RESEARCH INSTITUTES: KANSAS STATE UNIVERSITY

There's no place like IER

by Shari Shallard

To many people, Kansas is known for the infamous tornado that whisked away Dorothy and her little dog Toto in the 1930's film *The Wizard of Oz*. If only that tornado had torn through a few decades later, Dorothy may have been more adequately outfitted for her windy trip. Kansas, you see, is now home to the United States' top facility for research on the thermal comfort properties of fabrics, clothing, and sleeping bag systems: the Institute for Environmental Research (IER) at Kansas State University (KSU).

Located in Manhattan, Kansas, KSU is a logical home for such a progressive institute—the university is proud of its ranking as one of the nation's 'cutting-edge schools'. Manhattan, nicknamed 'The Little Apple', is a lovely town that holds a zoo, a mall, 21 parks, a recreation trail that circles the city and, of course, the campus. With more than 23,000 students, the university's grounds stretch out over a 664-acre site in northeast Kansas.

Formed nearly 50 years ago when the university was given a sophisticated environmental chamber by the American Society for Heating, Refrigerating, and Air Conditioning Engineers, IER has developed into an internationally known centre dedicated to exploring factors that affect the relationship between people and their thermal environment. This interdisciplinary centre brings together graduate students and faculty from mechanical engineering and apparel design/textile science to study human thermal comfort, heat stress/cold stress, heat transfer properties of textile systems, indoor environmental engineering, and related topics. It is one of few centres in the world that has the environmental chambers and supporting instrumentation necessary for this type of research.

Dr Elizabeth McCullough, co-director of IER and a professor of textile science in the university's Apparel, Textile and Interior Design department, has spent about 30 years evaluating the thermal comfort properties of textile products. "We assist companies with product development and the evaluation of their fabrics, garments, bedding, and sleeping bags," she says. Specialised equipment in eight computer-controlled environmental climatic chambers is used to measure the insulation and



Soldiers have been used to evaluate the effectiveness of personal cooling systems worn under body armour in hot environments.

Kansas State University

evaporative resistance (or moisture permeability) of textile systems. "We help companies compare their current products with new prototypes and with competitors' products to improve their thermal performance."

These chambers are capable of recreating indoor, desert, tropical or arctic conditions. A bank of lights in one chamber, for example, simulates different solar loads, while large fans can be used to create wind. Fooled into thinking they are being exposed to earth's varying elements, fabrics undergo a number of tests to determine how well they will fare in the real world.

First, the hot plate

A fabric's first stop is the sweating hot plate, a device used to measure the insulation provided by a single fabric or a fabric system. The plate's surface is heated to the average skin temperature of a human (98.2°F), then covered with the material(s) to be assessed. The amount of electrical power it takes to keep the plate heated to the correct temperature in a cooler environment is proportional to the heat that is transferred through the fabric, and the insulation value is calculated. "In general, the thicker the material, the more insulation it provides," says Dr McCullough. "The air that is trapped inside the textile and on its surface is providing the insulation. The fibres [of the fabric] function to stabilise the air and block radiation heat losses."

Hot plates can also be used to measure the evaporative resistance of materials—the opposite of moisture vapour permeability. When a person sweats, it is the act of the perspiration evaporating off the skin that actually cools the body. If an athlete's clothing or bedding layers inhibit the evaporation of sweat, he or she will feel uncomfortably warm—the evaporative resistance test is designed to determine whether this may prove to be a weakness of a fabric. Water is fed to the plate surface, which is covered with a breathable barrier that allows water vapour to go through, but keeps the fabric sample from getting wet. The amount of power measured is proportional to the amount of heat removed from the plate through evaporation.

IER performs several other tests that measure the moisture vapour transmission rate of fabrics, including different upright and inverted cup methods: a cup of water is covered with a fabric, for example, and the rate of water vapour diffusion through the fabric into the drier environment is measured by weighing the cup periodically over time.

"The diffusion of moisture through a material is largely dependent upon the pores in the structure because the water molecules pass between fibres," explains Dr McCullough. "They may also be absorbed by fibres and then desorbed into the environment, but the diffusion between them is the more important pathway."



Human subjects can be used to verify temperature ratings for comfort on sleeping bags.

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The Institute also operates the dynamic moisture permeation test cell, and is in fact the only non-military laboratory in the United States to offer this. (The test was developed by Phil Gibson, a scientist at Natick—a soldier-support organisation responsible for researching, developing, fielding, and managing food, clothing, shelters, airdrop systems and soldier support items—and later became an industry standard method.) The test measures the moisture vapour transmission rate of fabrics at many different humidity gradients. This is particularly important because hydrophilic film laminates, such as that which coats many shell fabrics for jackets to create wind and water resistance, often have higher permeability characteristics at higher humidity levels.

"For film laminates and coated fabrics, there are several mechanisms by which moisture can move from one side of the material to the other," says Dr McCullough. "Liquid moisture moves through a fabric by wicking or travelling along a fibre via capillary action."

Significantly, fabric wicking tests do not adequately predict how comfortable a material will be during actual use. More complex forms of testing are required to assess this subjective—but all important—element.

Bring in the manikins

Manikins are essentially hot plates shaped like people; their human form allows for more sophisticated analysis. Manikins take into account variables such as body coverage, the uneven distribution of materials over the body, and the increase in surface area for heat loss. Because manikin tests are more realistic, the results can be used in biophysical models to predict human thermal comfort under different

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conditions. Several life-size thermal manikins can be found at IER.

'Sam' is used exclusively for measuring the insulation of sleeping bags and bedding systems. These values are used in body heat loss models for predicting the lowest air temperature for comfort—what is noted by many manufacturers as the temperature rating. Land's End, for instance, classifies its adult outerwear as being appropriate for either five degree, fifteen degrees below zero, or even forty degree below zero; classifications are achieved through manikin tests such as these at IER.

Although some companies such as Land's End have their own 'copper man' (as the outdoor apparel company describes it), IER's Sam is struggling to keep up with his own workload. "We conduct insulation tests for many manufacturers and the military," says Dr McCullough. "We have just ordered a new brother for Sam due to the high volume of work in this area."

Some tests require more than just a warm body: 'Stan' and 'Fred', dedicated to clothing research, are manikins that can walk and sweat as needed. "We can also use Stan for evaluating the cooling effectiveness of personal cooling systems worn under protective clothing," she says. "In these studies, we quantify the amount of cooling provided and how long it will last."

Testing on humans

Of course, even manikins have their limits. For the third level of evaluation, human subjects are brought in and instructed to exercise at specific levels in an environmental chamber. These studies are very time consuming and expensive to execute. Depending upon the number of subjects involved, how many clothing systems they are wearing, the environmental conditions to which they are exposed, and the number of research personnel involved, studies easily run from $15,000 to $150,000.

To conduct a human study, IER's first step is to recruit subjects from the pool of potential users. A physical exam and series of questions help to ensure that participants are healthy and physically fit enough to partake. The exercise protocols vary with the type of clothing being tested and the types of environments in which it will be worn. "We typically measure internal body core temperature, skin temperature, heart rate and oxygen consumption during the tests," says Dr McCullough. "There is a tremendous amount of data that is collected on each subject during one test. We could not do it without computer data acquisitions systems."

Human studies also require the use of one of IER's less glamorous pieces of equipment: the washing machine. "We have to have enough clothing in the proper sizes to run the comfort trials, and we do a lot of laundry during these experiments," she says.





Stan the manikin measures the heat transfer properties of sports apparel.

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The final level of evaluation should be a field study, but this is not something IER does very often. "Unfortunately, some companies start evaluating their products at the fourth level first. They give out free pieces of a product and ask for feedback," she says. "If a company gives you a free jacket, you're probably going to tell them it is wonderful. It is difficult to document exactly when the person wore the item and under what conditions." She says companies try to build on this imprecise information. "The companies then come to us with anecdotal data saying the product is great, and they want us to prove that it's great. That is not the way we do research."

Sophisticated sweaters

This is the way IER does research: with a lengthy list of services, the IER offers an array of standard tests for clients that employ its cutting-edge instruments. Fabric thermal insulation, for example, can be assessed at $350 per fabric type, while the cooling effectiveness of a personal cooling system can be assessed for $1,400 per system. Additionally, the institute can develop unique experiments to meet a company's needs.

Under the directorship of Dr Steve Eckels (who is also a Professor of Mechanical Engineering at KSU), the institute and its arsenal of interesting equipment continues to grow: a new sweating head that can be used to better evaluate helmets should be arriving soon, as well as a new sweating foot that can be used to design and evaluate shoes and boots. So, while performance material manufacturers continue to develop new ways of coping with Mother Nature's diverse environmental conditions, researchers at IER will continue to develop more sophisticated ways of assessing the efficacy of those fabrics.

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