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Introducing the concept of Acoustic Personalised Environmental Control systems (Acoustic PECS) within the framework of IEA EBC Annex 87

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ABSTRACT

The availability of systems that can locally adjust environmental parameters holds the potential to enhance building occupant satisfaction by considering individual sensitivities, expectations, and needs. To this aim, Personalised Environmental Control Systems (PECS) are being studied as solutions that can provide individually controlled environments in the immediate surroundings of an occupant, without affecting directly the entire space and other occupants' environment. The concept has been primarily developed to address individual control of the thermal environment and perceived air quality, as in chairs with heating/cooling functions and desks equipped with personalized ventilation systems. By extending the concept of PECS to the acoustic domain, a framework on Acoustic PECS is here introduced and exemplified. The study builds on ongoing research within the IEA EBC - Annex 87, dedicated to investigating the Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems.

1. INTRODUCTION

The availability of successful control actions on the indoor environment can enhance occupants' satisfaction, as extensively explored in the literature on indoor environmental quality (IEQ) [1], especially with reference to the satisfaction towards the thermal environment [2]. Systems that facilitate localized adjustments to the surrounding environment empower direct control by each occupant and cater to the diverse individual sensitivities, expectations, and needs. The notion of devices capable of delivering personalized control over local environmental conditions originated within the thermal and indoor air quality (IAQ) domains through (thermal and air quality) PECS (Personalised Environmental Control Systems), also capitalizing on the potential energy savings achieved by conditioning the environment locally rather than uniformly to achieve thermal comfort. The principle has recently been extended to the other domains of IEQ (i.e., visual and acoustic) within the scope of IEA EBC Annex 87.
In the following sections, we will provide an overview of the activities conducted within Annex 87 and briefly introduce the concept of thermal and IAQ PECS, which will serve as a reference for developing and discussing a framework on acoustic PECS in this paper.

1.1. The IEA EBC Annex 87

The International Energy Agency's Energy in Buildings and Communities Programme, the IEA-EBC Programme, is an international energy research and innovation programme in the buildings and communities field. It is mainly undertaken through a series of research projects called Annexes. The Annex 87 deals with energy and IEQ performance of PECS since it recognizes the potential of this technology as well as its limited real-life applications and commercial diffusion. Therefore, Annex 87 aims to establish standards for PECS design and

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operation that synthetize achievable benefits for the occupants along with buildings energy performance enhancements. Moreover, within Annex 87 the PECS concept is being extended, for the first time, to all the environmental comfort domains in line with the most recent multi-domain comfort approaches [3]. Indeed, PECS conceptualization was born in the field of thermal and air quality domains, but the same principles can be recognized in systems devoted to personal lighting or acoustic control. The definition of a common multi-domain framework can support the development of PECS that also account for combined and cross-modal effects to further reduce energy needs to keep high IEQ standards.

1.2. The concept of Personalised Environmental Control Systems (PECS)

Conventional heating ventilation and air conditioning (HVAC) systems are total volume systems designed to condition the entire building. On the other hand, thermal and IAQ personalized environmental control systems (PECS) - also recognized in the literature as personal comfort systems (PCS) - are HVAC systems that target only the occupied zones of the space (i.e., heating, cooling, ventilation) while relaxing the thermal and air quality conditions in the surrounding space to acceptable levels. Common systems are often furniture-integrated (chair or desk fans, heated or cooled seats, radiant panels) or building-attached (personalized ventilation, exhaust) or wearables (heated or cooled clothing). PECS offer occupants the possibility of controlling their environment with local control options, thus improving the acceptability of occupants to their environment. With proper control, and by relaxing the requirements for the background environment, PECS have been also shown to decrease energy usage [4].

1.3 Objectives

This contribution aims to initiate a preliminary discussion on the application of the concept of PECS in the acoustic domain with the aim of: 1) providing a tentative definition of acoustic PECS, and 2) illustrating the concept by presenting some examples of solutions currently used in the acoustic field that can fall within the definition of acoustic PECS.

2. METHODS

The study is based on collegial discussions within the activities of Annex 87 that have led to the definition of acoustic PECS. Additionally, it draws upon the preliminary results of an ongoing literature review, which aims at identifying technological solutions that align with the definition of acoustic PECS. Discussion of the review process and results analysis is out of the scope of the present contribution. Instead, examples of acoustic PECS will be extracted from the material collected from the ongoing review process, with the objective of initiating discourse on the concept of acoustic PECS and soliciting initial feedback from the scientific community.

3. RESULTS AND DISCUSSION

3.1 A definition of Acoustic PECS

The fundamental elements underlying the definition of acoustic PECS are twofold:

1) the ability for the occupant to control the acoustic environment
2) modifications to the environmental conditions are localized, meaning they occur within the immediate vicinity of the occupant, thus avoiding impact on adjacent occupants.

Therefore, acoustic PECS can be defined as:

"a system that can provide individually controlled acoustic environments in the immediate surroundings of an occupant, without affecting directly the entire space and other occupants' environment".

3.2 Acoustic PECS typologies

Examples of acoustic PECS derived from the literature based on the definition provided in section 3.1 are presented in Table 1. Systems can be distinguished based on two fundamental criteria.

The first distinguishes between active and passive systems, where passivity implies that the system does not contain electronic components for modifying the acoustic field (e.g., loudspeakers), but only physical structures that disrupt sound waves through phenomena of soundproofing and sound absorption.

The second criterion concerns the application mode of the PECS, distinguishing between systems installed in the environment and those that are applied directly on the person themselves (i.e., wearables).

Wearable passive acoustic PECS encompass earplugs and earmuffs, which directly reduce incoming sound in the ear canal. Building-attached passive acoustic PECS are less common and primarily involve prototypes of sound-absorbing/insulating structures positioned around each individual and adjustable independently. For instance, Zhang et al.'s prototype noise-reducing devices for classrooms resemble canopies suspended above desks, offering individual control with the ability to open and close them [5].

Wearable active acoustic PECS include headphones, earphones, and ear buds, with or without active noise cancellation. These increasingly popular systems offer a personalized listening experience without affecting the acoustic environment of nearby individuals.

At the room level, examples of active acoustic PECS include loudspeaker systems integrated into the headrests of chairs, such as those featured in the noise-canceling office chair prototype developed by Sujbert and Szarvas [6], or active noise barriers embedded with sound masking systems for protecting the speech privacy in open-plan offices [7]. Another example is represented by "sound zones" [8], which involve advanced signal processing techniques and arrays of loudspeakers [9]. This solution empowers individuals to regulate the sound environment in targeted areas of a room while leaving other areas unaffected. Consequently, it facilitates the creation of "acoustic bubbles" within the same room, without the need to wear headphones.

Table 1: Examples of acoustic PECS categorized into active and passive systems, and further differentiated based on whether they are directly worn by the occupant (wearables) or installed in the environment where the occupant is situated (building-attached/furniture-integrated)

	Building-attached/ Furniture-integrated	**Wearables**
Passive	▪ Passive sound absorbing/insulating devices	▪ Earplugs/Earmuffs
Active	▪ Active sound zoning systems ▪ Chairs with integrated loudspeakers ▪ Active noise barriers with sound masking systems	▪ Headphones/earphones/earbuds with/without noise cancelling

Medical devices like hearing aids are not considered, as the focus is on solutions suitable for office-like work environments, with medical applications falling outside the scope of the Annex.

5. FINAL COMMENTS AND CONCLUSIONS

This paper introduces the concept of Acoustic Personalized Environmental Control Systems (Acoustic PECS) within the scope of IEA EBC Annex 87. These systems offer individually tailored acoustic environments for occupants in their close proximity, without directly affecting the overall space or the environment of others. Acoustic PECS hold promises for enhancing comfort, well-being, and productivity in multi-user settings (e.g., open plan offices) by providing a personalized acoustic experience, thus also addressing the different noise sensitivities people may have (i.e., aural diversity [10]). The Annex activities can inform the development of new technologies for customizing and managing individual acoustic environments, while also assessing their impacts on users. Additionally, it will explore the potential connection to reducing energy consumption and environmental emissions related to space cooling and ventilation, such as by examining whether Acoustic PECS could facilitate the adoption of natural ventilation systems in acoustically polluted environments where opening windows might be challenging.

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