ability to guarantee optimum working conditions in the hangar. The static requirements of the builders were met fully by the D.O.S. structure used. As far as the static requirements are concerned, the structure has to be both strong and dimensionally stable for the same stress/strain behaviour in both the warp and weft directions; it must also exhibit an optimum weight/strength ratio and this has been achieved by the straight, parallel, load-absorbing arrangement of the yarn layers. It must also have a high initial tear resistance and tear propagation resistance, and this is achieved by bunching of the yarns during tearing.

Technical data relating to the membrane construction
Tear propagation resistance (DIN 53 363):
Warp, 200 N
Weft, 150 N
Cohesive strength (Complan standard): 16 N/m
Cold resistance (DIN 53 361):
– 25 °C
Heat resistance (Complan standard):
+ 70 °C
Flexural strength:
meets DIN 53 359 A, no tears
Flammability:
meets DIN 4102 B 1
Finish:
acrylic lacquer applied to both sides
Light permeability:
approx. 45% at 550 nm
Dimensional stability:
high, thanks to the firm stitch tying-in arrangement used

Technical data relating to the D.O.S. structure
Material (warp and weft):
dtex 1100 f 200 high-strength, low-wick polyester
Density:
Warp, 2.4 yarns/cm
Weft, 2.4 yarns/cm
Weight (coated): 500 g/m²
Type of coating: PVC
Max. tensile strength (DIN 53 354):
Warp, 950 N/5 cm
Weft, 900 N/5 cm
Breaking elongation (DIN 53 354):
Warp, 20%
Weft, 20%

The building of this spectacular construction proves just how useful warp-knitting technology, with its ability to produce D.O.S. support structures, is in the technical and industrial fabrics sector.

To the figures:
The hangar for housing the CargoLifter has a volume of 5.5 million m³ and can be opened at the front (courtesy CargoLifter).
Loading and unloading of heavy, bulky goods from the air (courtesy CargoLifter).
The hangar itself is made up of several layers of textile membrane; the inside is made from a weft-inserted, raschel-knitted construction.
Assembling the huge hangar and mounting the textile components.

DIPL.-ING. (FH) MARIANNE HEIDE*

Spacer fabrics: trends

Their three-dimensional construction and the possibility of being able to use a variety of different materials make spacer fabrics ideal for functional applications for use next to the skin.
The manufacturing technology itself offers a wealth of possibilities, and enables "tailor-made" textile structures to be produced for a range of end-uses.
The Institute is one of the 281 German organisations working on projects designed to develop functional spacer fabrics for medical applications, which are registered in Germany and recognised world-wide, and which were represented at the EXPO 2000 world exhibition under the slogan of "Man, nature, technology: a new world is emerging", whose theme was the main factors affecting the future of mankind. A new feature of this international exhibition was that the majority of the projects being carried out world-wide are also shown externally. The results of the development work on the project can be viewed in the Institute's own exhibition rooms until 31. 10. 2000.
The aim of the development project is the construction and design of innovative spacer fabrics for improving the health of the population. The range of products involved extends from soft, elastic, moisture-transporting constructions for therapeutic medical aids, through strong, compression-resistant spacer fabrics in new constructions for seats, to flame-resistant spacer fabrics for protective clothing.
Some typical examples of end-uses will now be presented.

Spacer fabrics for use as therapeutic medical aids

- in orthopaedic medicine
- for preventing bedsores
- in rehabilitation

Different types of foam materials and foam composites are still used in many cases for producing therapeutic medical aids. The disadvantages of these materials are their poor air permeability and breathability, which causes the patient to perspire as the heat builds up. The thermal comfort properties are therefore very poor.
Spacer fabrics can be used as an alternative to these materials. The special characteristics of these warp-knitted substrates and the pos-

* Textile Research Institute, Thüringen-Vogtland e.V., Greiz

sibility of being able to use a wide variety of different materials, constructions and designs make them especially suitable for these end-uses.

Spacer fabrics consist of two outer textile substrates which are joined together and kept apart by pile yarns which act as the spacers. This means that there is always a ventilated, breathable intermediate zone between the two layers. The construction and design of the spacer zone will depend on the end-use. The distance set between the knock-over comb bars, which determines the thickness of the textile, the number of pile yarns per cm^2, the thickness of the pile yarns and the pile yarn laying angle as a function of the comb plate spacing are important parameters which will all affect the subsequent end-use.

Spacer fabrics for therapeutic aids in orthopaedic medicine

The following characteristics are important for textiles used in orthopaedic medicine and these can all be guaranteed by spacer fabrics:

- breathable, temperature-regulating
- compression-resistant
- soft, with a specific elasticity
- soft on the skin, good physiological properties
- moisture-transporting ability
- good surface resistance

Monofilament polyester yarns in fine counts are the most suitable spacer yarns for use next to the skin. They ensure that the required gap is maintained and that the surface is soft in the region next to the skin. The thicker the count of the pile yarn becomes, the "scratchier" the surface feels. The elastane processed can be formed into knitted constructions at counts of up to 130 dtex and guarantees that the required elasticity is achieved. Coarse elastane yarns in counts of up to 470 dtex can also be processed as the inlay yarn and to guarantee good compression properties.

The combination of PES with elastane can create problems for the dyer. Strong, dark colours are often needed, which necessitates a two-bath dyeing process.

The design of the two outer textile surfaces has a decisive influence on the construction and how it feels against the skin. The ability to wick perspiration from the body to the textile substrate facing away from the skin is just as important as good ventilation and a light surface construction.

The patient must feel comfortable if he is to accept the product.

Spacer fabrics for preventing bedsores

The most important requirement made of products for preventing bedsores is that they should be able to alleviate pressure. The textile structures developed at the TITV, Greiz, can be used to complement existing systems for preventing bedsores, such as foam mattresses, variable pressure mattresses, etc., but they can also be used on their own.

Their advantage is that the air-filled zone between the two outer substrates creates a microclimate between the body of the patient and the cover, which prevents heat from building up and moisture in the form of perspiration can pass from the skin into the second textile layer by using the right type of material combinations. The construction of the relatively soft, compression-resistant spacer zone reduces the pressure exerted by the body and helps to prevent the formation of bedsores.

Spacer fabrics for use in wheelchairs

The aim of the work was the development and use of warp-knitted spacer fabrics with improved compression resistance and temperature-control characteristics for use in wheelchairs. A wide variety of wheelchair cushions are available on the market, which must be suitable for the patient's particular problem. Foams of different density, air-cushioned materials, gels combined with foam, and a range of other combinations are used, and these materials are not only expensive, they must also be able to suit the requirements of the user. The characteristics of the cushion cover and their effects on the physiological perception of comfort while sitting are rarely considered. However, the breathability, thermoregulatory characteristics and pressure-relieving effect of spacer fabrics

The extreme pressure exerted by the patient while sitting requires that the construction has different structural parameters. Important requirements of the textile are that it should relieve pressure in the bottom area (lower pelvis) and that it should be able to control the temperature. Both of these requirements can be met by using the correct materials and by utilising a new surface construction.

Pressure measurements carried out on a standard folding wheelchair, covered with a 1.5 cm thick foam cover, showed that the pressure on the lower pelvis of the patient was 33.5% higher than for a 0.5 cm thick spacer fabric.

The risk of certain groups of patients (e.g. paraplegics) suffering from pressure sores is reduced by using wheelchairs with cushion covers made from spacer fabrics, and the comfort while sitting is greatly improved.

Warp-knitted spacer fabrics as flame-retardant protective textiles

The aim of the work was to develop flame-resistant spacer fabrics for use as protective textiles worn next to the body for a range of different applications, for example:

- high-temperature-resistant spacer fabrics as linings for firefighters' protective clothing
- flame-retardant mattress covers for the medical care sector

Warp-knitted spacer fabrics as linings

In addition to providing protection from heat and flames, the physiological comfort of firefighters' protective clothing is also extremely important. A figure produced by the NFPA (National Fire Protection Association) reveals that roughly half of all deaths among firefighters can be attributed to heat stress. This makes comfort an important safety factor, and meeting the physiological requirements of the clothing becomes a significant factor in protection.

Spacer fabrics used as linings in firefighters' protective clothing are subjected to extremely high temperatures, although the compression load

The construction parameters were therefore selected to ensure that the spacer zone was wide enough to ensure that the intermediate layer of air can provide adequate insulation and wear comfort. The two outer textile layers were worked in a closed construction to guarantee good insulation. A twisted aramid yarn was used as the pile yarn to ensure that the gap in-between was retained. The material was tested in conjunction with an outer material (adjacent materials, BG1 and 2) laid down in EN 469 covering firefighters' protective clothing. The relevant safety requirements for firefighters' protective clothing in accordance with this standard, as well as those relating to flame resistance, were met without any problems.

Spacer fabrics as flame-retardant mattress covers

Polyester CS, also in combination with Nomex/Viscose FR, was used to produce flame- retardant spacer fabrics for mattress covers for use in hospitals and nursing homes. In addition to being reasonably priced, these fibres can also be processed very easily on the RD 6 N machine in a gauge of 22 E. They provide adequate protection for this particular application (in accordance with DIN EN 532 and 533 as well as with DIN EN 1021-1, part 1: glowing cigarette as the source of ignition). They also ensure that an adequate gap is maintained between the two outer layers of textile and thus help to prevent bed sores.

The compressibility is guaranteed by adapting the pile yarn laying angle to suit the gap, i.e. thickness of the structure. Even after being compressed by a human body, at least 85% of the original thickness is retained.

This represents good resilience and guarantees an adequate air circulation/thermoregulatory effect between the mattress and the patient's body.

By adapting the construction, moisture is able to wick away from the side nearest the skin to the side farthest away from the skin.

Table 1: Results of the flammability tests

Test parameter	Unit	Test results BG 1 19981	Test results BG 2 19981	Requirements in accordance with EN 469
Heat penetration of the flames				
Heat transmission index HTI 24	s	17	17	≥ 13
HTI 24–HTI 12	s	6.5	6.5	≥ 4
Heat penetration of radiant heat				
Heat transfer level t2	s	26	25	≥ 22
t2–t1	s	10	10	≥ 6
Diathermancy TF	%	36	40.5	≤ 60
Heat resistance/shrinkage of the lining	%	< 0.5	< 0.5	≤ 5
Limited flame spread		no	no	no
Subsequent burning		no	no	no
Formation of holes		no	no	no
Melting droplets				
Average duration of subsequent burning	s	0	0	≤ 2
afterglow	s	0	0	≤ 2

(Tested at the STFI, Chemnitz, textile testing centre)

Table 2: Test results obtained using the skin model

Article	Buffer effect, vapour phase Fd	Buffer effect, luquid phase Kf	F1 g/m²h mbar	G2
07981 FR (Mattress cover)	0.72	0.95	19.1	6.7
19981 FR (Lining)	0.57	0.98	16.0	8.4

(Tested at the Hohenstein Research Institute)

Physiological behaviour

Taking a flame-resistant spacer fabric as an example, the importance of the physiological behaviour of textiles will be demonstrated. One of the significant factors for the physiological behaviour of textiles is their ability to act as a buffer to prevent moisture build-up in the microclimate surrounding the skin when the human subject perspires intermittently, and to keep these conditions (moisture and temperature) within levels which will enable the user to feel comfortable. The buffer effect from the vapour phase and the liquid phase was measured using a thermoregulatory model of the human skin.

In order to ensure that the wearer feels comfortable, even when perspiring heavily, experience has shown that the tested spacer fabrics of comparable thickness to knitted fabrics used as apparel fabrics should exhibit a moisture equalising parameter, Fd, of at least 0.45. As the table shows, this requirement is definitely met by both samples.

The following criteria can be used to compare the buffer effect of a textile in relation to liquid perspiration:

	Kf	≥	0.95	very good
0.95 >	Kf	≥	0.85	good
0.85 >	Kf	≥	0.78	satisfactory
	Kf	<	0.78	unsatisfactory

On the basis of this classification, the buffer effect of both articles in relation to liquid perspiration can be rated as "very good".

Result: because of the three-dimensional construction and the right combination of materials used in the spacer fabrics tested, they are well able to buffer the moisture increase in the microclimate close to the skin during intermittent perspiration of the

human subject, and can thus guarantee excellent wear comfort.

Conclusion

Functional spacer fabrics are especially good for using next to the skin. The manufacturing technology and the correct use of materials and combinations of constructions enable textiles with excellent physiological characteristics and specific functional properties to be developed for a wide range of applications. Further research work, especially in the field of special sports clothing and protective clothing, and on designing seats for the rehabilitation and furniture sectors, is quite feasible and is likely to lead to the discovery of new possibilities.

Acknowledgement

We would like to thank the Federal Ministry for the Economy and Technology (Bundesministerium für Wirtschaft und Technologie, BMWi) for financial assistance with the research projects (BMWi nos. 70/97 and 22/98).

Techtextil Asia 2000

Technical textile sector which is growing allover the world was introduced at the 5th Techtextil Asia 2000 held in Osaka, Japan, from 18. to 20. October 2000. The exhibition organized by Messe Frankfurt together with Osaka International Trade Fair Commission is held every 2 years and its importance was appealed to both the relative industries and users in Japan and other Asian countries. The exhibitors were 82 companies from 13 countries and the scale of Exhibition was reduced as for number of exhibitors as well as countries comparing to the last Exhibition. Nevertheless, each exhibitor exchanged various information and the Exhibition covered all aspects of technical textiles. Especially innovative improved articles produced by warp knitting technology attracted considerable attention of the visitors. Approx. 25% out of the Exhibitors were foreign companies who considered that the Asian market is important for them and concentrated their sales target on the neighboring Asian countries and furthermore tried to find their sales partner in Japan.

The visitors were 5,044 from 20 countries, which was decreased by 36% comparing to the last Exhibition 2 years ago. Toray and Teijin who are one of the leading yarn manufacturers and the leaders of industrial textiles in Japan did not take part in the Exhibition, which caused less interest of the visitors. Many visitors were experts in the Research and Development Section, New Project Development Section and Sales Promotion of Articles for industrial textiles.

The visitors from overseas were 211, i.e. mainly from Korea, P. R. China, Taiwan and Russia. Many visitors actively collected various information about new development during the Exhibition and it seemed that it shows expansion of application of industrial textiles.

Techtextil Symposium Asia

The Techtextil Symposium Asia was held for 2 days simultaneously during the Techtextil Asia. 16 papers by experts of worldwide famous companies, such like Toyobo, Toray, Teijin as well as university lecturers were presented at the symposium and many audiences were attended.

Nippon Mayer presented various high-grade articles

Nippon Mayer exhibited various latest developments at its stand. The visitors could have a good opportunity to get a lot of information about industrial textiles by warp knitting technology. Many customers who are producing other articles than industrial textiles tried to collect information about industrial textiles as many as possible in order to examine entrance into new sector. Furthermore, the companies who are producing industrial textiles by weaving looms, etc. noticed possibility of warp knitting technology. Various articles and panels showed useful technical information to the visitors and some new developments by Karl Mayer were also exhibited.

At the Exhibition various kinds of spacer fabrics mainly for medical, geotextiles, automobile as well as home textiles and Malimo stitch bonded fabrics were presented. Especially for geotextiles, the geogrids for constructing and maintaining of the road, a miniature model of various application for civil engineering and the water impermeable sheet for industrial waste disposal sites were exhibited. For other sectors, automobile textiles incl. spacer fabrics for car seats as well as shield fabrics and furthermore for high-tech sectors, various D.O.S. constructions for textile reinforced composites, etc. were exhibited.

Agricultural textiles are one of important applications for warp knitting technology and various kinds of shield nets are included in this sector. Combination of net constructions and Mayer blankets are utilized for transportation by Nittsu who is one of leading express business because of easy handling as well as cost saving. Those wide ranges of articles in Mayer booth attracted attention of many visitors.

Warp knitted textiles presented by other exhibitors

Warp knitted constructions were also exhibited in other booths. At the