78	10.57
Lifestraw Personal	1	389.40 +/- 10.60	29.62
	2	441.42 +/- 15.42	43.08
LifeStraw Universal	1	413.04 +/- 6.29	17.58
	2	389.40 +/- 5.66	15.81
MSR Trailshot	1	322.31 +/- 2.96	8.27
	2	328.32 +/- 3.38	9.45
Platypus GravityWorks	1	316.43 +/- 4.69	13.10
	2	321.74 +/- 4.13	11.55
Sawyer Microsqueeze	1	229.69 +/- 4.70	13.13
	2	222.73 +/- 4.42	12.34
Sawyer Mini	1	221.27 +/- 2.65	7.40
	2	220.91 +/- 3.59	10.04
Sawyer Squeeze	1	219.85 +/- 4.40	12.28
	2	221.78 +/- 4.29	11.99

Hoop Stress

The hollow fiber membranes were treated as a thick-walled pressure vessel to determine *hoop* stress (σ_t). These calculations are hypothetical based on the following assumptions:

- The pressure (differential) acts on the exterior surface. Two exterior pressures (P_0) were considered: 5 and 20 psi. This range represents low and maximum exterior operational pressures for all of the filter membrane fibers that were considered.
- The *hoop* stress is calculated at the point where it is greatest—this occurs at the inner diameter dimension of the fiber wall. The calculated *hoop* stress decreases with increasing radial distance from the fiber center.

Compared to other POU hollow fiber membrane filters, the geometry of the Sawyer fibers yields a lower calculated hoop stress (Table 3). *Note that a negative pressure denotes a hoop stress in compression*.

Table 3. Calculated *Hoop* Stress under Hypothetical Operating Conditions

		hoop stress (σ_t), PSI	
Filter Name	**duplicate**	**P_0 = 5 PSI**	**P_0 = 20 PSI**
Katadyn BeFree	1	-18.6	-74.6
	2	-18.9	-75.7
Lifestraw Personal	1	-22.1	-88.4
	2	-25.7	-102.9
LifeStraw Universal	1	-20.1	-80.2
	2	-19.3	-77.0
MSR Trailshot	1	-18.8	-75.0
	2	-19.0	-76.1
Platypus GravityWorks	1	-18.4	-73.6
	2	-18.5	-74.2
Sawyer Microsqueeze	1	-14.8	-59.3
	2	-14.5	-58.1
Sawyer Mini	1	-14.5	-58.2
	2	-14.6	-58.3
Sawyer Squeeze	1	-14.5	-58.2
	2	-14.6	-58.2

With 5 and 20 PSI pressure differential, the maximum calculated hoop stress (in compression) for the Squeeze filter is approximately -14.8 and -59.3 PSI, respectively. Of the other filters evaluated, the highest maximum calculated hoop stress with -5 and -20 PSI differential is -25.7 and -102.9 PSI, respectively.

Generally, the Sawyer fiber membranes have a small inner diameter and a large wall thickness (Tables 1 and 2). With this geometry, the Sawyer fiber membranes experience less stress during hypothetical operation than the other filters considered. Conceptually, and assuming the same material properties for each filter considered, a lower *hoop* stress would translate into a higher safety factor for the hollow fiber membranes. The safety factor is defined as the maximum allowable stress on the fiber divided by the actual stress experienced during operation. ***As the material properties of the various hollow fibers are not known, a comparison of actual conditions cannot be made. For perspective, it is possible that the maximum allowable stress for the fibers of each filter is an order of magnitude (i.e., ~10x) greater than the actual stress experienced during operation.***