Solar Impulse – comfort for pilots under extreme conditions

Around the world without burning any fuel and using only solar energy – this is the goal of the high-tech aircraft Solar Impulse. So that the pilots neither perspire nor freeze during the flight stages, which will last up to five days and nights, special clothing systems are needed. These are being delivered by the textile experts at Empa.

TEXT: Rémy Nideröst and Beatrice Huber / PHOTOS: Empa

Consider the extreme conditions in the Solar Impulse cockpit: because the aircraft is to remain in the air throughout the night, temperatures will fall to as low as minus 20 degrees Celsius. The aircraft is not insulated in any special way because every gram counts (see the box, "Night flying thanks to the sun"), and so special clothing must take on this task. Although temperatures during the day can be comfortable, solar radiation can make the pilots perspire. Unsuitable clothing would have serious consequences. For instance, one's ability to concentrate suffers in extreme temperatures, while remaining seated for long periods can cause decubitus, better known as pressure ulcers. Further, because the pilot can barely move around in the cockpit – there's simply no room – he can't freely put on or take off layers of clothing.

Thus, off-the-rack clothing was not even a remote option for the Solar Impulse team; they had to find a flexible, adaptable clothing system. That was the perfect assignment for the textile experts at Empa. "Solar Impulse asked if we could develop a suitable clothing system for them," says Markus Weder from Empa's "Protection and Physiology" Laboratory.

Down filling for night time – ventilation during the day

For thermal insulation, the Empa experts reverted to a well-proven material. "Bird down is not only very lightweight, it also provides extremely effective thermal insulation and transports moisture very well," explains Weder. His team furnished the pilot's suit with a total of four down chambers – two each for the arms and legs – which function according to the vAIRis System (see the box, "Birds as the perfect model – the vAIRis System"). The chambers are surrounded on both sides by a breathable foil; depending on the desired level of insulation, air is forced into or out of the chambers. In the case of the suit for the Solar Impulse pilots, a micropump can either fill or empty the chambers in roughly three minutes.

Even when not exerting ourselves physically, we lose roughly a litre of water each day through our skin due to *perspiratio insensibilis*. In high temperatures or though physical activity, this amount can easily more than double. Perspiration must be efficiently transported away so that no unpleasant accumulations of moisture build up, which over time can macerate and damage the skin. For the Solar Im-

André Borschberg, CEO and co-founder of Solar Impulse and the pilot of the very first night flight in a solar aircraft, tested the system in Empa's climate chamber.

Night flying thanks to the sun

Solar Impulse is pursuing the goal of circumnavigating the globe using only solar energy. The primary concern of the team at Solar Impulse isn't about a sporting competition or making it into the Guinness World Records book. Rather, they want the project to demonstrate how much potential there is in renewable energy and technologies.

With a wingspan of roughly 64 metres, the HB-SIA prototype aircraft weighs only 1.6 tonnes. The Airbus A340, which specs a similar wingspan, weighs 170 tonnes, more than 100 times more. This large wingspan is necessary in order to make place for the roughly 12,000 solar cells which supply the energy for propulsion. So that the aircraft can continue to be flown at night, lithium-polymer batteries are on board. Weighing 400 kilograms, they take up a quarter of the total weight. Four electric motors, each rated at 10 horsepower, provide thrust. The maximum flight level is 8500 metres above sea level, and the average speed is approximately 70 km/h.

The men behind Solar Impulse are both Swiss: Bertrand Piccard and André Borschberg. The entire team consists of more than 50 people as well as countless other external specialists such as the textile experts from Empa. The HB-SIA's maiden voyage took place on 7 April 2010 at the Payerne airport in the canton of Vaud; the first night flight from 7 to 8 July – with André Borschberg as pilot wearing the Empa suit. The construction of the second prototype, in which Piccard and Borschberg will lift off to circumnavigate the globe, will start soon.

Picture credits: Solar Impulse

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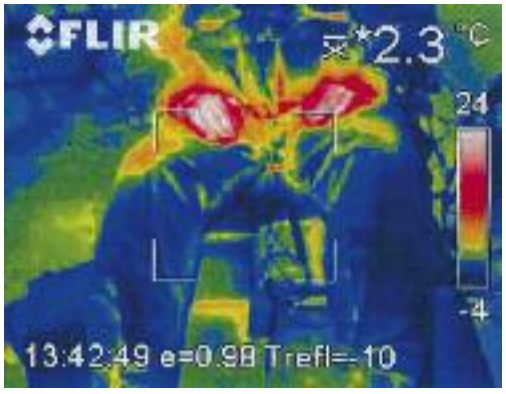

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Empa researcher Markus Weder discusses final details with André Borschberg of Solar Impulse before starting to run tests on the clothing system in the environmental chamber.

2
It gets cold in the environmental chamber, but the insulation does its job – only the electrically heated gloves radiate any heat. The arms and legs are protected by a layer of down.

3
Even when placed under a heat lamp, the pilot doesn't perspire very heavily.

pulse pilots, accumulations of moisture can become an especially serious problem because the seat in the aircraft covers a third of their body surface. In order to also purge moisture efficiently from the seating regions, Weder and his team incorporated active rear ventilation into the pilot's seat and the areas of the suit covering his back.

Successful tests in an environmental chamber

Together with partners from industry, the Empa researchers constructed a prototype consisting of a seat and a suit – a custom-tailored article of clothing for André Borschberg, CEO and co-founder of Solar Impulse and pilot of the first night flight ever in a solar airplane. After prototype tests in an climate chamber at Empa in St. Gallen, Borschberg was quite enthusiastic. The Empa team was very happy with the results, as well. “The clothing system fulfilled the requirements with flying colours. The tests show that both thermal insulation and the transport of moisture function flawlessly, even under extreme conditions,” comments Weder. As a second pilot, Bertrand Piccard will also get his suit, one tailored exactly to his body. This is important because only with custom tailoring does the thermal insulation reach its optimal level of performance. //

Birds as the perfect model – the vAIRis System

When it gets cold, birds fluff up their coat of feathers; the air pockets between the feathers serve as an insulating layer and protect them from the cold. Conversely, when it gets warm, birds bring their feathers in close to their bodies. Empa researcher Markus Weder and his team copied this behaviour from nature to develop a textile-based innovation, the vAIRis System (short for “variable insulation system”). This patented invention allows the production of down jackets whose insulating properties can be varied. As required, the jacket is filled with air to create effective insulation between the down material. If the ambient temperature rises or if someone performs physical activity, air can be blown out to prevent heavy perspiration. This development also serves as the basis for the pilot's suit for Solar Impulse.

Because the perception of and sensitivity to temperature is very individual, every person needs a bedspread suited to their own preferences. The vAIRis System is well suited for this, as well; Empa recently transferred the corresponding patent to the Swiss company ACT. They sold a licence to a German manufacturer of eco bed feathers and down material, which intends to manufacture year-round duvets which can be optimally adjusted in the summer and winter thanks to the variable insulation system.