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The homeostasis solution – Mechanical homeostasis in architecturally homeostatic buildings

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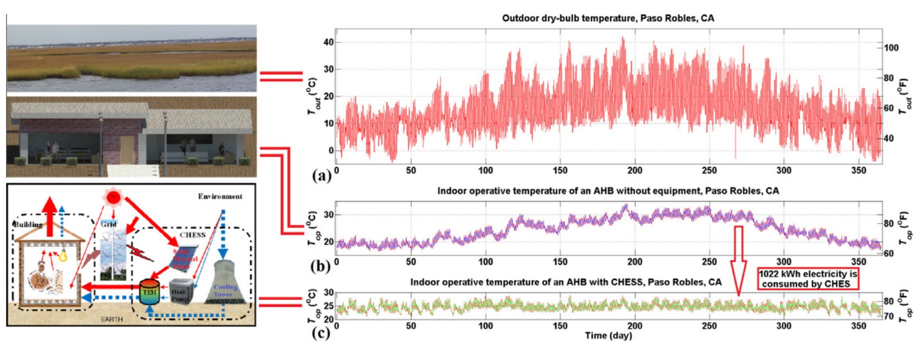
HIGHLIGHTS

- Architectural homeostatic buildings (AHBs) make sense because of the laws of physics.
- However, high efficiency can be obtained only with AHBs and equipment considered as systems.
- Mechanical homeostasis facilitates AHB-equipment system synergy with heat extraction.
- Entropically speaking a building needs neither energy nor a fixed amount of heat, but its homeostatic existence.
- Homeostatic buildings can reduce building energy consumption from 80% to 90%.

GRAPHICAL ABSTRACT



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ABSTRACT

We already know, for energy-saving potential, the necessary architectural features in well-designed buildings: high performance building envelope, sufficient interior thermal mass, and hydronic-network activated radiant surfaces for cooling and heating. Buildings with these features may be referred to as *architecturally homeostatic buildings* (AHBs); such a building-system is thermally semi-autonomous in the sense that its temperature variation stays within a certain range even without conditioning equipment, and, with conditioning equipment in operation, its thermal regulation is handled by its hydronic heat-distribution-network for controlling the temperature level of the building. At the present time conventional HVAC equipment is used for maintaining the heat-distribution-network: this arrangement, however, has resulted in great energy saving only for AHBs with accessible natural water bodies. In operation of general AHBs, a case is made here for a new kind of mechanical equipment having the attribute of *mechanical homeostasis* (MH). MH is a new energy transformation concept in a triadic framework. Superlative energy efficiency is predicted as a result of *combined* improvements in higher *triadCOP*s and lower total (inducted + removed) heat rates—evincing existence of synergy in architectural and mechanical homeostasis, which together will be referred to as the homeostasis solution.

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1. Introduction

Emden in 1938 [1] wrote,

Why do we have winter heating?
The layman will answer: "To make the room warmer." The student of thermodynamics will perhaps so express it: "To import the lacking energy."
If so, then the layman's answer is right, the scientist's wrong.

This haiku-like riddle has generated interest from a small army of responses [2–7]. What was demonstrated by Emden has been confirmed in a more detailed recent analysis, "A room is not heated by increasing its internal energy but by decreasing its entropy due to the fact that during heating, the volume and pressure remain constant and air is expelled" [6]. So the bound between room-heating and energy-import is broken: what a room needs is heat not energy [8]. But, the puzzle remains: building heating and cooling remain the problem of heating load and cooling load, remaining a HVAC practice of importing heat or removing heat regardless whether the outcome is in terms of higher internal energy or lower entropy. What are possibilities of "making the room warmer" as implied by Emden, other than the standard HVAC practice, remains unanswered. This paper provides one concrete answer to this riddle.

The first step of formulating the long answer presented here was taken in 1993, when Meierhans [9] combined radiant-surfaces conditioning with the use of the thermal mass substrate (concrete slabs) of the radiant surfaces for energy storage, a practice which has become known as thermally activated building systems (TABS). TABS works especially well for buildings with accessible natural water bodies such as Kunsthaus Bregenz [9], a museum in Austria. A large body of literatures devoted to TABS research [10–43] has been compiled in a review paper [44]. Despite considerable interest in TABS building concept, the promise of TABS buildings remains unfulfilled: evidence of which is the still inadequate understanding of the precise role in building thermal mass. Treatment of the role of interior thermal mass in how a building interacts with locality-specific climatic condition resulting in a functional relationship of envelope *U*-value, thermal mass, window-to-wall-ratio (WWR) has been developed by Stony Brook University researchers [8]. They also made the case for the advantage of using heat extraction devices for the reason of physics that all reversible processes are heat extraction process [45]—and the suggestion that both the use of TABS "elements of radiant surfaces [and] energy storage, and [the practice of] heat extraction are necessary for their synergistic combination. . .Their optimal application is the only path for real energy efficiency" [44].

This paper studies details of the suggested synergy between TABS and heat extraction. In the course of the investigation we develop the answer to the Emden riddle by clarifying the concept of homeostasis based on a new advancement on the understanding of energy transformation in Section 2. Section 3 presents a description of composite heat extraction system (CHES) as an example of mechanical homeostasis. Section 4 informs the simulation modeling and its assumptions including building data, equipment data, and weather data. Section 5 reports the simulation results, which show that it is crucial to have the activation of the heat pump circuit and that of the cooling tower/solar thermal panel circuits based on separate temperature signals for realizing synergy between architectural and mechanical homeostasis: homeostasis existence is shown to require no *fixed* heating and cooling load. Discussion of results continues in Section 6, which focuses on the role of interior thermal mass on bringing about thermal comfort and energy efficiency. The paper closes with concluding remark in Section 7, in which it is summarized that building homeostasis is the answer to the Emden riddle, which amounts to a new conception of building.

2. Building homeostasis: mechanical homeostasis and architectural homeostasis

"A house is a machine for living in," Le Corbusier famously pronounced. The equally famous F.L. Wright begged to differ that a house is not a machine but an organic object, "Organic architecture seeks superior sense of use and a finer sense of comfort, expressed in organic simplicity." Should we conceive buildings as machines or organisms? In the former case, as it was practiced in the 20th century, engineers were responsible for selecting mechanical equipment for the indoor environmental (IE) control of the building. Today most architects and engineers consider the equipment-centric 20th century practice to be a mistake. Architects are once again responsible for design building elements that

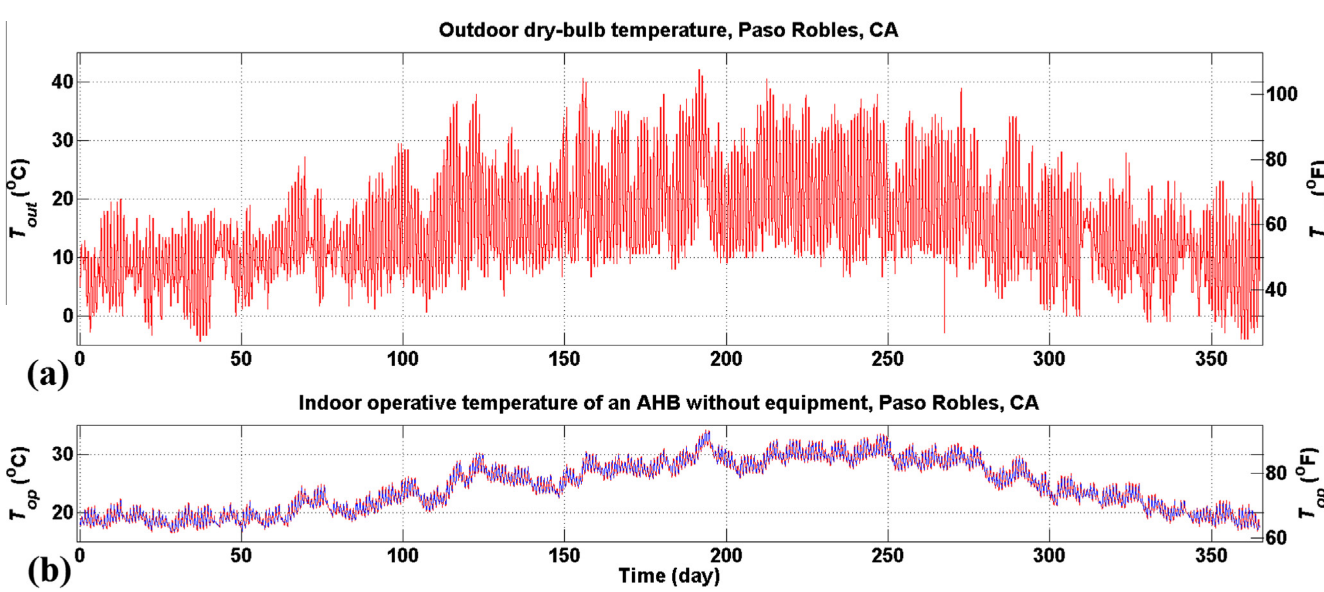

Fig. 1. An example of a TABS building with its conditioning equipment turned-off in Paso Robles: (a) the outdoor ambient temperature for the duration of one year, and (b) the thermal semi-autonomy of the building, i.e., architectural homeostasis damps the indoor temperature range with the indoor temperature level remaining to be controlled.