AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL POWER DEPARTMENT

SIMULATION OF RADIATIVE COOLING SYSTEMS IN CLEAN ROOM APPLICATIONS USING COMPUTATIONAL FLUID DYNAMICS

A THESIS

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Examiner Committee

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Statement

This dissertation is submitted to Ain Shams University in fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

The work included in this thesis was made by the author during the period from 2007 to December 2010 at the Mechanical Power Engineering Department, Ain Shams University.

No part of this thesis has been submitted for degree or qualification at any other university or institute.

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Abstract

Radiant cooling techniques have been developed rapidly over the last years for its capability to provide draft free and thermally homogeneous environment. These specific conditions are required in some clean room applications such as hospitals and measurement laboratories. The study investigates air dynamic and thermal behavior in three cases, two of which are validation test cases that were experimentally conducted before by others. The experimental results of those test cases are presented and compared to the simulation outputs, reached by the CFD (Computational Fluid Dynamics) software used in this study, in order to validate it. The first validation test case involves a room that is air conditioned via a normal convection HVAC system depending on a cold air draft coming out from an air jet. The second validation test case involves a room that is air conditioned via a radiant ceiling panel. The last test case presented in this thesis is a study of the proposed convection and radiant cooling systems, done for a measurement laboratory, located in the National Institute of Standards, Mariutia, Cairo, Egypt. The results show that radiant cooling techniques are capable of producing more dynamically stable, thermally stable and comfortable conditions than conventional convection HVAC techniques.

The CFD work, presented in this thesis, is conducted by a CFD simulation software, called PHOENICS using a module, dedicated for HVAC applications, called FLAIR. The software copy, used in this work, is licensed for research purpose only.

The software was developed by the CHAM company, located in Wimbledon, England.

Table of Contents

Nomenclature

a	Absorptivity
Ar_d	Archimedes Number, $Ar_d = g\beta d\,(T_{in} - T_m)\ /\ U^2_{in}$
C	Mass (kg) – Constant
Ḉ	Specific Heat Capacity (W/m^3)
c_p	Specific Heat at Constant Pressure (J/kg.K)
d	Diameter (m)
f_{cl}	Ratio of Clothed Surface Area to Nude Surface Area
g	Gravitational Acceleration (m/s^2)
H, h	Enthalpy (J/kg)
h_c	Convective Heat Transfer Coefficient (W/m^2 K)
I_{cl}	Thermal Resistance of Clothing (m^2 K/ W)
I_m	Mixing Length
J_0	Radiosity (W/m^2)
k	Thermal Conductivity (W/m K)
K	Turbulent Kinetic Energy (m^2/s^2)
L	Wall Distance (m)
L_0	Wall Gap (m)
L_H	Thermal Load of The Human Body (W/m^2)
L_S	Turbulent Length Scale (m)
M	Metabolism Rate in The Human Body (W/ m^2)
P	Pressure (Pa)
P_a	Water Vapor Partial Pressure (Pa)
Pe	Peclet Number, Pe = Re Pr
Pr	Prandtl Number, $Pr = c_p \mu / k$