Breathing comfortably and staying dry

The outdoor sports industry owes a huge amount to the development of waterproof breathable membranes. They made it possible to enjoy all sorts of sports and activities with levels of comfort previously unknown. Yet in an industry pre-occupied with features and benefits (F&Bs), the feature of breathability cannot always be guaranteed to be a real consumer benefit since it is so difficult to find a test which truly simulates real life.

Waterproof, windproof and breathable

"We and several of our customers feel that there is a need for clarity and standardisation when rating 'breathability' (moisture vapour transmission). At present, many garment makers are not using a 'standard test' but are shopping for a test that will show the highest numbers regardless," comments one of the most senior industry chiefs, highlighting the concerns over the pursuit of marketing leverage instead of actual consumer benefits.

If one considers the opening remarks of the 2003 study[1] on moisture vapour transmission, it is clear that this is a long term concern. "It is difficult for outdoor apparel manufacturers to interpret the technical information provided by fabric suppliers concerning fabric 'breathability' properties because different methods and test conditions are used. In addition, fabrics with hydrophilic components change their properties under different humidity conditions."

What we are dealing with here is an issue of consumer comfort as Elizabeth McCullough and her co-authors state, "Fabric treatments such as finishes, coatings and film membranes are added to shell fabrics to reduce or prevent water and wind penetration into clothing layers. However, some of these treatments inhibit the evaporation of sweat from the body surface and its transport through the fabric layers to the environment. If the water vapour cannot escape, it may condense in the cooler outer layers of the clothing system or on the inner surface of the shell fabric. The accumulation of water vapour inside the clothing microclimate may cause discomfort to the wearer."

To help understand what is going on the group performed a number of water vapour transmission/resistance tests on waterproof, windproof, and breathable (WWB) shell fabrics. The tests used are shown in Table 1:



Table 1: Water vapour transmission/resistance tests

ASTM E 96 B	Upright cup (g/24 h/m^2)
ASTM E 96 BW	Inverted cup (g/24 h/m^2)
JIS L 1099	Desiccant inverted cup (g/24 h/m^2)
ASTM F 1868	Sweating hot plate method (m^2 Pa W-1)
ASTM F 2298	DMPC diffusion test (g/24 h/m^2)

[1] *Elizabeth A McCullough, Myoungsook Kwon and Huensup Shim (2003): A comparison of standard methods for measuring water vapour permeability of fabrics Institute for Environmental Research, Kansas State University, 64 Seaton Hall, Manhattan, KS 66506, USA. Published in Meas. Sci. Technol. 14 (2003) 1402–1408.*

These five standard tests measure water vapour transmission/resistance (WVTR). A high result is used as indicative of 'breathability' and comfort. What varies in the four tests that measure in grammes per 24 hours per square metre is the water vapour pressure gradient across the fabric specimens. This pressure measures the driving force of the water vapour diffusion and the volume of water transmitted per unit time. What the paper shows is that "different test instruments under different conditions" are "not directly comparable".

The sweating hot plate test measures "the resistance to evaporative heat transfer, so low values are desirable for comfort". This test simulates heat and mass transfer conditions on a clothed body. The Gore Fabric Technology Story, produced in 2000, indicated that a figure of less than 13m^2 Pa W-1, is considered very breathable. The vast majority of the materials tested and all the best known materials such as eVENT, Gore-Tex and Sympatex all came in well below this number. Table 2 shows the results the Kansas University Study produced.

Table 2: Results from different water vapour transmission/resistance tests performed on WWB shell fabrics.

Trade Name	ASTM E 96 B	ASTM E 96 BW	JIS L 1099	ASTM F 1868	ASTM F 2298
Fabrics with Microporous Coating or Laminate					
Entrant G2TM-XT (Type C)	926.0	5084.8	21,272.8	5.5	5742
eVent (Nylon Fabric)	984.8	7265.6	27,825.6	5.9	6162.5
eVent (Polyester Fabric)	942.8	6201.6	20,716.0	6.5	6039.2
Omni-Tech Dry	913.6	5317.2	16,728.8	6.6	5098.5
Omni-Tech Mini-Faille	742.4	4360.0	7,788.0	12.3	2499.4
Fabrics with Monolithic Coating or Laminate					
Diaplex (Rip stop weave)	742.4	6180.4	14508.0	7.0	2654.2
Diaplex (Plain weave)	715.2	7285.6	12052.8	11.7	2441.8
Marmot MemBrain	618.8	4368.0	8728.8	13.5	1962.2
Pertextion	446.4	4510.0	6672.8	21.5	1174.5
Sympatex	783.2	5876.0	11669.6	6.8	2960.1
Fabrics with Bicomponent Treatments					
Eclipse Twin Sensor (Rip stop)	811.6	5441.6	14998.4	7.7	3840.7
Eclipse Twin Sensor (Plain)	782.0	4243.2	10361.6	9.9	3163.1
Gore-Tex XCR	864.4	7513.2	21193.6	4.9	3193.3
Gore-Tex	758.8	5674.8	16612.8	6.2	2865.6
Marmot Dry Touch	875.6	4537.6	12616.8	8.6	3769.5
Storm F.I.T.	804.8	7604.4	15360.8	3.9	3053.5
Mean of all fabrics	**772.1**	**5297.9**	**12662.3**	**10.0**	**3289.4**

Source: E A McCullough 2003

Simplifying complexity

A good way to get a better grip of all this is to have a look at material prepared by the ASF Group. ASF Group, founded in 1987 by Dave Clark and John Furomori, maintains its objective to offer new solutions to the developing outdoor market. Based in San Pedro, California, it is a highly-focused textile company that specialises in building high performance fabrics. It selects the fibres and builds prototypes, taking the process all the way through to the delivery of the finished fabric. It works directly with mills, finishers, and fibre companies in the Far East and has offices in Los Angeles, Osaka, and Taipei and —even without a huge amount of branding clamour — has provided leading products for diverse functions as demanding and far apart as FootJoy golf and recreational fishing and angling.

In a simplified form ASF explained to *WSA* how the two main classes of waterproof breathable coatings and laminates work. The first is the most well-known being the class of hydrophilic laminates and coatings which 'breathe' by absorbing perspiration vapour that has condensed into liquid form.

The most common method for testing this type of WWB system is JIS L 1099B (Inverted cup). This test basically measures how much perspiration the laminate or coating can absorb.

"Our years of testing experience show that a practical maximum on this test would be 35,000mm/m^2/24hrs. Many garment makers are touting 20,000mm/ m^2/24hrs as a very high rate of breathability, but it actually measures at approximately 57% of maximum breathability."

The second type of coating and laminates are hydrophobic. This class of waterproof breathable 'breathes' by allowing moisture vapour to pass through its microporous structure. This type of coating and laminate absorbs no liquid. Therefore, moisture vapour that does not pass through the microporous structure will condense on the inner surface of the hydrophobic coating or laminate. The most common method of testing this type of WWB is JIS L 1099 A-1 (Upright cup).

"Because the above tests A-1 and B-1 have different test procedures it is not possible to correlate these tests accurately for comparison. Also, we find that while many hydrophilic WWB systems test high on the Inverted Cup (B-1), they test poorly on the Upright cup A-1. It is the reverse for Hydrophobic WPB systems."

According to ASF, new WWB systems have been developed with more balanced breathability. These systems have mainly hydrophobic characteristics, but have enough hydrophilic ingredients to 'charge' the inner surface of the WWB system to allow moisture generated by perspiration to be absorbed. These are new systems and are only now being adopted, mainly because of the confusion in the rating system; the garment makers are therefore able to easily relate these to the present rating system.

So, what are we to do? Keep on comparing apples with oranges? ASF is now proposing devising, refining and adopting a 10 point rating system for both hydrophobic and hydrophilic systems. The rating would basically be a percentage of the top rating expressed on a 10 point scale.

- JIS L A-1 (Upright cup): Maximum would be 10,000mm: Example: 8,500g/m^2/24hrs would receive a rating of 8.5 on the 10 point scale.
- JIS L B-1 (Inverted cup) Maximum would be 35,000mm: Example: 20,000mm/m^2/24hrs would receive a rating of 5.7 on the 10 point scale.

This is an example of how a new standard rating system would work. This type of system would be a step toward standardisation, because other test methods could be examined against the highest practical rating and given ratings on the 10 point scale.

In addition, according to ASF's CEO Dave Clark, after consultation with REI internal testing lab, "We have found that the new bi-component systems rate very

highly on their 'Comfort Rating' which is an internally-devised measure of which WWB fabrics provide the most comfort. We have not finalised a rating system for bi-component systems yet, but we are thinking that since we test these systems for both upright cup rating and inverted cup rating, that we would simply add them together and have a 20 point rating system for these, but further thought is required here.

"Our main point is that now we are all comparing apples with oranges. In order to advance, and give true value to our products we need a new rating system that accurately compares both hydrophilic and hydrophobic systems.

"Our system may seem simplistic and some may say not scientifically grounded enough, but a simple system tends to be an understandable system to all and this system is quick and easy."

It is good to have a simple approach in all this, but there are others around to help to confuse again. These include Alan Dixon, product review programme director at BackpackingLight.com who wrote the article, "Introduction to Waterproof Breathable Membrane Technology". In this paper, also available on the Japanese site doyouhike.net, Dixon describes the evolution of Gore-Tex and the curious aspect of the addition of a thin PU layer to the basic PTFE to help it withstand contamination with body oils and dirt. This PU was adjusted to be hydrophilic and work in conjunction with the PTFE by being made very thin, creating a delicate structure which has to be protected in the way it is used in a garment.

By comparison eVENT, which is also based on PTFE, is engineered to repel body oils and other contaminants. This means that moisture can be moved out from the body faster and more easily as shown in table 2.

Polyurethane membranes are also relevant and some, like Toray's Entrant G2-XT which is a PU membrane on a nylon fabric, gave results midway between Gore-Tex and eVENT. The PU alone is good on durability and is generally lighter in weight. Urethane technology has certainly seen considerable development over the last two decades. Entrant G2-XT has a microporous hydrophobic membrane. Generically, the Entrant product range is defined as a waterproof, breathable fabric made with a three-layer coating structure that incorporates two different microporous layers. The inner layer allows perspiration to escape from the skin during exercise while the exterior layer is waterproof.

Table 3: ASF group breathability comparison chart (10 point maximum)

JIS L 1099 A-1 (Upright Cup)	JIS L 1099 B-1 (Inverted Cup)	Standardized Score
10,000g/m²/24hrs (MAX)	35,000g/m²/24hrs (MAX)	**10.0**
8,000g/m²/24hrs	28,000g/m²/24hrs	**8.0**
6,000g/m²/24hrs	21,000g/m²/24hrs	**6.0**
5,000g/m²/24hrs	17,500g/m²/24hrs	**5.0**
3,000g/m²/24hrs	10,500g/m²/24hrs	**3.0**
2,850g/m²/24hrs	**10,000g/m²/24hrs**	**2.8**
1,400g/m²/24hrs	5,000g/m²/24hrs	**1.4**

Calculation based on 10 point system with 10,000g/m²/24hrs being MAX for UPRIGHT CUP 35,000g/m²/24hrs being MAX for INVERTED CUP

A test is just a test

At the end of the day Dixon quotes industry experts as reminding us that a test is just that. "Much of the confusion about the breathability performance of various membranes and fabrics is fostered by the multitude of breathability test methods. Thus far, no standard test exists for measuring the breathability of a waterproof or water-resistant fabric. Membrane manufacturers are likely to select a test method and/or the conditions for that test method that allows their product to outperform their competitors. Test results on fabrics are just that: tests on fabric."

In his paper, he warns readers to view laboratory test results used by manufacturers with caution, as often they will have little linkage to the way the garment is used, and indeed designed. PU-only fabrics and bi-component PTFE fabrics incorporating PU breathe better when the humidity inside the garment is higher and warmer, whereas the newer hydrophobic microporous materials such as eVENT and Entrant are still good at breathing at low humidity levels.

For the wearer he also gives rules, which emphasise the importance of trying to avoid base layers getting soaked, or becoming too hot or cold. This may involve slowing the pace of activity, removing a layer, or opening a jacket.

The importance of construction is further emphasised by OutDry from Nextec Srl in Italy whose non-porous hydrophilic membrane is incorporated into leather footwear and garments using a special 3D laminating process which laminates the membrane directly to the leather.

This is a complex subject, entrenched within a lot of complex science which is often used to confuse the consumer rather than to enlighten. It is also an area where marketing has played an enormous role, giving the management studies industry outstanding case studies on ingredient branding.

Seven facts on heat and sweat

- Core Body Temperature: 37°C
- Skin Temperature: 20°C - 35°C
- Sweat Glands per body: 2.5 million
- Percentage of sweat from consumed fluids: 25% (average)
- Inactive person transpires: 0.75-1.0L/day
- Maximum perspiration: 16L/day

The human body is a little like the engine of a car, it requires fuel in the form of food to create energy to move. At the same time it produces waste energy in the form of heat. The more effort and movement, the more heat is produced. However, the core of the body needs to be kept at a constant 37°C and if it cannot achieve this the result can be catastrophic. The most effective method of cooling down is sweating. By evaporating liquid from the surface of skin the body is able to maintain its core temperature. So, the harder you work, the more heat you generate, the more sweat you produce.

And while, as the test results show, not all garments are equal when it comes to helping to transport that sweat away and keeping the body comfortable—and not all tests tell the true story—advances in the last few decades have certainly transformed our opportunity to enjoy active outdoor activity in all weather conditions.