Cairo University

NUMERICAL INVESTIGATION OF VENTILATION METHODS IN AIR CONDITIONED BATTERY STORAGE ROOM.

By

Mahmoud Adel Abd El Razik El-Nakeeb

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the Requirements for the Degree of
MASTER OF SCIENCE
In
MECHANICAL POWER ENGINEERING

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Title of Thesis:
NUMERICAL INVESTIGATION OF VENTILATION METHODS IN AIR CONDITIONED BATTERY STORAGE ROOM.

Key Words:
Ventilation; Hydrogen emissions; Indoor Air Quality; Batteries storage rooms; CFD

Summary:

Ventilation performance inside vented batteries storage rooms was investigated numerically using Ansys Fluent 16. The Model was built and meshed by Ansys design modeler part of Ansys software yielding around 2.6 million elements after making good use of symmetry boundary condition, and around 5.1 million in elements for the cases that have no geometrical symmetry. Validation was done at first against experimental published data and comparison between different turbulence models was performed. Standard k-ε turbulence model offered the nearest results to the experimental data.

Parametric Study is done to investigate the effect of three different factors on the efficiency of the ventilation system. First, the relation between the ACH employed and the average volumetric hydrogen. Second, the effect of changing inlets and outlets grilles location under fixed 8 ACH on hydrogen concentration inside the room. Third the effect of splitting the long single row into two halves vertical rows (double rack single step and double rack double step) on ventilation performance is investigated. Storage of the batteries in double vertical racks with double steps offered the best ventilation performance, using wall type inlet grille at the lower wall section and outlet grilles at the roof while the batteries rack are surrounded by curtains to act as local exhaust ventilation technique.

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Table of Contents

List of Tables

List of Figures

Nomenclature

Symbol	Quantity
a	Sonic speed, m/s
C	Constant
Cp	Constant pressure specific heat, J/kg.K
D	Diffusion coefficient
E	Total Energy of fluid particle, J
$\vec{F}$	External Body Forces, N
g	Acceleration of gravity, m/s^2
Gk	Generation of turbulence kinetic energy due to mean velocity gradients
Gb	Generation of turbulence kinetic energy due to buoyancy
h	Enthalpy, J/kg
$\vec{J}_i$	Diffusion flux of species i
k	Thermal conductivity, W/m °C
	Turbulent kinetic energy, m^2/s^2
M	Mach number
	Molecular Weight
P	Pressure, Pa
Pr	Prandtl number, Pr = cp μ / k
Q	Volumetric flow rate, W/m^3
Ri	Rate of production of species i
S	Source term
	Modulus of the mean rate of strain tensor
Sc	Schmidt number
T	Temperature, K
u_j	Velocity magnitude in direction of x_j, m/s
$\vec{v}$	Velocity vector
Yi	Mass fraction of species
x,y,z	Cartesian co-ordinate components

Greek Letters

δ	Boundary Layer thickness
	Differential
$\bar{\bar{\tau}}$	Stress tensor
σ	Turbulent Prandtl number
ε	Turbulence dissipation rate
μ	Dynamic viscosity
ρ	Density
∇	Gradient
β	Thermal expansion coefficient

Superscripts and Subscripts

$\bar{}$	Mean property
b	Buoyancy
i	Counter
ij	Indicates two different Cartesian coordinates
k	Turbulent kinetic energy
m	mass
p	point node property
T	Transpose
	Thermal
t	Turbulent quantity
w	Wall property
μ	Dynamic viscosity

Abbreviations

VLA	Vented Lead Acid
VRLA	Valve Regulated Lead Acid
CEV	Controlled Environmental Vault
HVAC	Heating, Ventilation and Air-Conditioning
ASHRAE	American Society for Heating, Refrigerating and Air-Conditioning Engineers.
UPS	Uninterruptible Power Supply
LFL	Lower Flammability Level
UFL	Upper Flammability Level
LEL	Lower Explosive Level
UEL	Upper Explosive Level
CFD	Computational Fluid Dynamics
CAE	Computer-Aided Engineering
IEEE	Institute of Electrical and Electronics Engineers
ACH	Air Change Per Hour
UFAD	Under Floor Air Distribution
PV	Personalized Ventilation
CC	Chilled Ceiling
RNG	Re-Normalization Group
SBS	Sick Building Syndromes
MV	Mixing Ventilation
DV	Displacement Ventilation
PDV	Passive Displacement Ventilation
RH	Relative Humidity
VOCs	Volatile Organic Compounds
TVOC	Total Volatile Organic Compounds
IAQ	Indoor Air Quality
NFPA	National Fire Protection Association
RKE	Realizable K-ε Turbulence Model
RNG	Re-normalization Group K-ε Turbulence Model
SKE	Standard K-ε Turbulence Model
SST	Shear Stress Transport

Abstract

Indoor air quality inside NiCd battery storage rooms is investigated in the current research. A proper ventilation system will ensure safe environment inside the battery room by keeping vented gasses within their safe threshold allowed by standards and yet achieve energy saving by avoiding unnecessarily high values of air change per hour (ACH). This should be done by selecting the optimum configuration of inlets and outlets grilles location as well as choosing the most suitable way of battery storage whether on single rack, double rack or double rack with double steps.

Indoor air quality inside the battery storage room subjected to hydrogen gas emissions from the stored vented batteries is investigated numerically throughout the current research using Computational Fluid Dynamics (CFD). ANSYS 16.0 software was used. Validation was done at first against experimental published data and comparison between different turbulence models was performed. Standard k-ε turbulence model offered the nearest results to the experimental data.

Parametric study is done to investigate the effect of three different factors on the efficiency of the ventilation system. First, the relation between the ACH employed and the average volumetric hydrogen concentration was found non-linear and inversely proportional. Second, the effect of changing inlets and outlets grilles location under fixed 8 ACH was found to have strong impact on hydrogen concentration inside the room. At fixed ACH proper design could offer low hydrogen concentration as low as 0.42 % vs. 6.11 % for the inefficient design. Third the effect of splitting the long single row into two halves vertical rows (double rack single step and double rack double step) on ventilation performance was investigated. Storage of the batteries in double vertical racks with double steps offered the best ventilation performance, using wall type inlet grille at the lower wall section and outlet grilles at the roof, while the batteries' racks are surrounded by curtains to act as local exhaust ventilation technique.

Chapter 1 : Introduction

1.1. General

Proper ventilation system in battery rooms is of crucial importance for safety considerations, not only for equipment safety, but for individuals as well. Stored batteries emit gases during charging, especially hydrogen gas which has explosive nature. If hydrogen concentration reached its explosive limit; explosion may occur. Accident took place at battery storage room in California, USA in 2001[1]. Fire department responded to a report of a building explosion, when firefighters entered the building they found several blown walls and visible smoke from a room that housed several large batteries. Firefighters also reported that a 40-foot section of the roof was missing just over the area of the explosion, collapsed numerous walls and ceilings throughout the building, and significantly damaged a large portion of the 50,000 sq. The facility was formerly a large computer center battery room. The company evacuated the building, moved out computer equipment; however the battery back-up system was left behind. Fire investigators along with hazardous materials response team from fire department determined that the cause of the explosion was that the batteries were charging for a long period of time with no ventilation, the detector was alarming and hydrogen continued to build up until it found an ignition source and hence the explosion occurred. The lesson to pass on is that ventilation is critical in these facilities. Great care should be taken to ensure that ventilation is adequate to dilute hydrogen gas emitted from the batteries. The below figures 1.1 and 1.2 show the damage caused by the explosion that took place.

Fig. 1.1: Damage caused by the explosion in battery room in California, USA [1].