FIT
Fiber Innovation Technology

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4DG™

Clemson University Research Technology Put To Practice

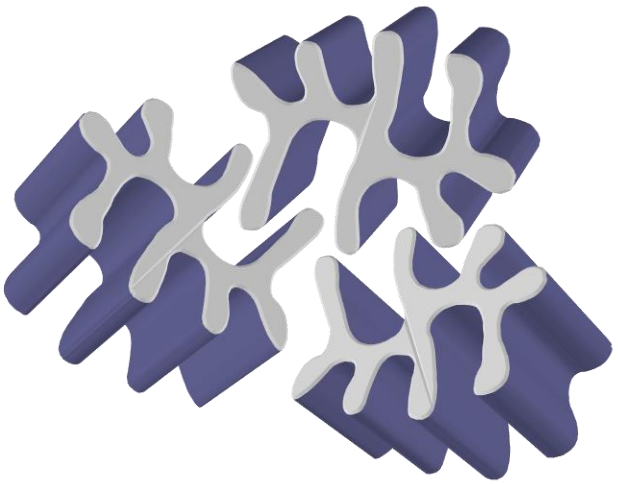
Type 4DG™ Deep-Grooved Fiber

What is it?

- **Fiber from Thermoplastic Polymer (PET, PP, Nylon)**
- **Fiber with VERY Novel Cross-sectional Shape**
- **Fiber with Stuffer-box (Saw-Toothed) Crimp**

(except an uncrimped wet-lay version)

Type 4DG ™ is a uniquely designed product with deep grooves or channels along the longitudinal axis of the fiber. These grooves provide unique features to the fiber that can serve as ducts to move fluid spontaneously, store or trap substances, provide large surface areas for a given denier per filament, and many other features. Choices of finish applied to the fibers include hydrophilic or hydrophobic, based on the needs being served by the fiber.

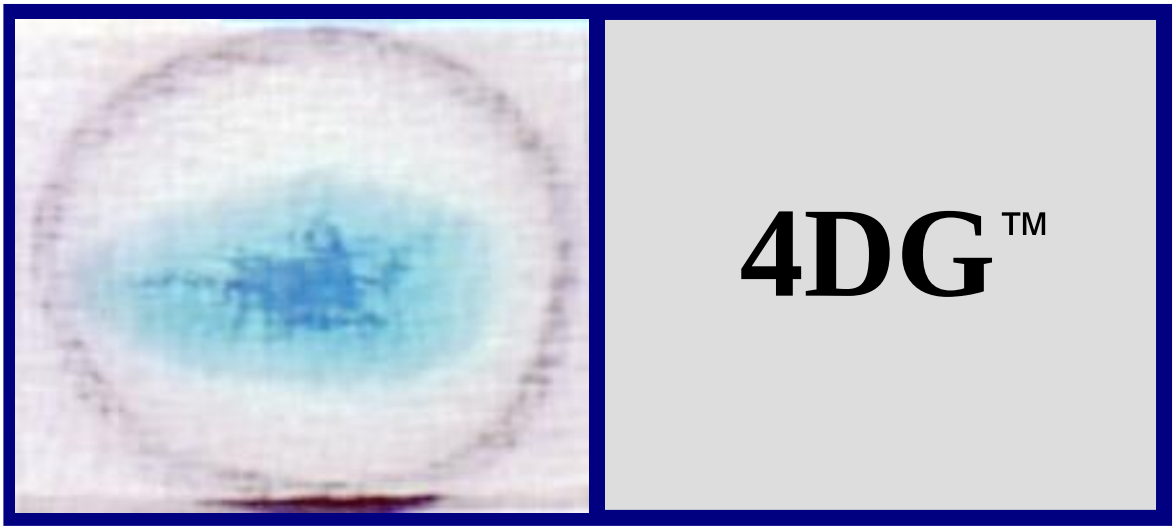


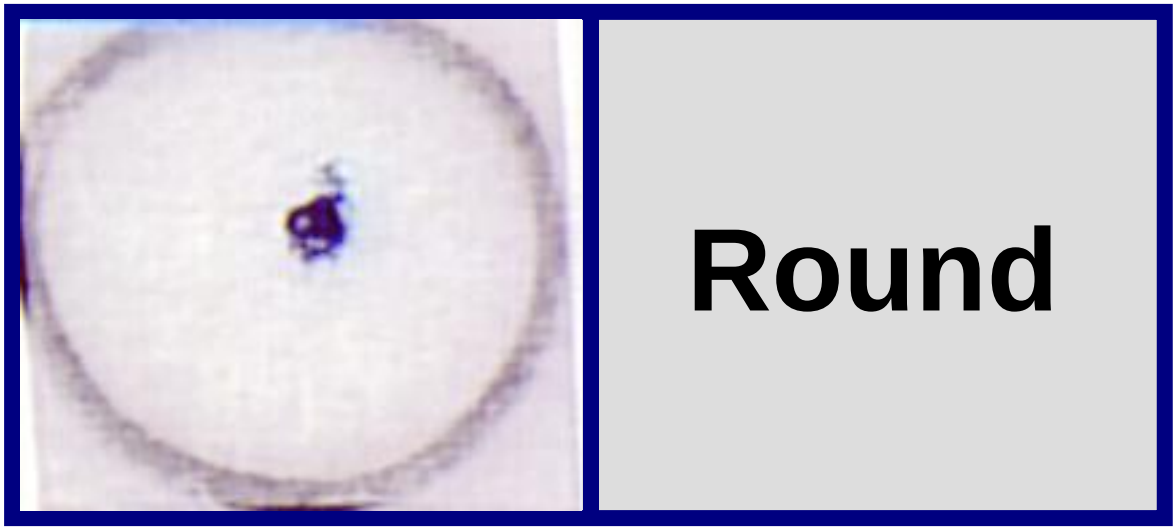
Characteristics

- **Move Fluids Spontaneously**
- **Store and Trap Substances**
- **Provides Large Surface Area**
- **High Thermal Insulation**
- **High Acoustical Insulation**
- **More Bulk and Cover Than Round Fiber**

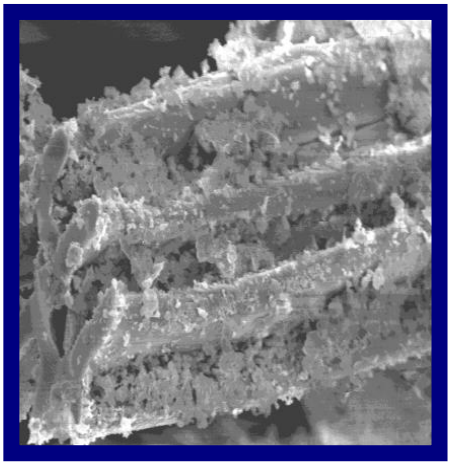
Characteristic: FLUID MOVEMENT

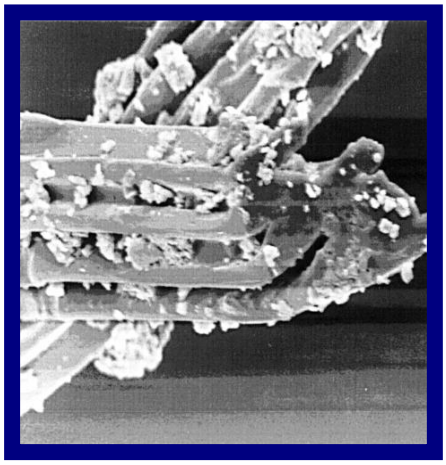
Fluid movement is shown below in a nonwoven fabric of 4DG fiber vs. round fiber using 6 d/f both being bonded with binder fiber and with the same hydrophilic lubricant. The fluid is Milliken *Syl-Tint*® blue and has spread for 20 seconds. In addition to this visual test, fluid movement is measured by a maximum potential flux test (MPF) developed by Eastman and recorded as cubic centimeters of fluid per gram of fiber per hour. Data for individual fibers is shown in Table 2.





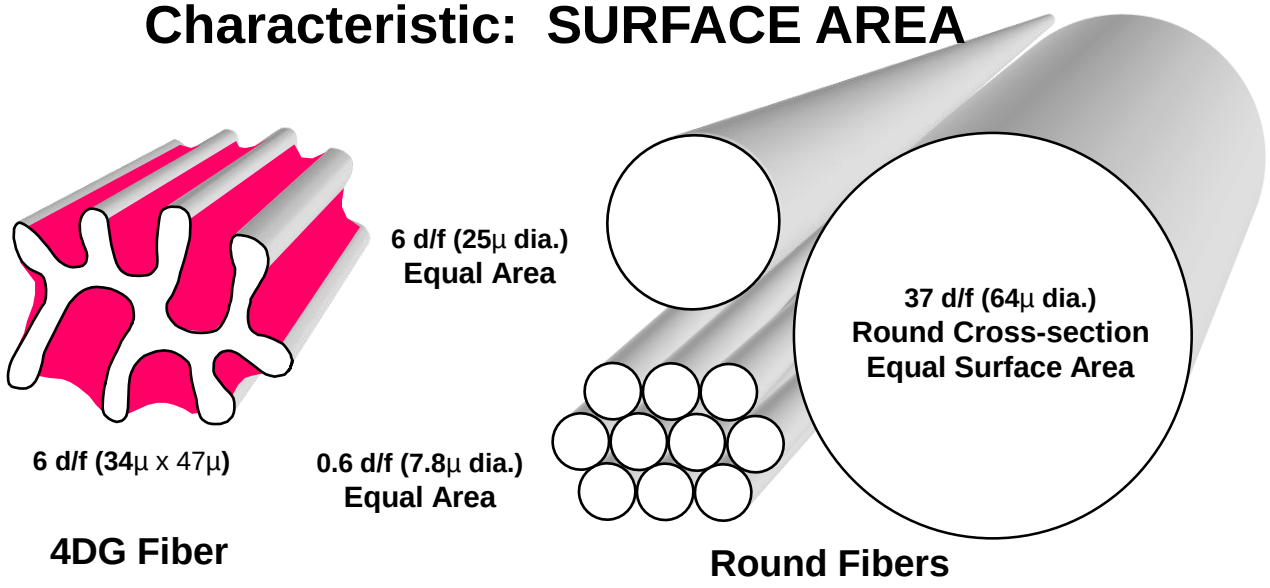
Characteristic: STORE and TRAP SUBSTANCES





The size of the grooves are large enough as indicated below to contain many types of substances, whether they accumulate in use or are intentionally placed there for release while being used. Above are examples of dust particles collected in the grooves on the left and carbon particles placed in the grooves for odor absorbency on the right.

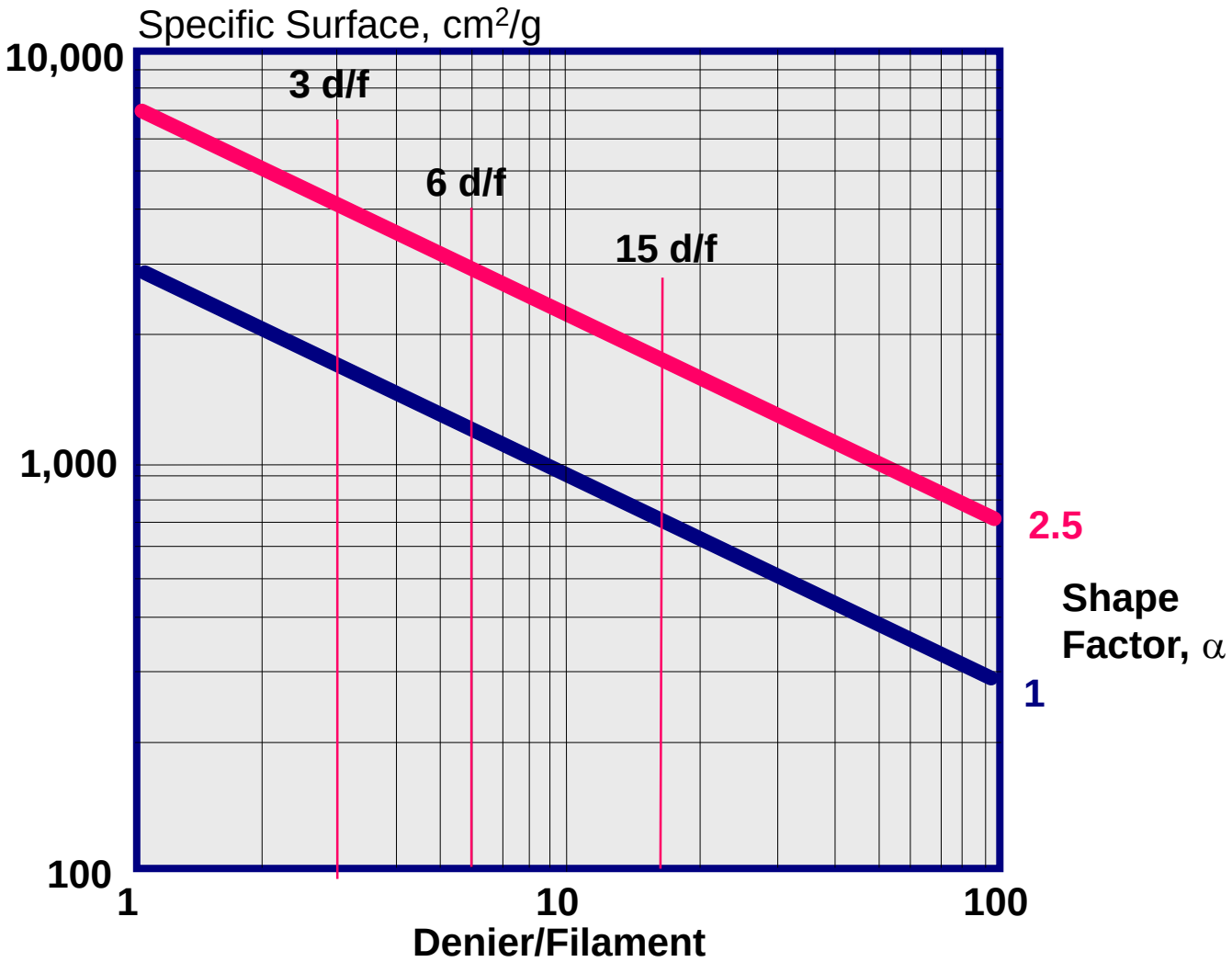
Characteristic: SURFACE AREA



The cross-sectional views above show the 4DG fiber compared to round cross-section fiber. Both fibers by definition have the same cross-sectional area when the polymer type and d/f are the same. Note: 1) the relative size and number of micro-denier round fibers and 2) the size of a single round fiber needed to match the perimeter or surface area of the 4DG fiber. The specific capillary volume (SCV) relates to the dark-colored open area of the grooves as opposed to the light-colored area of fiber mass shown.

Specific Capillary Surface Area (SCSA) vs. DPF

The graph below shows specific surface area as a function of denier per filament for a round fiber (shape factor = 1) and a 4DG fiber (shape factor = 2.5). The shape factor is a ratio of the perimeter of a fiber to that of a round fiber of the same denier per filament. Shape factors for 4DG fiber range from 2.5 to 3.0 producing surface areas of 250 to 300 percent of round fiber.



Formulae:

$$SCSA = \alpha \left(\frac{4 \pi L}{\rho dpf} \right)^{\frac{1}{2}} \frac{cm^2}{g}, \quad \alpha \geq 1$$

$$\alpha = \frac{P}{4\sqrt{4 \pi A_{CS}}}$$

where: ρ = 1.38 g/cc, PET fiber density
dpf = denier per filament
L = length, 9×10^5 cm
A_{cs} = cross-sectional area
P = fiber perimeter

Characteristic: Fiber Properties

Table 1: Physical Properties of 4DG™ Polyester Fiber

	Dry Lay Applications			Wet Lay
Denier/Filament	6	10	15	10
Tenacity, g/d	3.2	2.8	2.6	1.6
Elongation, %	40	66	92	184
Crimps per inch	9	8	7	0
Crimp Angle, degrees	92	84	84	n/a
Shrinkage, 190 C Air	0.9	0.5	0.7	65
100 C Water	0	0	0	65

Table 2: Shape and Fluid Movement Properties of 4DG™ Polyester Fiber

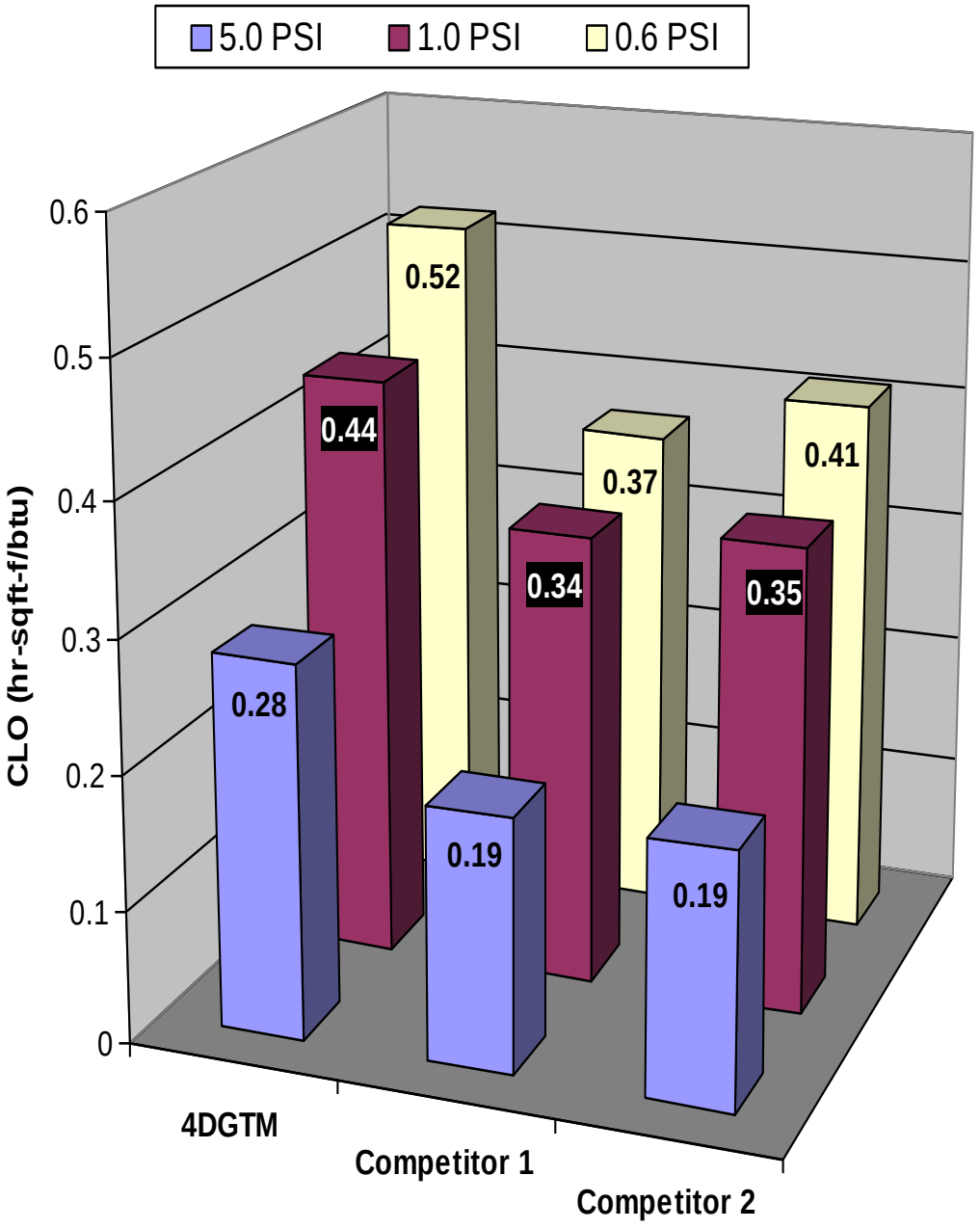
Denier/Filament	6	10	15
Shape Factor	2.7	2.7	2.4
Fiber Cross-sectional Width, μ	34	42	50
Length, μ	47	58	74
* Specific Capillary Volume, cm /g^3	0.49	0.47	0.39
Specific Capillary Surface Area, cm /g^2	3130	2210	1710
Major Channel Width, μ	8	11	12
Depth, μ	13	18	21
** Channel Area, percent	40	40	35
*** Maximum Potential Flux, cc/g/hr	122	113	148

* Ratio of Channel to Fiber Cross-sectional Area x 1/ρ

** Ratio of Channel to (Channel + Fiber) Cross-sectional Area x 100

*** Internally developed test at Eastman

Insulation Measurements at Three Levels of Compressive Loading



Characteristic: BULK and COVER

Fiber bulk is achieved by the same factors that produce higher surface area. The space occupied by the 4DG fiber in structures is much greater than round fiber from the same polymer. 4DG has a preferred bending modulus to provide unusual softness rather than stiff resilience.

Excellent cover is a result of these features, also. Here are equal weight nonwoven fabrics of the same d/f and polymer. Note the Eastman logo being masked by the fabric using 4DG fiber.

Product Ideas and Concepts

The diverse characteristics of 4DG fiber lend it to a wide area of end-use applications. Functionality may even be enhanced by the interaction of more than one characteristic at a time, for example, cover and fluid movement or bulk and surface area. The idea of filling the grooves with materials for subsequent release either immediately or over a period of time, or for controlling surrounding conditions, just begins of the potential. Use your imagination and find solutions for your new or existing end-use applications.

Examples of Potential Applications

Agricultural Media
Athletic Field Surfaces
Blood Anal. Elements
Boat Hull Substrates
Computer Disk Liners
Condensate Collectors
Cosmetic Applicators
Deodorant Substrates
Fabric Softener Strips
Filter Media
Geotextiles
Humidifiers
Ink Cartridges
Mascara Brushes
Military Gear/Apparel
Mops and Brushes
Oil Absorbers
Orthopedic Cast Liners
Pap Smear Swabs
Paint Applicators
Perspiration Shields
Polish Applicators
Saddle Blankets
Sweat Bands
Shoe Liners and Composites
Socks
Throat Swabs
Towel Scrim
Wipes
Wound Care

Capillary Surface Materials

The Capillary Surface Materials Group of Eastman Chemical Company developed technology to produce 4DG™ fiber. Several patents have been issued with several still pending. Eastman donated this technology to the Clemson University Research Foundation in January, 2000. A license has been provided to Fiber Innovation Technology, Inc. (FIT) to manufacture and market the 4DG™ fiber.