THE ACTIVE MANIFOLD SKIN: FEASIBILITY, PROTOTYPING, AND PERFORMANCE STUDIES OF A WALL SYSTEM INTEGRATING DISTRIBUTED SOLID STATE, SOLAR POWERED COOLING AND HEATING TECHNOLOGY

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Proposing a thermoelectric-based cooling and heating system integrated in a double skin wall system, the research has thus far designed and mocked up a system at large scale for testing in real-life conditions. Deploying one actively cooled and heated prototype with another 'control' prototype of identical construction, experiments are under way to measure the capabilities of the system. Experiments have partially confirmed the qualitative performance of the system as it was originally hypothesized, but more experiments are needed to accumulate the data necessary to describe the capabilities (and shortcomings) of the system as it currently stands. The near-future outcome of the work will be an improved design for the system that will be directly informed by observations of the current system.

The Active Thermal Manifold Skin:
Feasibility, Prototyping, and Performance Studies of a Wall System Integrating Distributed Solid State, Solar Powered Cooling and Heating Technology

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The project, as funded by the AIA research grant of 2008, proposed the design and construction of a set of prototypes that would test the performance of a thermoelectric-based cooling and heating system integrated in a double-skin wall system. Thermoelectric technology is a solid-state method for transferring heat that has become common in many small applications yet is only emerging as a potentially important technology for controlling the climate in buildings. The specific approach explored in the project – to integrate the technology into a double-skin 'manifold' wall – is a potentially new and untested approach. Two prototypes were to be used in experimentation: one 'active' unit equipped with the experimental system, and another identically constructed 'control' prototype. The additional significance of the project is the scale at which the prototypes were constructed (230 cubic feet), the relatively large size of the thermoelectric array (rated at 130 cooling watts), and the relatively large photovoltaic power supply (0.51kW).

Figure 1: The two prototypes being moved to an exterior roof deck.

At the time the original report was submitted at the end of 2008, the project had realized the two full-scale prototypes complete polycarbonate double skin walls, integrated through-wall thermoelectric devices, and a complete photovoltaic system. A research fellowship with additional funding came from CERES (The Center for Energy Research/Education/Service at Ball State University) to support the project in its final stage of development in the fall of 2008. The final hypothesis of the system was that the thermoelectric devices would drive a temperature differential significant enough to drive air into the interior chamber of the prototype from the interior of the double skin wall, in turn drawing air from the interior back into the double skin: an 'active' manifold. After initial experimentation, it was determined that the most favorable condition for such an organized temperature differential would occur without the fan system that was factory-mounted on the cold side of the thermoelectric devices.

With the support of CERES (The Center for Energy Research/Education/Service at Ball State University) the two prototype units were moved to an exterior roof deck in the summer of 2009 (Figure 1) where finishing touches were completed on the units and the first experiments were carried out. Before the cold weather arrived in the fall of 2009, four experiments were carried out with both the active and control units in place (Figure 2).

Figure 2: Four exiperments were performed on both the active and control unit.

Many aspects of the initial hypothesis have so far been confirmed.

First, compatibility between the thermoelectric technology and the photovoltaic power source at this scale has been demonstrated. The sizing of the P.V. system and its battery seem to be imperfect, but the system has operated independently at full load of 432 watts for up to five hours with the thermoelectric devices continuing to produce heat transfer through the wide voltage range produced by the P.V. system.

Secondly, the experiments have confirmed the hypothesis that the thermoelectric devices would produce meaningful cooling within the double skin cavity that would result in air exchange with the interior chamber. In one experiment, carried out on a sunny day, the temperature within the active prototype's double-skin wall was up to 14 degrees cooler than the double-skin wall in the control unit. Total air transfer through the double-skin manifold, measured with a hot-wire anemometer, was almost 4 cubic feet per minute when observed during another experiment, suggesting a total cycle of the test chamber volume through the manifold in just over an hour.

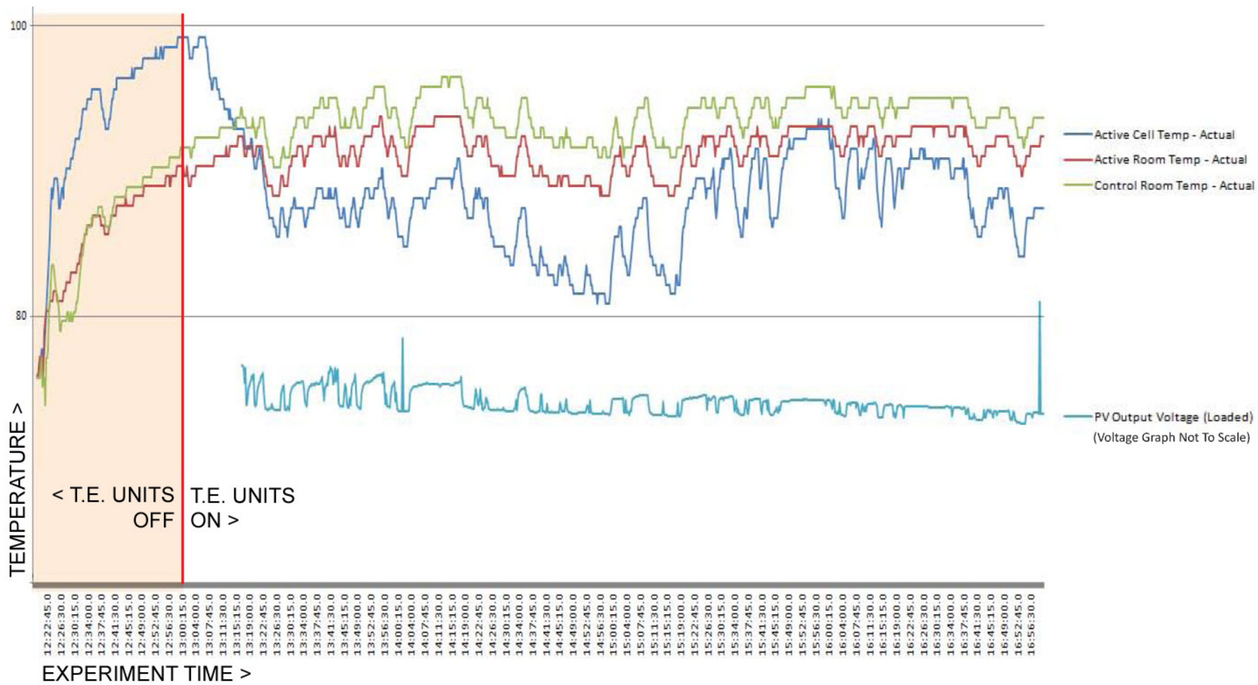

Figure 3: Solar radiation vs interior chamber temperature

Thus far experiments have generally resulted in a marginally lower interior chamber temperature (between 1 to 3 degrees) in the active unit when compared with the control unit, while the units are affected nearly equally by solar radiation (Figure 3). Yet these observations are not yet consistent enough to conclude with certainty the success of the system in removing heat from the interior chamber of the prototype. More experiments and are imperative to fully characterize the performance of the system and the relationship of its many physical variables (manifold geometry, amount of sun shading, positioning of thermoelectric devices, etc.) to the outside factors of air temperature, incident solar radiation, and wind.

The primary objective of the experiments remains to accumulate data (primarily temperature readings) that demonstrates the cooling and heating capacity of the system, providing a better understanding of its viability and its shortcomings. As more extensive experimentation continues, reliable and reproducible outcomes are expected that can support this objective. Yet as the work currently stands, having large, operational, instrumented mock ups has been extremely valuable in understanding the performance of the proposed system under actual conditions.

Observing the current system is directly informing the next phase of research, where the development of a modified manifold design is under way. The integration and position of the thermoelectric devices and the design and construction of the manifold itself will be among the major refinements for the next version. Unlike the first set of prototypes, the design of the next version will be directly informed by observations, evidence, and computer simulation and modeling drawn from the last two years of work; moreover, the current body of work will greatly enhance the effort to draw future funding and especially opportunities for collaborative work with fellow academics and with industry.