



# The Attributes of Thermal Comfort

## ERGONOMIC CRITERIA FOR THE DESIGN OF “BREATHABLE” WORK CHAIRS



*A chair should “breathe”; its surface materials should provide comfort and allow conduction of heat and dispersion of moisture away from the surface of the sitter’s skin.*

*A work chair should have a neutral effect on body-surface temperatures, so that thermal comfort is not posture dependent.*

## What We Know

People are more comfortable when ambient temperatures are neutral, allowing the body to maintain thermal equilibrium without sweating or shivering. Increased humidity at the skin's surface can lead to sitting discomfort.

The human body is designed to maintain thermal equilibrium with its outside environment, so that body heat produced by activity and metabolism roughly equals the amount of body heat lost to the ambient air. When this equilibrium is disturbed, the body compensates by shaking to generate more heat or sweating to transfer heat away from the body surface through evaporation.

Thermal comfort, then, is relative to body temperature. One study found that its subjects' definitions of a comfortable temperature varied with the current temperature of their own bodies (Shitzer et al., 1978). "Ideal" ambient temperatures vary from person to person and over time as body temperature varies.

Humidity is another important aspect of thermal comfort. A seated person will usually feel uncomfortable when humidity builds up at the skin's surface because moist skin creates increased friction coefficients (Reed et al., 1994), causing it to stick to clothing or chair upholstery and inhibiting the small movements required to shift weight off pressure points.

## Therefore

A comfortable chair will have a neutral effect on thermal comfort by allowing the flow of heat or the dispersion of water vapor generated by the body.

## Design Problem

Design a work chair that "breathes" so that sitters experience the same thermal conditions when seated as they experience when standing.

Conventional approaches to office-chair upholstery have been typically fabric-over-foam padding. Such padding has insulating properties that prevent conduction of heat away from the body. A study of different materials used for wheelchair seat cushions found a significant rise in skin temperatures under the thighs

and sitting bones of test subjects in chairs using four-inch-thick foam rubber pads (Fisher et al., 1978).

Foam padding can also impede water-vapor transfer from the skin's surface. One study found that, along with different foam compositions, permeability of seat cushions varied with compression (Diebschlag et al., 1988). This suggests that thermal comfort could vary for different people using the same type of work chair, depending on where and how much they compress the foam cushions of the seat pan and backrest.

In some climates, the cost of additional air conditioning required to counteract the insulating properties of non-breathable seating materials can be a significant expense. A report published by the Rocky Mountain Institute estimates that an office chair upholstered with a non-breathable material insulates 20 to 25 percent of the body's surface. This can add \$140 to \$290 per worker in HVAC and utility equipment costs (Houghten et al., 1992). By helping to maintain neutral body temperatures, a chair with a breathable material requires less cooling. It may, over the life of the chair, generate enough HVAC cost savings to offset the chair's initial cost.

## Design Solution

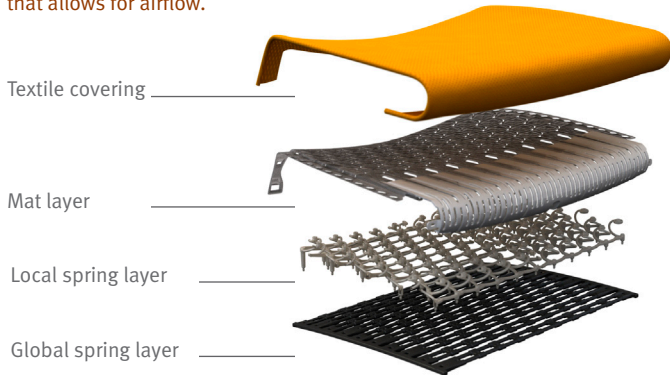
Develop breathable and porous seat and backrest materials that provide comfort and allow conduction of heat and dispersion of moisture away from the surface of the skin.

The porous quality of suspension materials such as Pellicle<sup>®</sup>, AireWeave<sup>™</sup>, TriFlex<sup>™</sup>, Cellular Suspension<sup>™</sup>, and FLEXNET<sup>™</sup> allows for unobstructed moisture dispersion and conduction of heat away from body surfaces that touch the backrest or seat pan.

A more recent development is the Pixelated Support<sup>™</sup> system. It uses both a global and a local spring layer to fit the sitter's body shape. / See Figure 1 / This contoured, layered design allows for air to flow through the layers.

Tests of subjects sitting in chairs with these breathable materials and in chairs with both traditional and highly porous foam found that buttock skin temperature increased when the subjects sat

The Pixelated Support system is composed of three layers. At the base is a global spring layer. Sandwiched between it and the mat layer is a local spring layer. The system is covered with textile. Negative spaces in the structure of the system provide openness that allows for airflow.

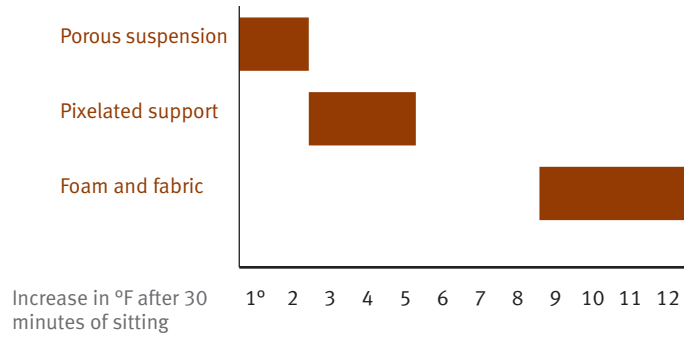


/ Figure 1 /

in the foam-padded chairs but remained essentially unchanged in chairs with the breathable suspension material. Test subjects' sitting temperatures remained essentially constant and comparable to their standing temperatures even after 30 minutes of sitting in chairs with breathable materials. / See Figure 2 / The Pixelated Support seat, which uses a layered design, yielded net temperature increases of about +4 degrees F. This increase is about three times that of Pellicle, the most porous material, yet less than half the typical temperature rise that occurred with foam seating.

In previous thermal studies of similar duration temperature differences of up to 12 degrees have occurred as subjects sat on foam. This is a significant temperature increase to the body's surface: A temperature difference of 10.7 to 12 degrees is equivalent to the temperature change between a hot shower and a cold shower.

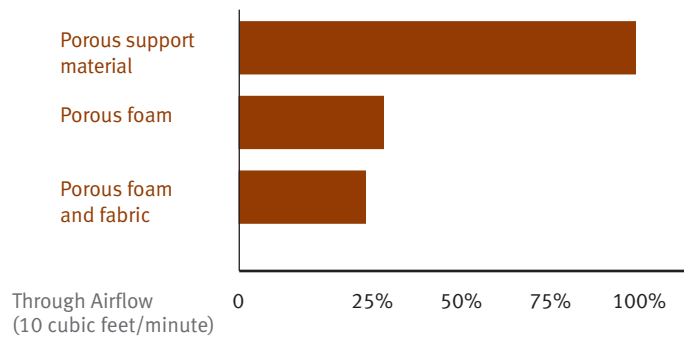
A chair designed with breathable and porous seat and backrest materials allows airflow to the parts of the body in contact with the chair that is comparable to the airflow that reaches the more exposed parts of the seated body. For example, an American Society for Testing of Materials airflow test (D3574-91) of Pellicle material found no measured pressure drop from one side of the material to the other when air was directed through it at 10 cubic



/ Figure 2 / With porous material, seated skin temperature remains essentially constant. With foam, sitting skin temperature rises.

feet per minute, signifying that the Pellicle material is virtually porous. Using even a highly porous foam in the same test dramatically restricted the airflow. / Figure 3 / Adding a completely non-porous chair shell structure would then result in total blockage.

Taking its cue from the porosity of classic wicker or rattan furniture, a chair made with breathable suspension material is virtually "transparent" with regard to airflow and heat transfer, acting as a conduit for, rather than a barrier to, the surrounding thermal environment. People who work in an office furnished with such chairs should be able to dress for the ambient conditions and not notice temperature changes when they move between standing and seated tasks.



/ Figure 3 / Breathable and porous support materials, unlike foam/fabric, do not restrict airflow.

## References

Diebschlag et al. (1988), "Recommendation for Ergonomic and Climatic Physiological Vehicle Seat Design," *Society of Automotive Engineers Technical Paper 880055*.

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Shitzer et al. (1978), "Human Response from Heat Stress with Relation to Comfort," *Ergonomics*.

## Credits

Jerome Caruso is the designer of Celle® chair. Caruso's designs extend beyond seating and the workplace. As Sub-Zero's designer for over 20 years, Caruso has been influential in shaping the look and function of kitchen products and appliances. The innovative mind and design expertise of Caruso is evident in the more than 75 design patents he holds. Jerome and his son, Steven, designed Herman Miller's Reaction® chair in 1998.

Don Chadwick co-designed, along with Bill Stumpf, the groundbreaking ergonomic Equa® and Aeron® chairs for Herman Miller. He has been instrumental in exploring and introducing new materials and production methods to office seating manufacturers.

Bill Dowell, C.P.E., leads a team of researchers at Herman Miller. His recent work includes published studies of seating behaviors, seated anthropometry, the effect of computing on seated posture, the components of subjective comfort, and methods for pressure mapping. Bill is a member of the Human Factors and Ergonomic Society, the 3-D surface anthropometric survey, the work group that published the BIFMA Ergonomic Guideline for VDT Furniture, and the committee that revised the BSR/HFES 100 Standard for Human Factors Engineering of Computer Workstations. He is a board-certified ergonomist.

Gretchen Gscheidle is a product researcher at Herman Miller. Educated as an industrial designer, Gretchen now applies her creativity and problem-solving skills in her role as researcher on cross-functional product development teams. She has been the research link in the company's seating introductions beginning with the Aeron chair in 1994. Her research focuses on laboratory studies of pressure distribution, thermal comfort, kinematics, and usability, as well as field ethnography and user trials.

Gretchen is a member of the Human Factors and Ergonomics Society and represents Herman Miller on the Office Ergonomics Research Committee. Her work has been published in peer-reviewed journals.

Studio 7.5, located in Berlin, Germany, designed the Mirra® chair. Studio 7.5 is composed of Burkhard Schmitz, Claudia Plikat, Carola Zwick, and Roland Zwick. With the exception of engineer Roland Zwick, the designers are cofounders and partners of the firm, which opened in 1992, and also teachers of industrial design and product design at universities in Germany. An interest in the tools that define how people work has led Studio 7.5 to design software interfaces, office seating, and medical equipment. Studio 7.5 has been collaborating with Herman Miller since the mid 1990s.

The late Bill Stumpf studied behavioral and physiological aspects of sitting at work for more than 30 years. A specialist in the design of ergonomic seating, his designs include the Ergon® chair, introduced by Herman Miller in 1976 and, with Don Chadwick, the equally innovative Equa and Aeron chairs. He contributed significantly to the design of the Embody™ chair prior to his death in 2006. In that same year, he posthumously received the National Design Award in Product Design presented by the Smithsonian's Cooper-Hewitt, National Design Museum.

Jeff Weber credits his love of furniture design to working with Bill Stumpf, who designed for Herman Miller for 30 years. Weber joined forces with Stumpf's Minneapolis firm in 1989. That led him to his association with Herman Miller. Weber worked with Stumpf on the Embody chair and, after Stumpf died in 2006, Weber evolved the design at his Minneapolis-based Studio Weber + Associates. In addition to the Embody chair, Weber's designs for Herman Miller include the Intersect® portfolio, Caper® seating, and the Avive® table collection.

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