Cold Weather Apparel

By: Harun Venkatesan
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Abstract

Water proof-breathable fabric has been interest in the area of protective clothing and sportswear in cold weather. For these materials, the protection level against water is known to have an inverse relationship with the vapour permeability, or breathability. That is, textile material of more open structure would show high air permeability and low water resistance, while that of compact structure would show opposite characteristics. There are could be three types of waterproof fabrics. One is impermeable fabrics that prevent all permeation of aerosols, liquids, vapours and gases. Another is water repellent fabrics that repel splash of liquids and permeate gas or vapour. The other is water-proof/breathable fabrics which can prevent liquid phases and permeate gas or vapours.

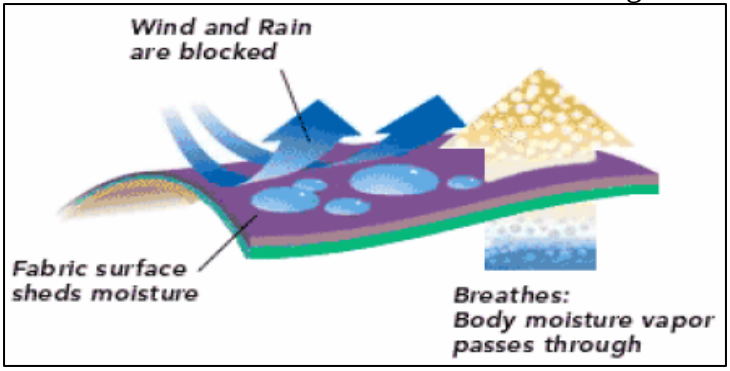
For water-proof breathable clothing, both the water resistance and the vapour transmission are very important for user comfort. The water resistant fabric with low vapour transmission would build up humidity and sweat under the garment very quickly, possibly causing the hyperthermia. Hence, there is necessity of developing a waterproof-breathable fabric that can block water while exhibiting a certain level of vapour/permeability.

Due to the inverse relationship between the water resistance and the vapour/air permeability, the protection level against water should be compromised to attain certain of vapour transmission. So this paper described about mechanism of waterproof breathable, various fabrics and its application in cold weather apparel.

Introduction

Garments which are waterproof and breathable provide great comfort to the wearers. For the consumers, comfort is an increasingly important factor when buying performance apparel. A garment which is both waterproof and breathable can often command a significant price premium from the point of view of manufacturers. However, price differences have narrowed over the years as waterproof breathable garments have become more affordable than in the past.

Water proofing's and moisture permeability are mutually contradictory. Therefore, it has proved to be a major challenge for manufacturers to produce a material which has both water proofing's and moisture permeability. In the past years, fabrics which offered protection from wind and rain did not breathe which made them extremely uncomfortable to wear. But great achievements have been made in waterproof breathable technology over the past 30 years.



USA-based W L Gore & Associates (Gore) has been given credit for giving birth to the performance outerwear segment and to the 3-

layer approach to dressing for the outdoors. In 1976 it introduced Gore-Tex, a PTFE (poly tetra fluoro ethylene) membrane. This membrane revolutionised the waterproof apparel market. The introduction of new waterproof breathable fabrics has greatly increased the range of choice. It has also led to greater diversification in the market. Technologies have been developed for specific end uses and weather conditions. New players have entered the marketplace and have challenged Gore-Tex's domination, intensifying their competition. This competition will continue to intensify in the coming future and it will lead to an increase in the temperament of innovation as companies try hard to raise comfort levels for those who pursue outdoor activities.

Clothing Comfort

Comfort is an increasingly important consideration when buying performance apparel. Physiologically, there are two aspects of clothing comfort.

1. Sensorial comfort: It is related to the mechanical touch. E.g. Cotton fabrics are more comfortable than Jute fabrics.
2. Thermo physiological comfort: A person feels comfortable in a particular climate if his energy production and energy exchange to environment are evenly balanced. The normal core body temperature is 37°C, and skin temperature is between 33 and 35° C, depending upon conditions. Body maintains this temperature by changing blood flow & evaporation perspiration from skin. Thus, Thermo physiological comfort considers heat balance of microclimate created between skin, air & clothing, with the external climate.

Heat energy that is produced from various activities and corresponding perspiration rates

Activity	Work rate(Watts)	Perspiration Rate (g/Day)
Sitting	100	3800
Sleeping	60	2280
Active walking	300	11500
Maximum work rate	1000-1200	38000-45600

During the physical activity the body provides cooling partly by producing insensible perspiration. If the water vapour fails to escape in to the surrounding atmosphere the relative humidity of the microclimate inside the clothing increases causing a corresponding increased thermal conductivity of the insulating air. This makes the clothing uncomfortable. If presentation cannot evaporate and sensible perspiration is produced, the body will be prevented from cooling at the same rate as the heat is produced. Body is to remain at the temperature required physiologically; clothes have to permit the passage of water vapour from perspiration at the rates under the activity conditions shown in the Table.

The ability of fabric to allow water vapour to penetrate is commonly known as breathability, which should be, more scientifically, referred to as water vapour permeability.

During rest, most surplus body heat is lost by conduction and radiation. During physical activity, the means of losing excess body heat is by evaporation of perspiration. One of

the commonest causes of occupational deaths amongst fire-fighters is heart failure due to heat stress caused by loss of body fluid required to produce perspiration. Fire-fighters can lose up 4 liters (4000 g) of fluid per hour when in proximity to a fire. Thus waterproof breathable fabrics prevent the penetration of liquid water from outside the clothing yet permit the penetration of water vapour from inside the clothing to the outside atmosphere.

Any Physical activity
↓
Perspiration
↓
No transfer of Perspiration
↓
Increase in R.H. inside the Cloth
↓
Thermal conductivity
↓
Uncomforting
↓
Hyperthermia

How Breathable Fabrics Work?

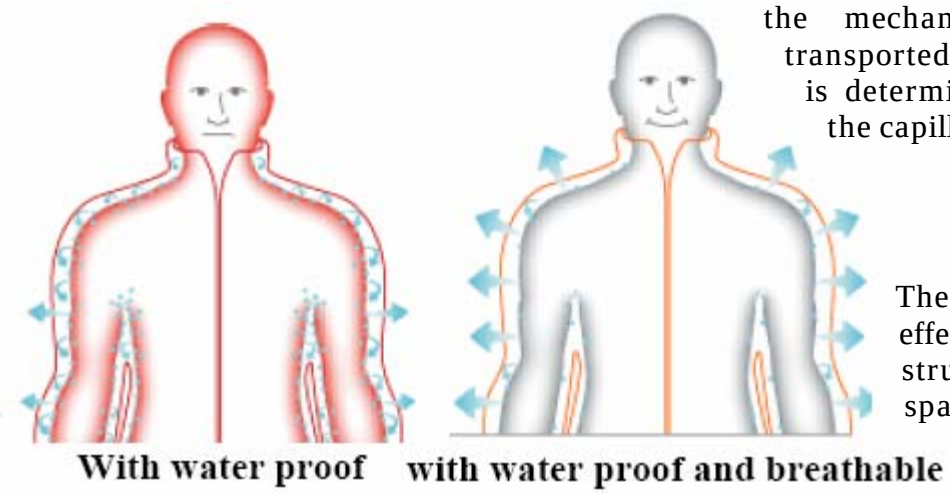
The concept behind breathable fabrics, which is fabrics that repel water but allow perspiration to escape, are tiny holes in the material that are too small for water droplets to pass through, but large enough for water vapour (perspiration) to escape.

When viewed under extreme magnification, these materials appear as crisscrossing and interlocking strands. The void areas in between these strands allow water vapour to pass through the material. Based on this simplified diagram, everyone might be wondering what happens if there are enough water droplets on the surface of the material to block all of the voids, which would trap the water vapour. To mitigate this situation, these fabrics incorporate a second layer called Durable Water Repellent, or DWR.

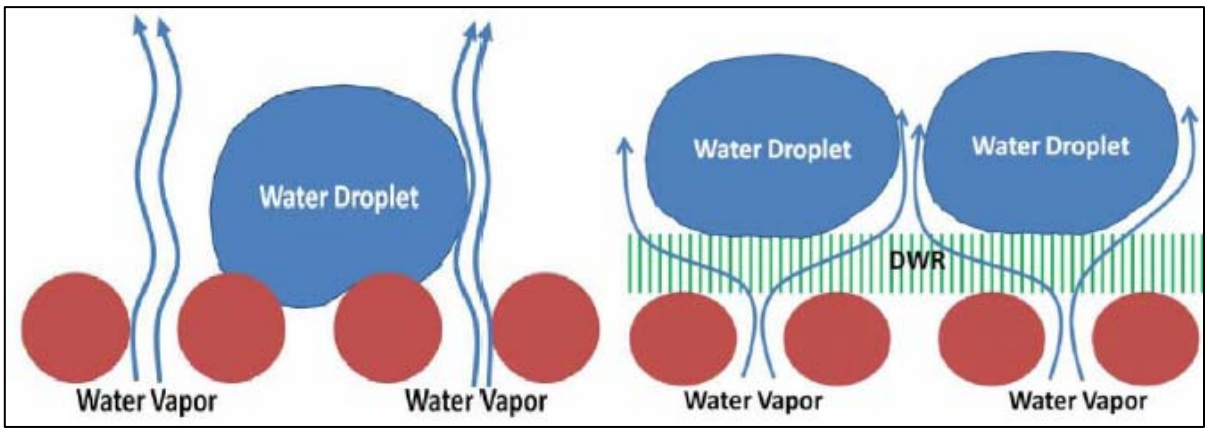
Moisture Transport Mechanism

The mechanism of the wicking of liquid in capillaries is similar to the mechanism by which moisture is transported in textiles. The Capillary action is determined by two main properties of the capillary:

- Its diameter; and
- Surface energy of its inside face.



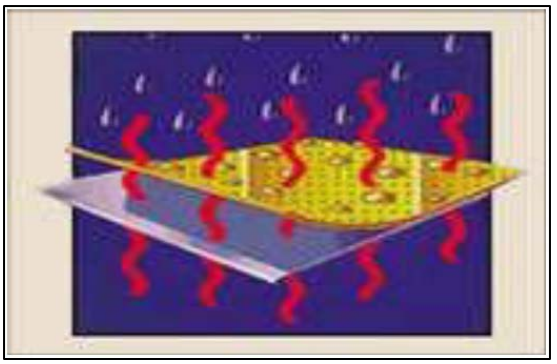
The spaces between the fibres effectively form capillaries in textile structures. Therefore, the lesser spaces between these fibres, the greater the ability to wick moisture. Fabric productions, which effectively form narrow capillaries, pick up moisture easily. Such



productions include fabrics made from micro fibres. However, capillary action ceases when all parts of a garment are wet. The energy of surface in a textile structure is determined largely by the chemical structure of the exposed surface of the fibre. They are as follows.

- Hydrophilic fibres have a high surface energy. Due to this, they pick up moisture more readily than hydrophobic fibres
- Hydrophobic fibres have low surface energy and repel moisture.

Special finishing processes can be used to increase the difference in surface energy between the face of a fabric and the back of the fabric to enhance its ability to wick.



Different Types of Breathable Fabrics

1. Densely woven water breathable fabrics
2. Laminated waterproof breathable fabrics
3. Coated fabrics

Densely Woven Water Breathable Fabrics (Pore Size 10-3 µm)

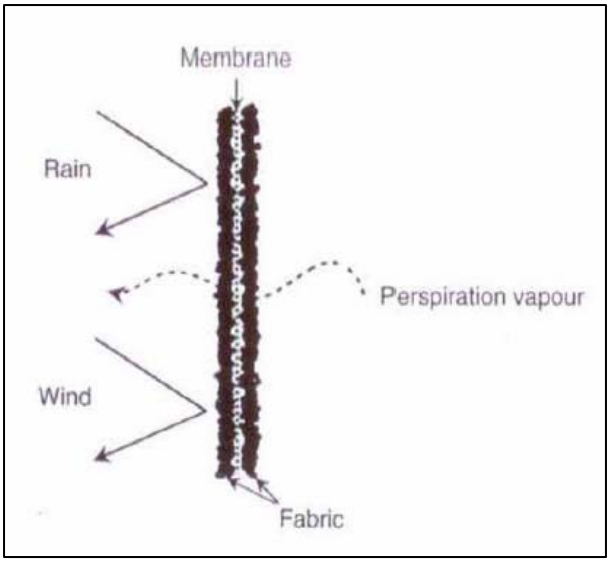
The densely woven waterproof breathable fabrics consist of cotton or synthetic microfilament yarns with compacted weave structure. VENTILE is one of the famous waterproof breathable fabrics. It was manufactured by using long staple cotton with minimum of spaces between the fibres. Normally combed yarns are weaved parallel to each other with no pores for water to penetrate. When fabric surface is wetted by water the cotton fibres swell transversely reducing the size of pores in the fabric and requiring very high pressure to cause penetration. Usually oxford weave is used. Therefore without the application of any water-repellent finishing treatment waterproof is provided. Micro-denier synthetic filament yarns can also be used to produce densely woven fabrics. Fabrics with very small pores can be engineered as the individual filaments in these yarns are of less than 10 micron in diameter.

Laminated Waterproof Breathable Fabrics (Using Membranes)

Laminated waterproof breathable fabrics made by application of membranes into textile product. Polymeric materials are used to make these thin membranes. They not only offer high resistance to water penetration but also allow water vapour simultaneously. The maximum thickness of the membrane is 10 micron.

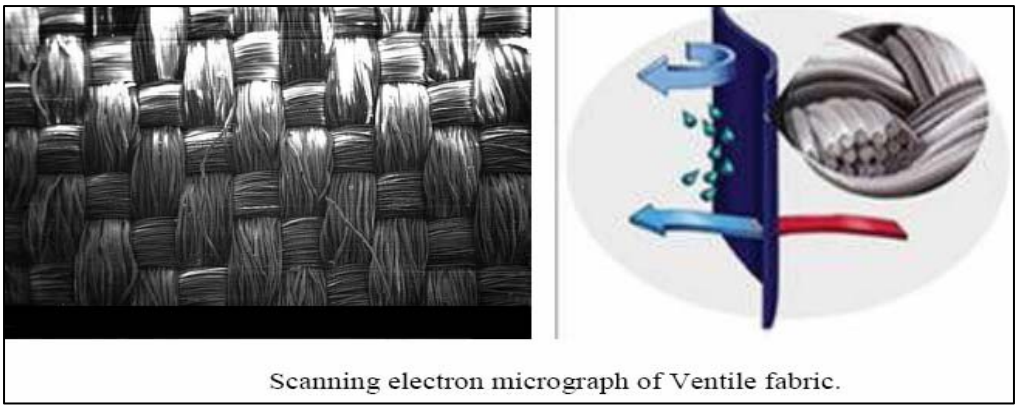
They are of two types:

1) Micro porous membranes
2) Hydrophilic membranes.



1. Micro porous membrane (pore size 3-0.11 µm)

The first and best known micro porous membrane, developed and introduced in 1976 by W Gore, is known as Gore-Tex. This if thin film expanded

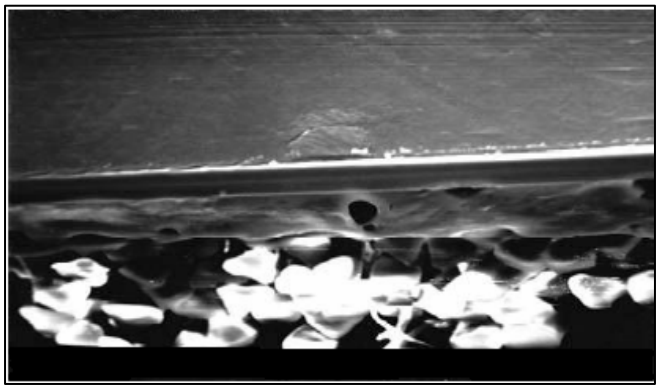


Scanning electron micrograph of Ventile fabric.

polytetrafluoroethylene (PTFE) polymer claimed to contain 1.4 billion tiny holes per square centimeter. These holes are much smaller than the smallest raindrops (2-3 _m compared with 100 µm), yet very much larger than a water vapour molecule (40-10-6 µm).

2. Hydrophilic membrane (pore size below 0.0011µm)

Hydrophilic membranes are very thin films of chemically modified polyester or polyurethane. They contain no holes and therefore are sometimes referred to as non-poromeric. The polyester or polyurethane polymer is modified by incorporating up to 40% by weight of polyethylene oxide. The poly ethylene oxide constitutes the hydrophilic part of the membrane by forming part of the amorphous regions of the polyurethane polymer system. These amorphous regions are described as acting like intermolecular 'pores' allowing water vapour molecules to pass through but preventing the penetration of liquid water owing to the solid nature of the membrane.



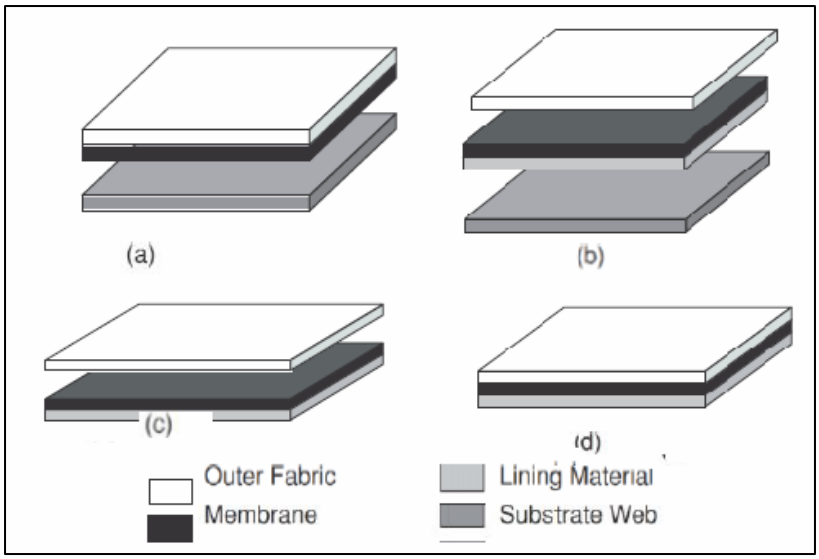
There are four main methods of incorporating membranes into textile products. The employed method depends on required function, processing conditions and cost.

1. Laminate of membrane and outer fabric (fig .A)

The lamination of the membrane is done to the underside of the outer side of the fabric to produce a two- layer system. This method has disadvantage of producing a paper like handle with reduced aesthetic appeal but has the advantage of having very effective protective properties of wind resistance and waterproofing. The production of protective clothing mainly uses this method.

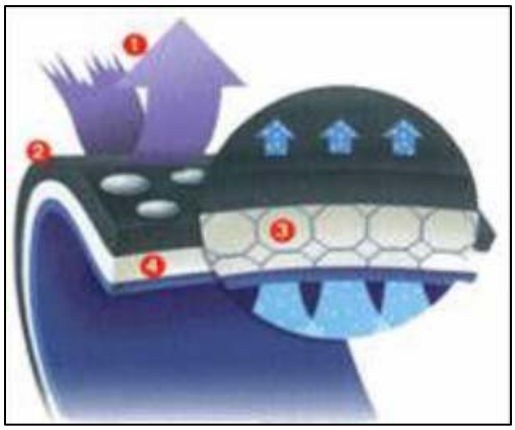
2. Laminate of membrane and lining (fig. B)

The laminate is attached to the right side of the material used for lining. The functional layer is incorporated into the garment as a separate layer independent of the outer fabric. The advantage of this method is that the fashion aspects can be maximized.



3. Liner or insert processing (fig. C)

The membrane is laminated to a light weight knitted material or web. From this material the pieces are cut to shape, sewn together and the seams rendered waterproof with special sealing tape. Then, the structure is loosely inserted between the outer fabric and the liner. The three materials (outer, laminate and lining) are joined by concealed stitch seam. This method has advantage of giving soft handle and good drape.

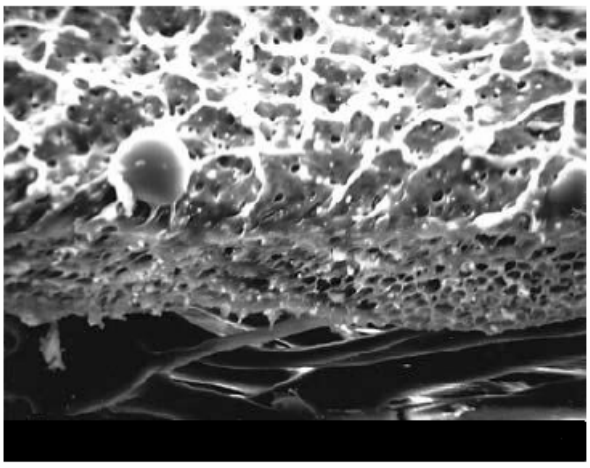


4. Laminate of the outer fabric, membrane and lining (fig. D)

This produces a three-layer system. It gives a not very attractive handle and drape than other methods. Therefore, it is not commonly used.

Coated Fabrics

Polyurethane is used as the coating material. These consist of a layer of polymeric applied to one surface of the fabric. Like membranes, the coatings are of two types, micro porous and hydrophilic. They are much thicker than membrane.



Scanning electron micrograph of a microporous coating.

1. Micro porous Coatings (pore size 3-2 µm)

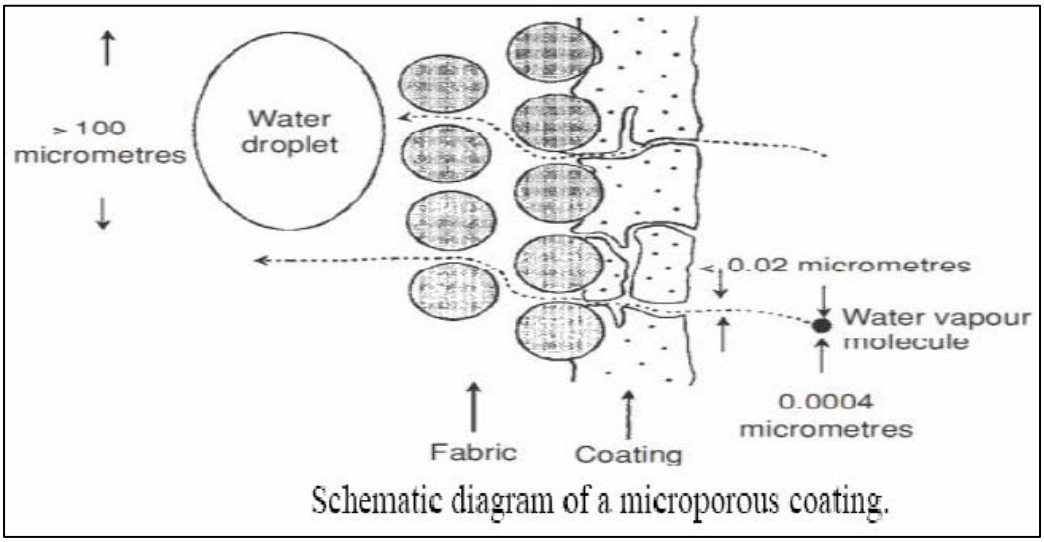
Micro porous coatings have similar structure to the micro porous membranes.

Wet Coagulation:

Polyurethane polymer is dissolved in the organic solvent dimethyl formamide to produce solution insolvable in water. It is then coated on to the fabric. The coated fabric is passed through a conditioning chamber containing water vapour. It is diluted and solid polyurethane precipitates, as the organic solvent is miscible with water. The fabric is then washed to remove the solvent. This leaves behind pores in the coating. The coated fabric is mangled and dried. This method requires high capital cost for machines and solvent recovery is expressive. Therefore it is not very popular.

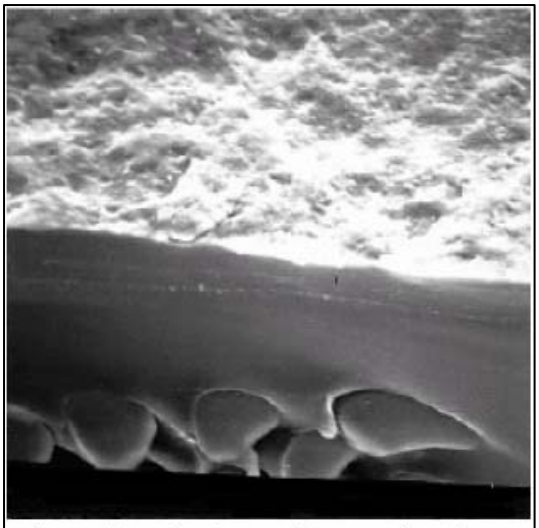
Thermo coagulation:

Polyurethane is dissolved in an organic solvent and the resulting solution mixed with water. The produced emulsion 'paste' is coated on to one side of the fabric. It then goes



Schematic diagram of a microporous coating.

through a two-stage drying process. In the initial stage it employs a low temperature to remove the organic solvent. It precipitates the polyurethane. The coating then becomes a mixture of solid polyurethane and water. The later stage employs a higher temperature to evaporate the water leaving behind pores in the coating.



Scanning electron micrograph of a hydrophilic coating.

Foam coating:

A mixture of polyurethane and polyurethane/polyacryclic and esters are disappeared in the water and then foamed. The foam is established with the aid of additives. The foam is then coated on to the one side of the fabric. The coated fabric is dried to form a micro porous coating. The fabric is fabric calendared under low pressure to compress the coating. A fluorocarbon polymer water-repellent finish is applied to improve the water-resistant properties, as foam cells are relatively large. This type of coating production is environmentally friendly as no organic solvents are used.

2. Hydrophilic coatings (pore size below 0.001µm)

Hydrophilic coatings use same basic water vapour permeability mechanism as the hydrophilic membrane. The difference between micro porous material and hydrophilic material is that with the micro porous material, water vapour passes through the permanent air permeable structure whereas the hydrophilic material transmits vapour by molecular mechanism involving adsorption-diffusion and desorption. These coatings are based on polyurethane, which is chemically modified by incorporating polyvinyl alcohol and polyethylene oxide.

Special Fibres Used

Hygra:

Hygra, (fig. 1) is a sheath core type filament yarn composed of fibre made from water absorbing polymer and nylon. The water-absorbing polymer has a special network structure that absorbs 35 times its own weight of water and offers quick releasing properties that the conventional water absorbing polymer cannot do. Nylon in the core gives tensile strength and dimensional stability on the other hand. Under low wet conditions even hygra has superior antistatic properties. The main apparel applications include sportswear.

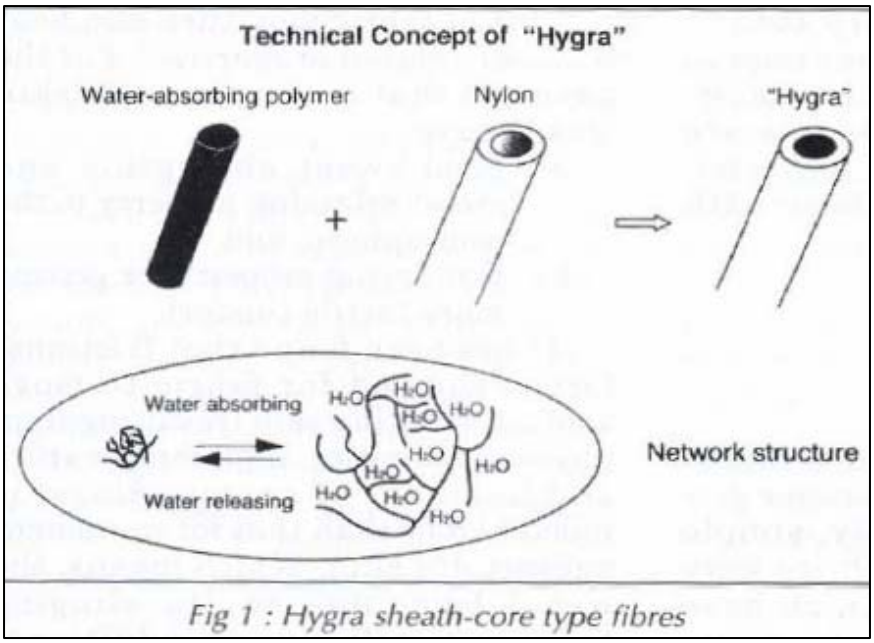


Fig 1 : Hygra sheath-core type fibres

Lumiac:

Lumiace is a collection of polyester filaments having different fineness

(0.5 - 2.0 denier per filament) and irregular cross sections. Hygra - Lumiace combination in knitted fabric is very popular in top Japanese athletes.

Dryarn:

Dryarn is a new fibre. It is a completely recyclable polypropylene micro fiber. Fabric from Dryarn is very lightweight and comfortable and used in different sports. It also has a soft handle and a high thermoregulatory capacity and dries quickly. It avoids unpleasant odour associated with decomposition of bacteria as bacteria cannot settle on smooth surface of the fibre.

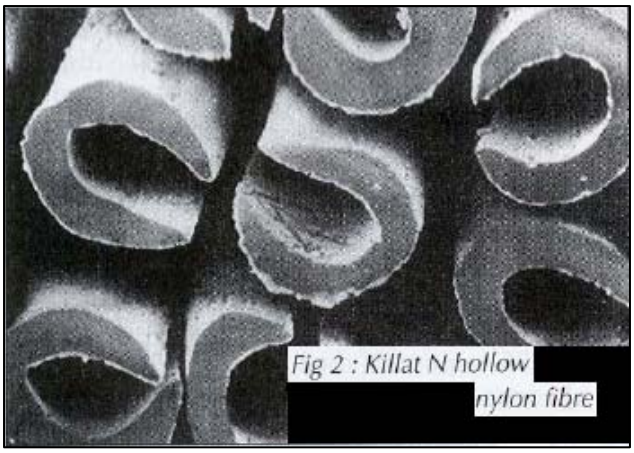


Fig 2 : Killat N hollow nylon fibre

Killat N:

Killat N is a nylon hollow filament. The hollow portion is about 33 per cent of the cross section of each filament due to which it gives good water absorbency and warmth retentive property. The yarn is spun as bi-component filament yarn with nylon as the skin portion and soluble polyester copolymer as the core portion. Then by giving alkali weight loss treatment the soluble polyester copolymer of the bi-component filament will dissolve and a large hollow portion (exceeding 30 per cent of the cross section) will be created.

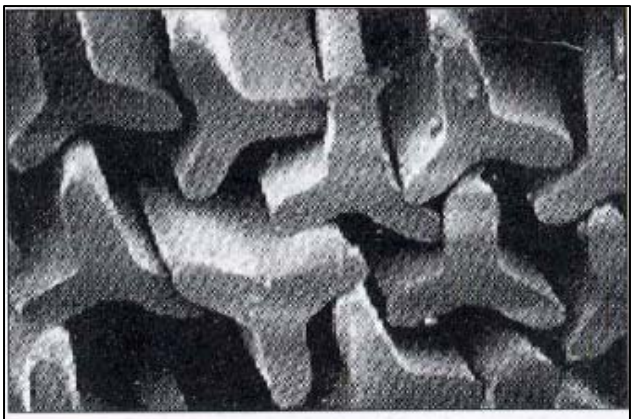


Fig 3 : Structural model of Triactor

Triactor:

Triactor (fig. 3) is a perspiration absorbing/quick drying polyester filament. Polyester is hydrophobic and does not absorb moisture but by changing the filaments to Y shaped cross section Toyobo has realised quick perspiration absorbency by capillary action. The hydrophobic nature and large filament surface of polyester filaments realise quick drying and refreshing properties at the same time.

There are many other fibres, which have good sweat absorption and fast drying property. Most of them are either nylon or polyester.

Lycra:

Lycra is a truly synthetic fibre of long chain polymer composed of at least 85% segmented polyurethane. It is used in swimwear, active sportswear, floor gymnastics because of its comfort and fit2O. A fabric attains stretch and recovery when Lycra is added to it. This is required particularly in gymnastics and swimwear where body skin flexing and stretching are inevitable.

Roica and Leofeel:

Roica is a polyether type spandex made by dry spinning method and Leofeel is a soft nylon66 yarn. The combination of Roica and Leofeel in mixed knitted tricot fabric gives a soft touch and excellent stretch. It is mainly used in swimwear. Various other fibres

like Elite, Linel Ac, Elastil and Sens from etc also have good stretch ability and are effectively used in swimwear.

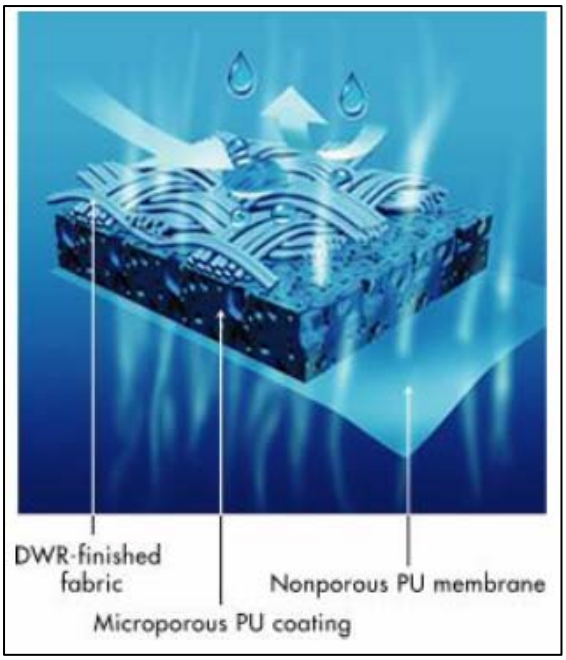
Applications of Waterproof Breathable Fabrics

Leisure	Work
• Heavy duty, foul weather clothing: Hats, gloves, gaiters, over trousers • Fashionable weather protection: Rainwear, skiwear, golf suits, walking Boot linings, foot wear linings • Tents • Sleeping bag covers	• Foul weather clothing: Survival suits, special military clothing, special clean room garments, surgical garments, hospital, mattresses and seat covers, packing, wound dressings, filtration • Domestic and transport: Non allergic bedding, curtains in ships, car covers, cargo wraps in air craft

Various Fabrics and its Application in Cold Weather Apparels

Entrant Dermizax EV

"Entrant Dermizax EV" is a lightweight fabric having a feather smooth texture with excellent waterproof/moisture permeability and durable water repellence such as 20,000mm of water pressure resistance and moisture permeability of 30,000 g/m2/24 hrs. It is an excellent and original active sportswear fabric with globally top class water proof/moisture permeability, as well as excellently durable water repellence.



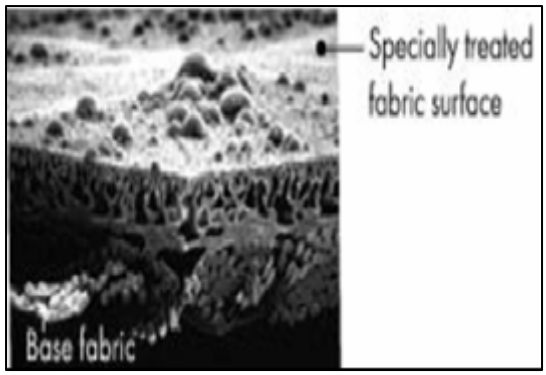
Entrant HB

- Extremely waterproof
- Highly moisture permeable
- Minimal condensation
- Durable water repellency
- Highly durable waterproof withstands many wash cycles

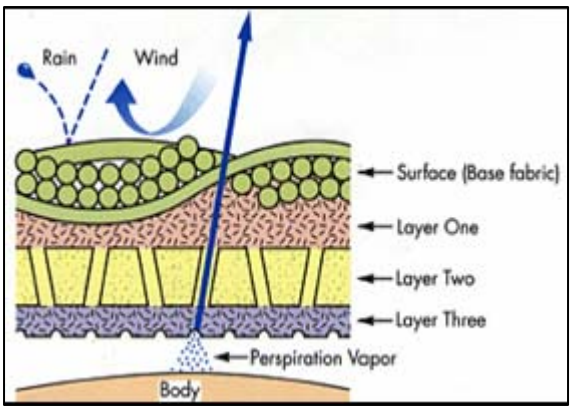
"Entrant HB" is a new generation fabric with hybrid structure that synergistically integrates the advantages offered by a coating (well-balanced moisture permeability) and lamination (high waterproof). Its main application is outdoor wear. It has high resistance to water pressure and high durability against repeated washings (80 points or higher after 20 wash cycles).

Entrant DT

- Refreshing dry touch
- Moisture permeable and highly waterproof.
- Durable water repellency and windproof
- Lightweight and pack able
- Soft and smooth



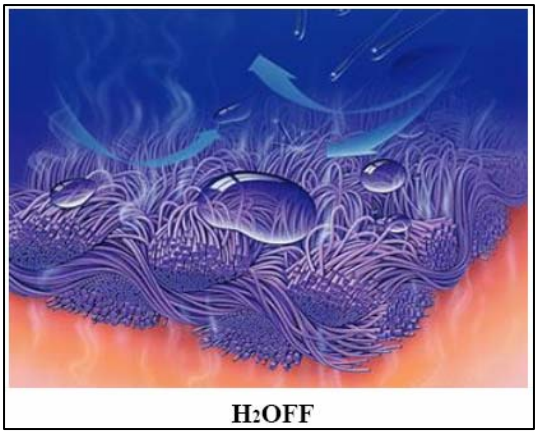
"Entrant DT" is a micro porous coated fabric offering a



smoother and refreshing dry touch as well as attractive appearance. It has patterns printed on a coated membrane and a dry touch obtained by improving the coated membrane as shown in fig. It features lightweight configuration, easy packing and high breathability/waterproof. It has an innovative inner surface treatment technology.

H2OFF

- Durable water repellence
- Without coating or adhesives, gives water resistance
- Non-coating configuration with a superior breathability
- Natural and soft hand feel
- It is easy to care for and withstands repeated washing.

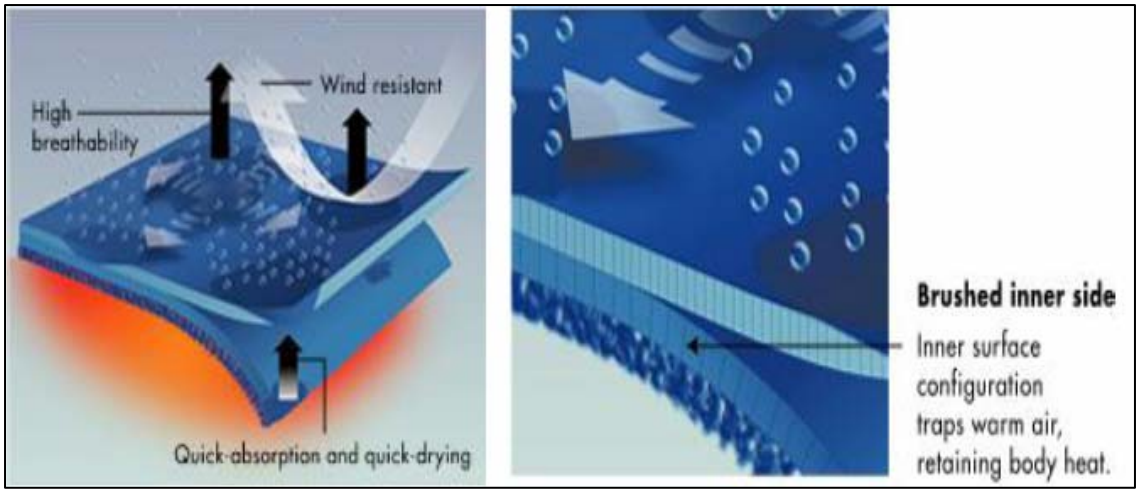


H2OFF

"H2OFF" is made up of polyester micro fiber fabric with a unique high-density weave structure comprising millions of micro crimped fiber loops (fig.6). It also features superb and durable water repellence, wind-chill resistance and superior breathability.

Fieldsensor

- Quickly absorbs perspiration
- Rapidly carries perspiration to the fabric's outer surface
- Disperses perspiration throughout the outer surface for rapid evaporation.



"Fieldsensor" is a polyester filament multilayered knitted fabric that offers perspiration absorbing/quick drying properties. Once the inner layer absorbs perspiration from the wearer quickly, it evaporates in the air. Capillary action is used in this mechanism. It is used in lining for skiwear and knitwear for athletic sports.

Naiva

Naiva fabric is made by combining the Naiva yarn with a nylon micro fibre 14. It is an Eval/nylon bicomponent filament yarn and Eval is nothing but a copolymer resin of ethylenevinylalcohol. Naiva yarn composition is 55% Eval (23% ethylene + 32% vinyl alcohol) and 45% nylon. In the Naiva fabrics there are many nylon micro loops Fig. on the surface, which are formed by making use of high thermal shrinkage property of Naiva yarn. The positive features of Naiva fabric is that it is lightweight, has capability of secondary finishing,

Naviva fabrics with microloops on the surface

good moisture permeability and softness. The fabric is used in mountaineering wear and other active sportswear.

Apparels in Defence

Extreme Wet/Cold Weather Jacket & Trousers

- Windproof, waterproof and extremely breathable two-layer fabric jacket and trousers.
- Hard shell jacket and trousers are completely waterproof and feature sealed seams throughout as well as reinforced knees and elbows.

Soft Shell Cold Weather Jacket & Trousers

- Durable and breathable jacket and trousers constructed with water resistant materials to resist penetration by water.
- The jacket features a center front opening with wind protection flap, two front pockets, raglan sleeves and a collar with cover for an enclosed collapsible hood.

Extreme Cold Weather Parka & Trousers

- A highly durable and breathable parka and trouser constructed with sport thermal bonded high-loft insulation and a water resistant outer shell fabric to resist penetration by water.
- The parka is a single-breasted insulated jacket featuring a drawstring hood and bottom with two pockets.
- The trousers feature elastic cuffs, a front fly fastener and a zipper on the outside of each leg to facilitate donning without removal of boots or shoes.

Mid-Weight Shirt & Drawers

- Highly breathable, moisture wicking mid-weight shirt and drawers constructed with heavyweight material which offers stretch to allow for increased comfort during movement.
- Long sleeve collard shirt features thumbholes to aid in donning multiple layers.

Light weather outer layer (LWOL) Jacket & Pants

- Highly abrasion resistant face fabric constructed with a fire-resistant nylon/pima/Lycra blend treated with Massif's new Halo Fusion Process.
- Inner fleece layer constructed with a modacrylic/Nomex/Lycra fiber blend.
- Water-resistant, flame resistant, durable, wind-resistant, and breathable.

Cold weather boots

- 400 grams of Ultra Insulation

- Breathable fabric bootie
- It has a flash and water-resistant leather upper
- Wicking lining prevents bacteria and fungus growth that causes rot and foot odours
- Ankle design protects the ankle from twisting and roll over
- Triple-Stitched

Ninja Design Protective Clothing

- Soft shell laminates construction for exceptional wind and weather resistance
- Fabric offers perspiration management, comfort and warmth
- When wearing glasses or sunglasses, ninja design minimizes pressure on temples
- For variable coverage, hood hinges back
- When tucked in, extended neck provides skin coverage
- Mid-weight fabric ear and breathing ports
- For ear-bud headphones, the ear ports open to back

Conclusion

Remembering the following points wearer will go a long way to ensuring comfortable safe clothing use in the harsh cold climate:

1) *There is no such thing as bad weather. It is only bad clothing.*
2) As much as possible, the clothing ensemble should be designed for the specific conditions to be encountered.
3) The wearer can widen the window of conditions in which a specific clothing ensemble can be used.
4) *Keep water molecules out of the clothing ensemble.*

This requires commitment to:

a) Proactive layering changes,
b) Aggressive clothing ventilation to expel moisture during the day,
c) Continuous efforts to remove moisture.