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Evaporative cooling systems to improve internal comfort in industrial buildings

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Abstract

Several studies were carried out to determine how hot or cold environments can affect task performance and can influence productivity. Usually, HVAC plants are exactly designed in order to guarantee comfortable internal conditions inside built environments, but not all kind of buildings are equipped with a heating or cooling plant, like for example, some industrial buildings. These buildings are often characterized by high internal thermal loads. For those buildings the ability of different plant configurations to improve indoor thermal conditions was considered taking into account the influence of several parameters, like weather conditions, internal gains, thermal transmittance, ventilation air flow rate, etc. Simulation results are compared in terms of energy savings and thermal comfort.

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1. Introduction

Industrial buildings have some features that make them very different than all other types of buildings like dwelling, offices, schools, hospitals, ecc… Firstly, in most of cases, these buildings don't have a heating or cooling system except for office space; secondly, internal heat gains have a huge impact on the energy balance of the building cause of work processes and electrical equipment. Electrical energy consumptions due to production processes, especially in case of high process loads, exceed, by far, heating and cooling energy requirements, that not are therefore the main purpose of energy saving strategies.

Moreover, the occupancy pattern and lighting affect significantly the thermal conditions inside the building.

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The industrial sector is one of the largest consumers of energy. In Europe, the sector used 26% of the total energy consumption in 2011 (Eurostat, 2013), while in the US, this sector consumed 31% in the same year (EIA, 2012) [1].

In last years a few guidelines on the energy saving potential of industrial halls have been published (ASHRAE, 2008; ASHRAE [2], 2011; NREL, 2009a; TargetZero, 2011), but their focus, for halls with higher process loads, was to reducing energy consumption due to production activity because it represents the main component of energy consumptions. Particularly in the "data processing centers" (CED) and in many dairy industries, defined today among the areas with the highest demand for energy for specific use [3,4].

This study deals with industrial halls with high process loads and the aim of the study is the evaluation of the behavior of several air-systems for increase the comfort conditions inside the hall.

In industrial buildings the evaporative cooling can represent a suitable way to make more comfortable the internal environment ether with direct or indirect system. An application of an indirect system for building cooling, based on a passive component, without forced ventilation, is presented and analyzed in [5]. However, evaporative cooling systems, based on mechanical ventilation, can be profitably installed in industrial sheds.

In a previous paper, a study about the ability of an evaporative cooling system to guarantee inside comfort conditions, saving electrical energy, has been carried out for a sample industrial building [6]. In particular, four different configurations have been analyzed: no system, external air ventilation system, external air ventilation system with direct evaporative cooling and external air ventilation system with indirect evaporative cooling. In this paper the behaviour of the same systems by means of TRNSYS simulations has been investigated taking into account the influence of several parameters, like weather conditions, level of internal gains, thermal transmittance of the envelope components. Moreover, in order to evaluate the effect of different systems in reaching internal comfort conditions, the wet bulb globe temperature index has been introduced, according to ISO 7243 [7].

2. Reference industrial building

2.1. Building parameters

An existing typical industrial building is used as the baseline for the present study. The industrial shed is a single floor building with a total gross floor area of 4800 m^2 and 7 m high. The glass area takes up the upper zone of the external wall, but, often, buildings are equipped with skylights, that are a very effective way to provide daylight over a large area of a single-storey building [8]. The characteristic of the building envelope are reported in Table 1.

Table 1. Details and thermal properties of building construction components.

Building component	A [m^2]	U [Wm^2K^{-1}]
External walls	1396	0.25 - 1
External doors	240	0.461
Glass surface	576	5.68
Roof/ground surface	4800	0.666 / 1.75

Industrial buildings are built using simple steel or concrete construction methods; in both cases, often, the suitable choice is steel sandwich panels or concrete panels in order to minimize the construction time and therefore construction costs. In order to evaluate the influence of the envelope heat transfer coefficient on the building thermal behaviour, several simulations have been carried out varying the thermal transmittance of the external walls. Comparisons among the results of the simulations has been made using as parameter the Cooling Degree-Hours, Base26 (CDH_26), defined by the following equation:

$$CDH(26°C) = m_k \sum_{k=1}^{n} \left(\vartheta_{ek} - 26\right) \quad (1)$$