Islamic University of Technology

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Project Tittle:

EXPERIMENTAL STUDY OF THERMAL COMFORT OF URBAN RESIDENTIAL

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Acknowledgement

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Declaration

This is to declare that the project titled "EXPERIMENTAL STUDY OF THERMAL COMFORT OF URBAN RESIDENTIAL" was designed & successfully implemented by us under the supervision of MD. Hamidur Rahman,Assistant Professor, MCE department, IUT. The following thesis has not been submitted elsewhere for the reward of any degree or diploma or for publication.

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CONTENT

ABSTRACT:

In residential kitchens insufficiency of ventilation of exhaust gaseous products from gas fired stoves is to be considered a major health apprehension. It may become the reason of destruction of property as well as human life. Our study aims to find out a better and comfortable condition in the kitchens through moderate ventilation. Aiming to the target, a typical kitchen having a standard dimensions of 19in*17in*24in was modeled. A 350W heater with resistance was used for modeling the kitchen that resembles the double burner gas stove of an urban residential kitchen in developing countries. The present numerical method was validated by comparing with the experimental data reported by Posner et al. [1]. The comparison showed very reasonable agreement. A grid independence test was also performed to determine the optimum grid resolution reflecting the

accuracy of the numerical solution. The comparative results are presented for various velocity of cooling fan, used for ventilation. The location of the breathing zone was at a height of 10in and a distance of 4in from the center of the heater. Huge variation of temperature profile was observed. If proper ventilation is not provided, this environment may cause serious health damage.

NOMENCLATURE:

P	[Pa]	Pressure
T	[K]	Temperature
V	[m/s]	Velocity
X	[m]	Cartesian x-direction
Y	[m]	Cartesian y-direction
Z	[m]	Cartesian z-direction
k	$[m^2/s^3]$	turbulent kinetic energy
€	$[m^2/s^3]$	turbulent dissipation rate

CHAPTER-1

INTRODUCTION

Thermal comfort is an important health safety measures for room occupants. It is a common problem in the majority of the residential buildings in developing countries due to the poor architectural design of the living places, especially kitchen, which is not properly followed by the optimum code of design for comfort ventilation. There is very little attention paid by the researchers in this particular sector. Few studies have been reported on this thermal comfort within the living spaces. However, a review of the literature reveals that the kitchen has been given a very less importance with regard to the proper ventilation and the efficient exhaust system.

CHAPTER-2

LITERATURE REVIEW

Chi-Ming et al. [2] conducted experiment to study the efficient side exhaust system for residential kitchens in Taiwan. They designed the exhaust system in three ways namely single slot, twin slot, fence slot systems.

Nantka [3] investigated indoor conditions in Silesian Buildings with natural ventilation. Results were obtained by questionnaires, measurements of ventilation processes in typical blocks of flats and office buildings in Silesia. The effects of air tightness, natural ventilation and some pollutants on the indoor environment were discussed.

Villi et al. [4] investigated the computational aspects of modeling different strategies for kitchen ventilation. Their paper dealt with the evaluation of different simulation approaches to kitchen ventilation modeling.

Rahman et al. [5] studied Carbon Dioxide Gas Emission from an Urban Residential Kitchen in Developing Countries in which determination of thermal distribution in kitchen was a an remarkable part.

From the above literature study, it is apparent that a number of investigations have been devoted both numerically and experimentally to account the effective way of ventilation within the kitchen space. Some specific design methodologies have also been recommended to improve the comfort level.

Therefore, this paper aims to investigate the indoor air thermal distribution and heat transfer characteristics under natural, forced and no ventilated conditions.

CHAPTER-3

GOVERNING EQUATIONS

For this numerical study, flow through turbine was considered. As three dimensional, steady and turbulent. The differential form of conservation equations for flow and heat transfer can be written as:

Conservation of Momentum: where,

$$\frac{D}{Dt}\left(\rho\vec{U}\right)=\nabla\cdot\sigma_{ij}+\rho g \qquad \frac{D}{Dt}(\;)=\frac{\partial}{\partial t}(\;)+u\frac{\partial}{\partial x}(\;)+v\frac{\partial}{\partial y}(\;)+w\frac{\partial}{\partial z}(\;)$$

Conservation of Mass

$$\frac{\partial}{\partial t}(\rho)+\nabla\cdot\left(\rho\vec{U}\right)=0$$

Conservation of Energy

$$\rho\frac{D}{Dt}(h)=\frac{D}{Dt}(p)+\nabla\cdot(\lambda\nabla T)$$

The general form of the transport equation for an additional variable such as mass concentration of components is given by

$$\frac{\partial\rho\phi}{\partial t}+\nabla\cdot\left(\rho U\phi\right)=\nabla\cdot\left(\rho D_{\Phi}\nabla\phi\right)+S_{\phi}$$

Table 1: Computational cases

Test Case	Test Condition	Types
Validation	Posner et al. [1]	---
Case 1	Close vent	No ventilation
Case 2	Open vent	Natural ventilation
Case 3	0.5 m/s vent	Forced ventilation
Case 4	1.5 m/s vent	Forced ventilation

CHAPTER-4

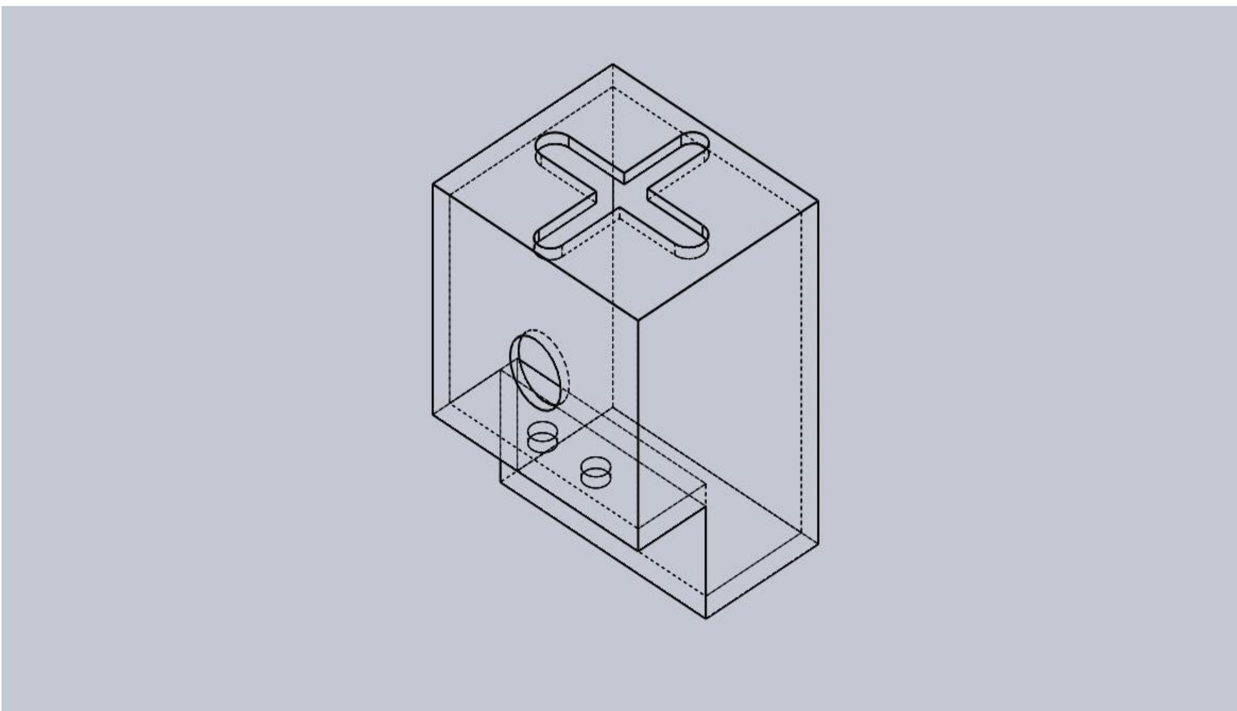
EXPERIMENTAL SETUP

- **Fabrication of a kitchen model:**

- In this study, a typical kitchen having a standard dimension of ***42.6cm*48.6cm*60cm*** was fabricated with single open door exit.
- ***Celluloid sheet*** was used to construct the boundary of the kitchen.
- Two ***Electric heat sources*** were used to resemble the double burner gas stove of an urban residential kitchen in developing countries. In our experiment, we used an electric heater of ***350W*** which was controlled by variable resistor providing a temperature around ***35-40*** ^{0}***C*** to the kitchen atmosphere.
- As a ***Heat insulating material***, we was using cork sheet.

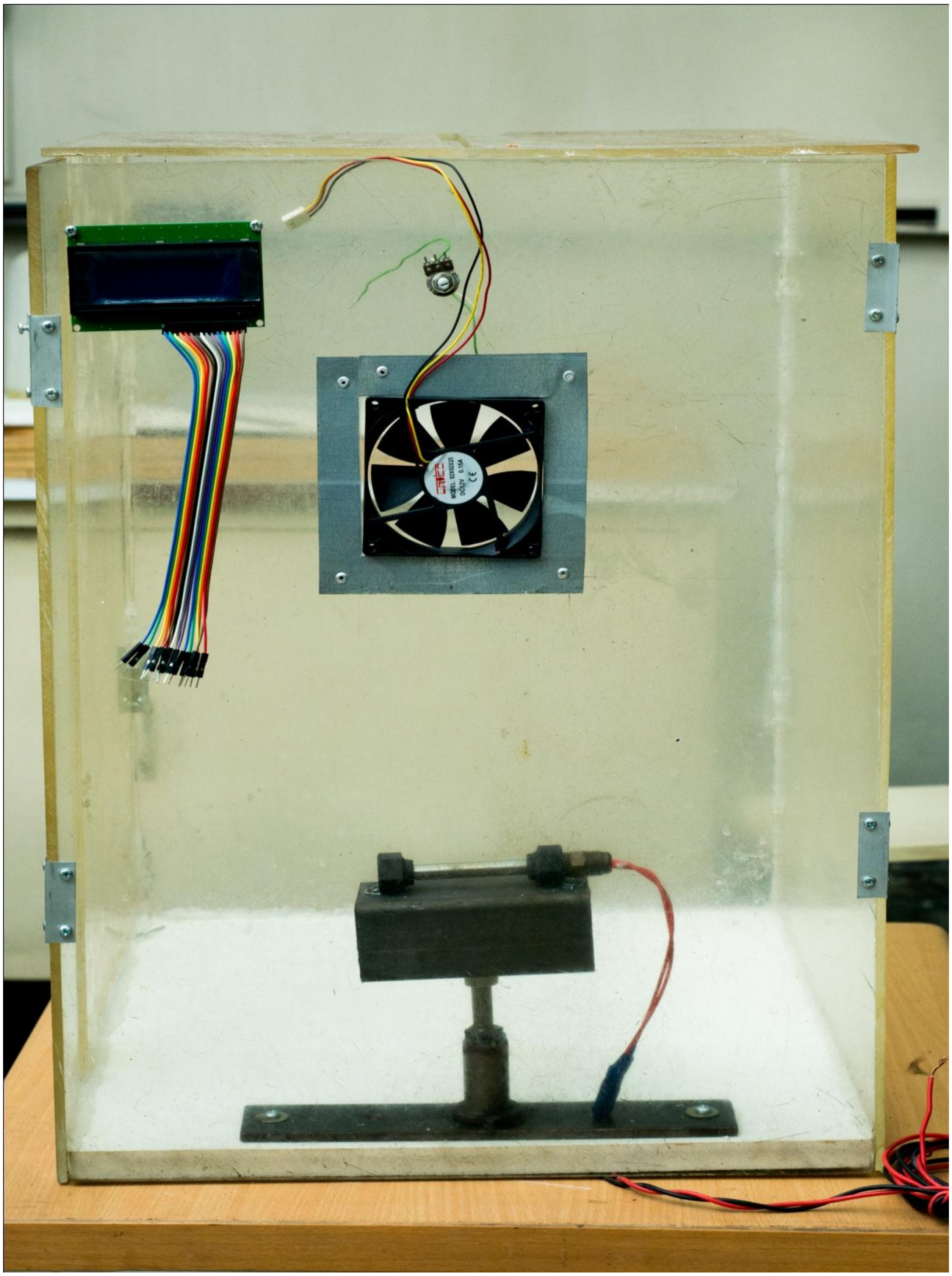
- Then we prepared a ***Data acquisition system*** which automatically recorded the temperature coming out from the sensor from time to time in a computer.
- When we performed our experiment under forced ventilation, an ***Exhaust Fan*** was used.

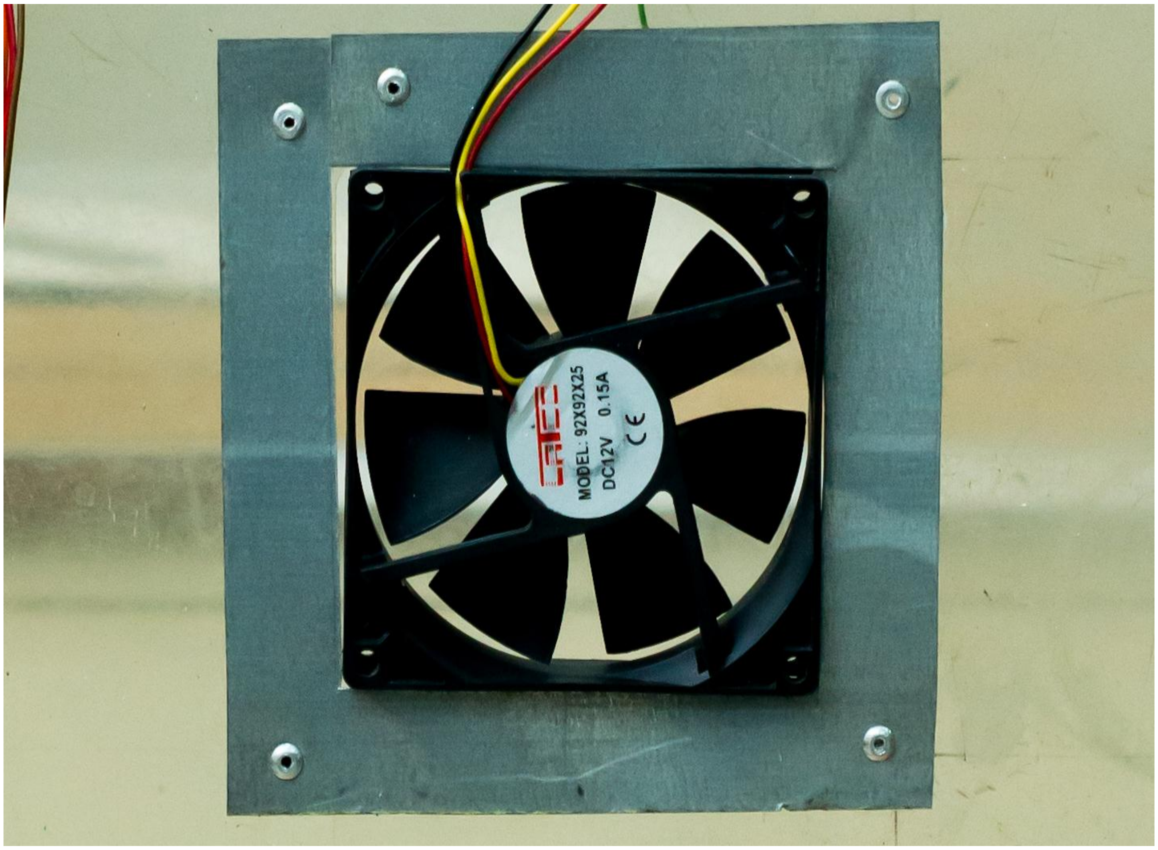
Thus our ***Kitchen Fabrication*** step was accomplished.



SOLIDWORKS DESIGN OF KITCHEN MODEL

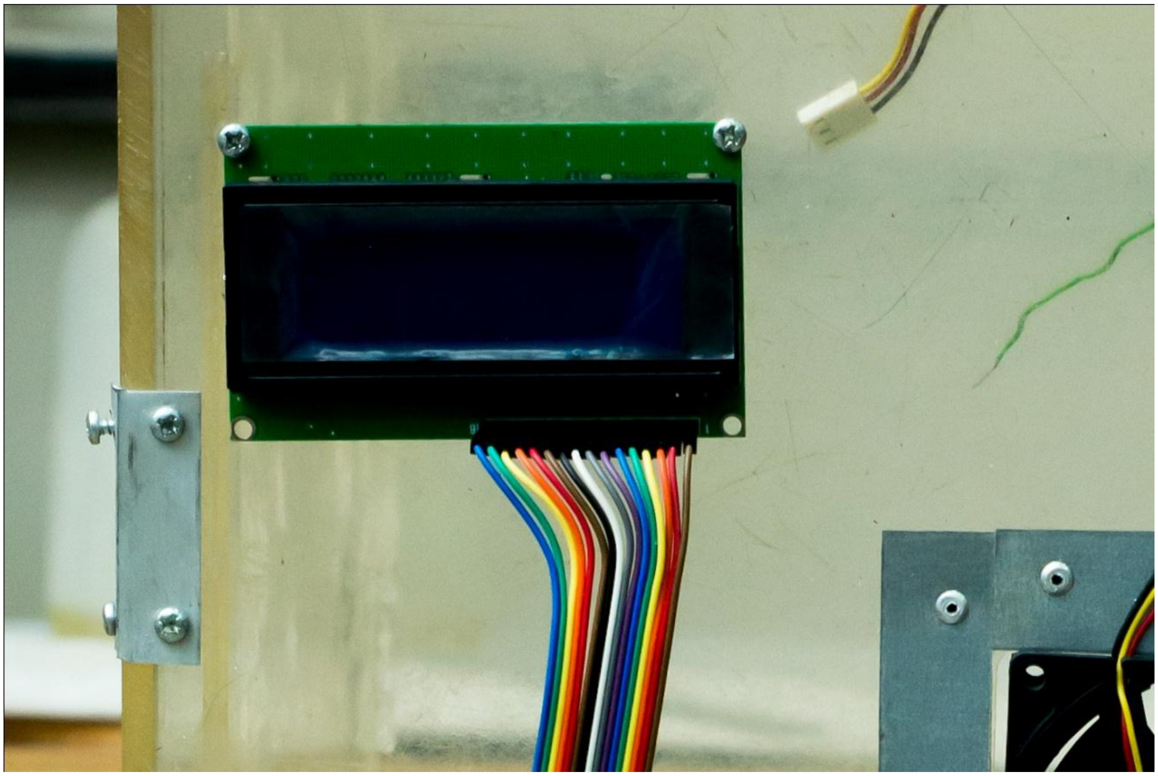
PRACTICAL VIEW OF EXPERIMENTAL SETUP

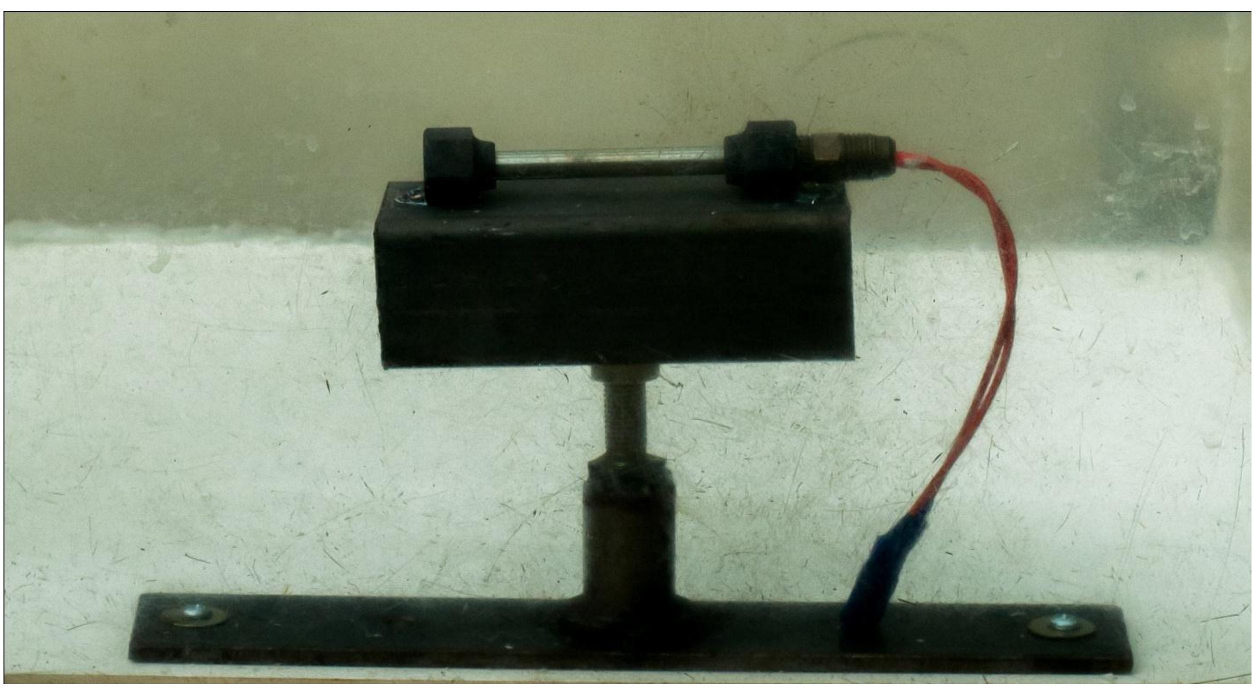




COOLING FAN USED

LCD DISPLAY &HEATER USED





CHAPTER-5

DATA ACQUISITION SYSTEM

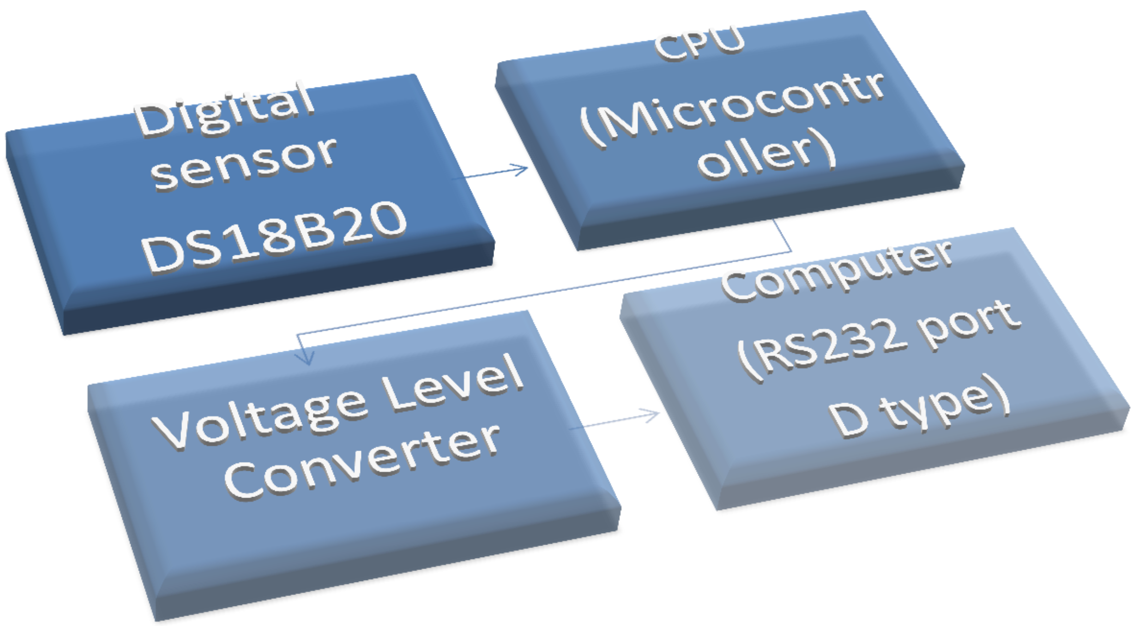
- **Function:**

- To Stream different temperature data and record in a PC via Serial port (RS-232).

- **Working principle:**

- **Step 1** : Digital Temperature sensor will sense the temperature using standard One Wire communication protocol.
- **Step 2** : Multiple sensors will send the digitized temp readings to a Hi-speed Microcontroller that acts as a host of the whole system.
- **Step 3** : The microcontroller unit then process the data and feed it to a computer though the RS-232 Serial Port.
- **Step 4** : The host MCU will also Control & Regulate the force ventilation as and when needed .

BLOCK DIAGRAM OF THE DATA ACQUISITION SYSTEM



CIRCUIT DIAGRAM

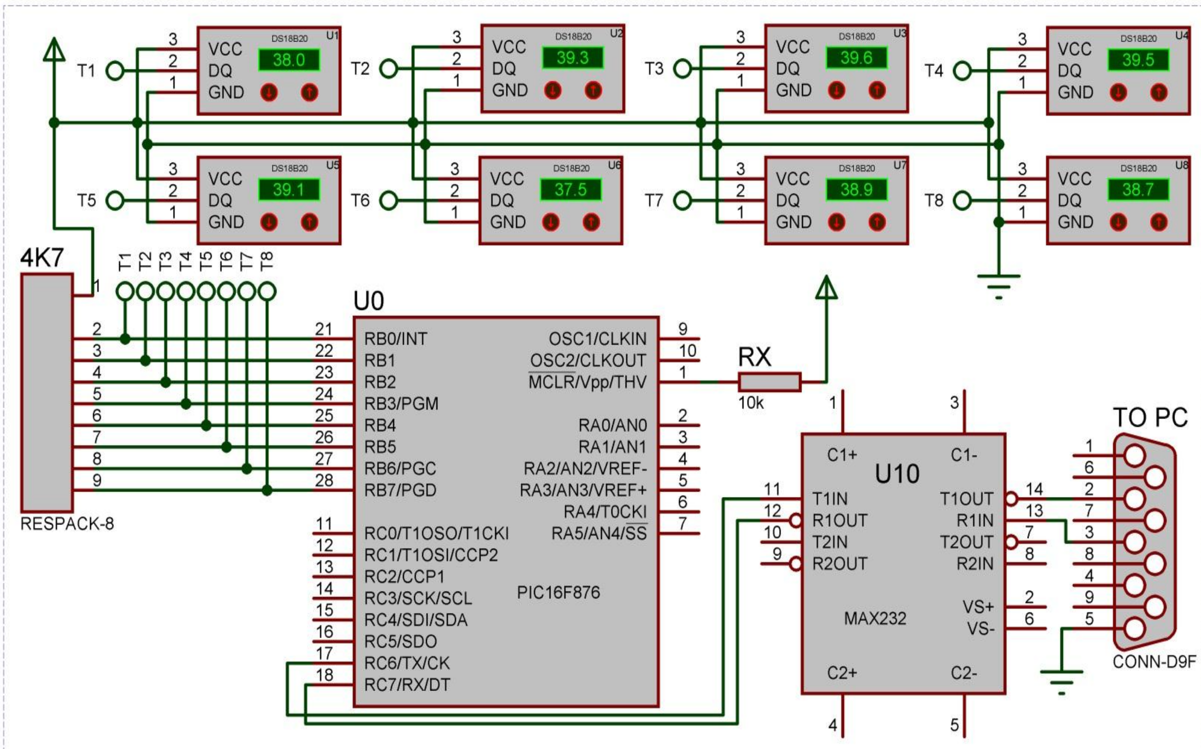


Fig : 8x DS18B20 RS-232 Temperature Data Logger using PIC16f876A @ 8.0000 MHz

TECHNOLOGY INVOLVED

✓ **Hardware**

- **Microcontroller**: PIC16F876A @ 20 MHz produced by Microchip Inc. USA
- **Sensor**: DS18B20

  Produced by Dallas Semiconductor, USA
- **Converter**: MAX-232

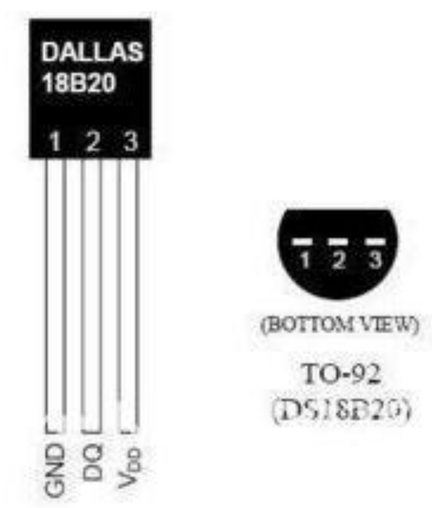
  Produced by Maxim, USA

✓ **Software :**

- MicroC Pro for PIC Ver. 6.0 (Code Editor and ANSI C compiler)
- One Wire protocol and CRC.
- SPI/USART Protocol for RS-232.
- Real Term as a GUI on PC end.

TEMPERATURE SENSOR:

- DS18B20 Digital Sensors has been used.
- Measuring range is -55^{o} C to 127 ^{o} C.
- Resolution: 0.0625
- Power supply range is 3.0V to 5.5V
- ±0.5°C accuracy from –10°C to +85°C



MICROCONTROLLER:

- PIC16F876A at 20 MHz (28 pin DIP).
- Advanced Harvard Architecture, RISC CPU.
- 8 KB Flash Program memory.
- ICSP, SPI, EEPROM, ADC, Interrupt, Sleep, Vref, CCP.
- Conditional Resets and Code protection.

COMPUTER COMMUNICATION

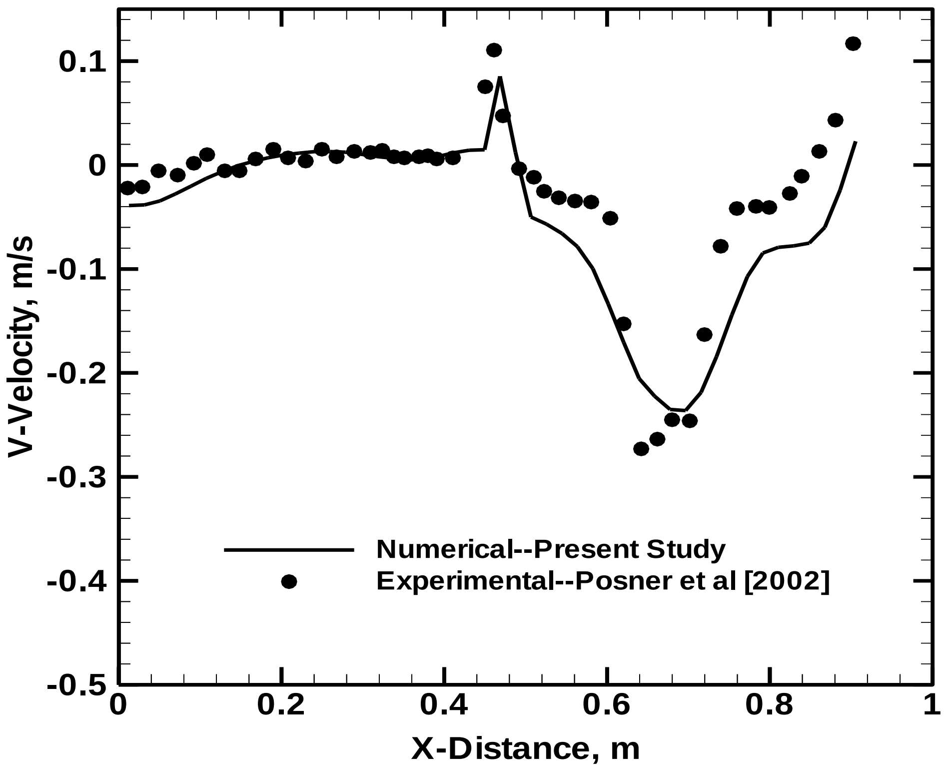
- Serial Communication.
- RS-232 SPI/USART Bus.
- 9 pin D-connector.
- To communicate with the embedded system, a voltage level converter (MAX-232) will be used a medium.

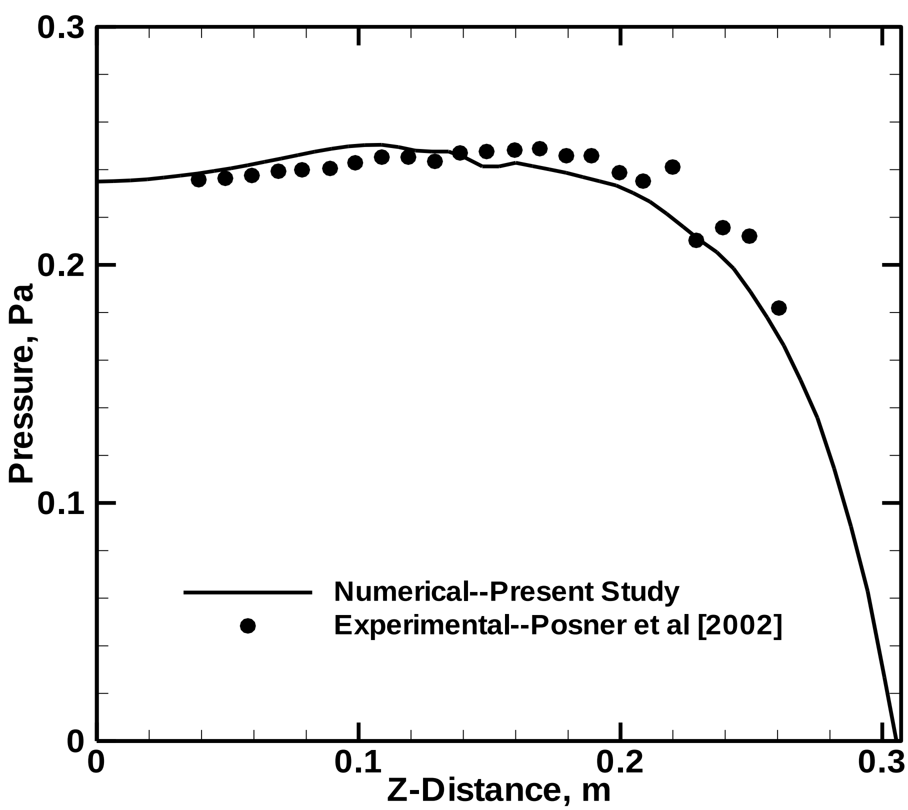
CHAPTER-6

VALIDATION AND GRID TEST

In order to perform computational validation, the experimental work of Posner et al. [1] was considered. This is because no experimental data similar to the present numerical study was available. In ref [1], experiment was performed in a model room to measure indoor air flow. Their experimental test conditions were imposed to formulate same model room as a validation case of the present study.

The numerically calculated values of pressure and velocity were compared with the corresponding experimental data. Good comparison gave us the confidence that the current numerical method can be adopted for the kitchen ventilation modeling.


V-Velocity, m/s
X-Distance, m
Numerical--Present Study
Experimental--Posner et al [2002]
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
0
0.2
0.4
0.6
0.8
1

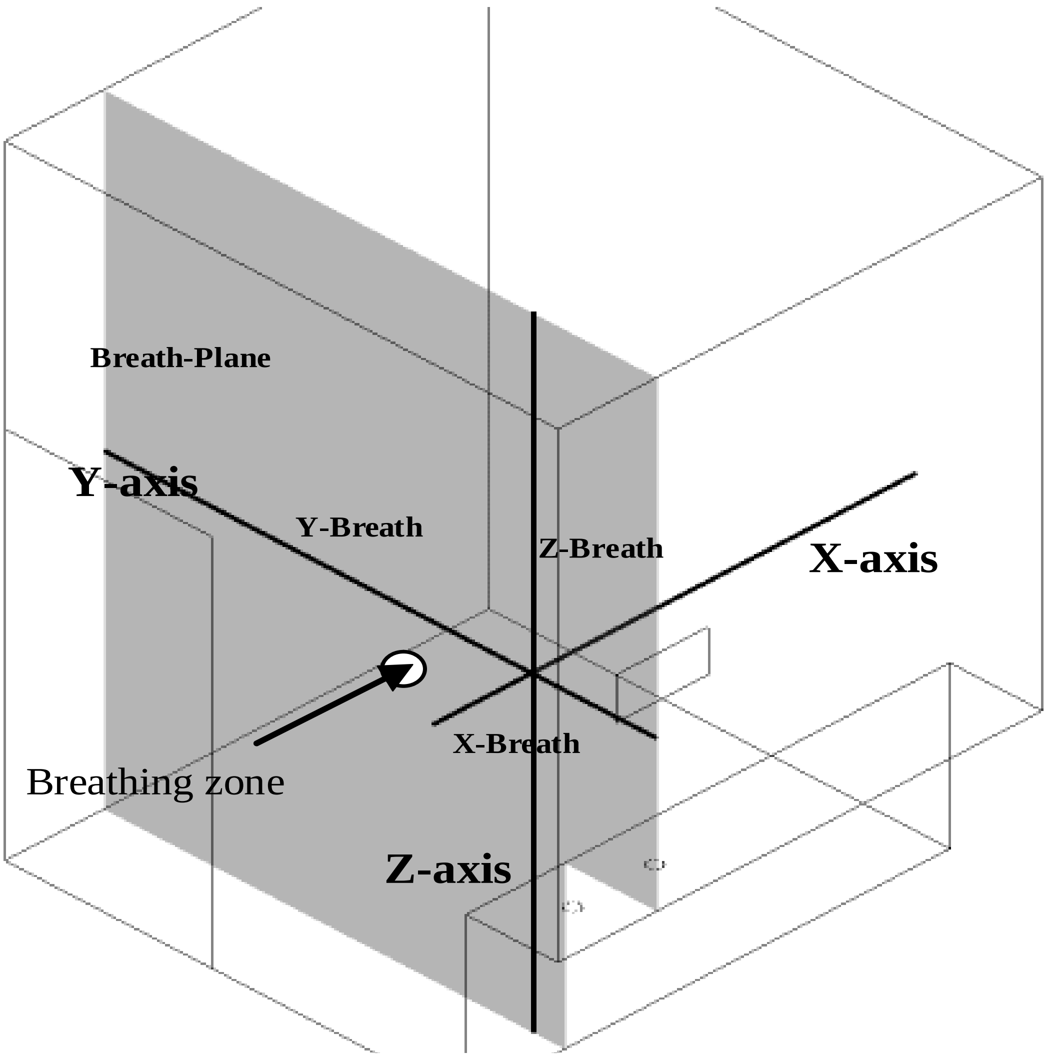

Pressure, Pa
Z-Distance, m
Numerical--Present Study
Experimental--Posner et al [2002]
0.3
0.2
0.1
0
0
0.1
0.2
0.3

CHAPTER-7

RESULTS AND DISCUSSIONS

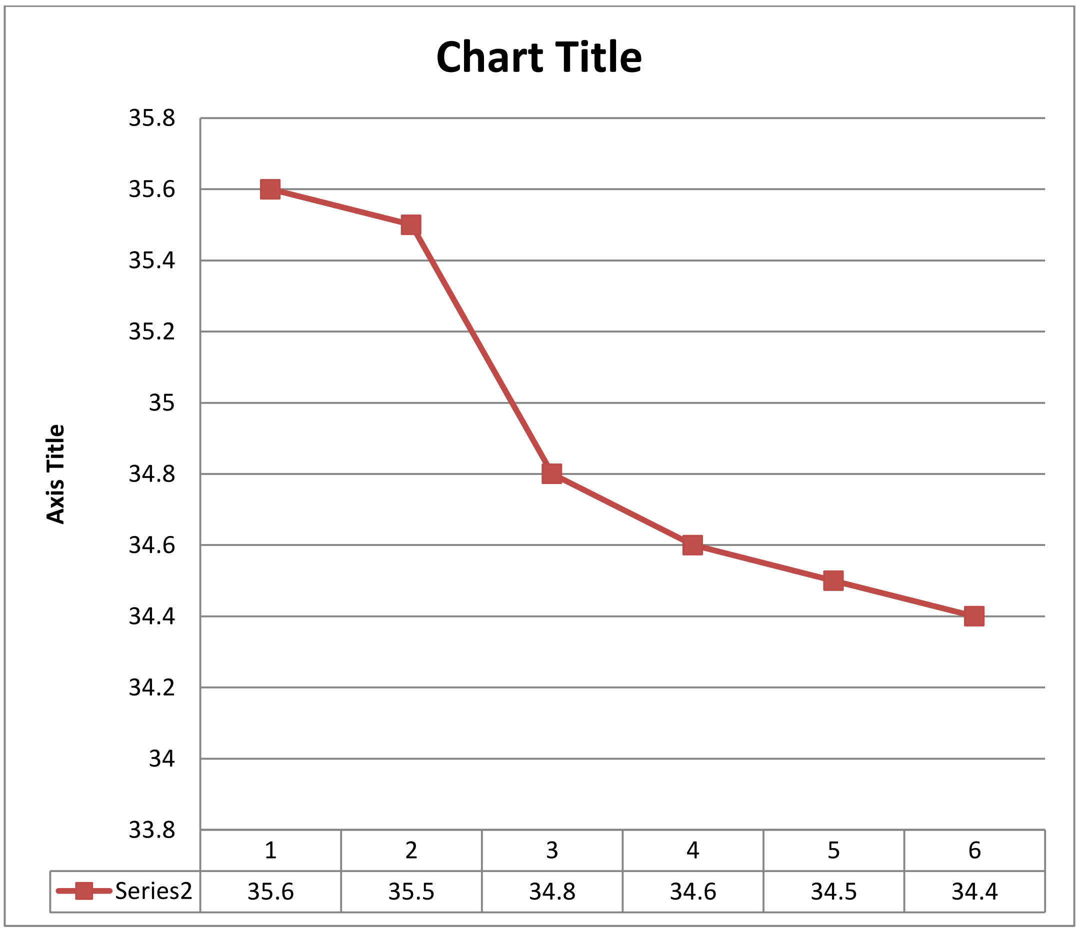
The numerical results for different cases for locations namely X-breath, Y-breath, Z-breath. The X-breath is located close to the cooking bench and assesses the nature of the air circulations in lateral directions. Y-breath is located on the plane-breath in longitudinal direction and Z-breath is a vertical line on the plane breath. All these lines are passing through the breathing zone. The plane-breath was selected at a section where the critical flow field characteristics around the burner, section of the vent and the vent wall, and 3-dimensional nature of the air circulations through the door could be well demonstrated and understood. The room temperature within kitchen was set 302K and considered as comfort level of temperature for the occupants.

LOCATIONS OF THE INVESTIGATED PLANE AND LINES

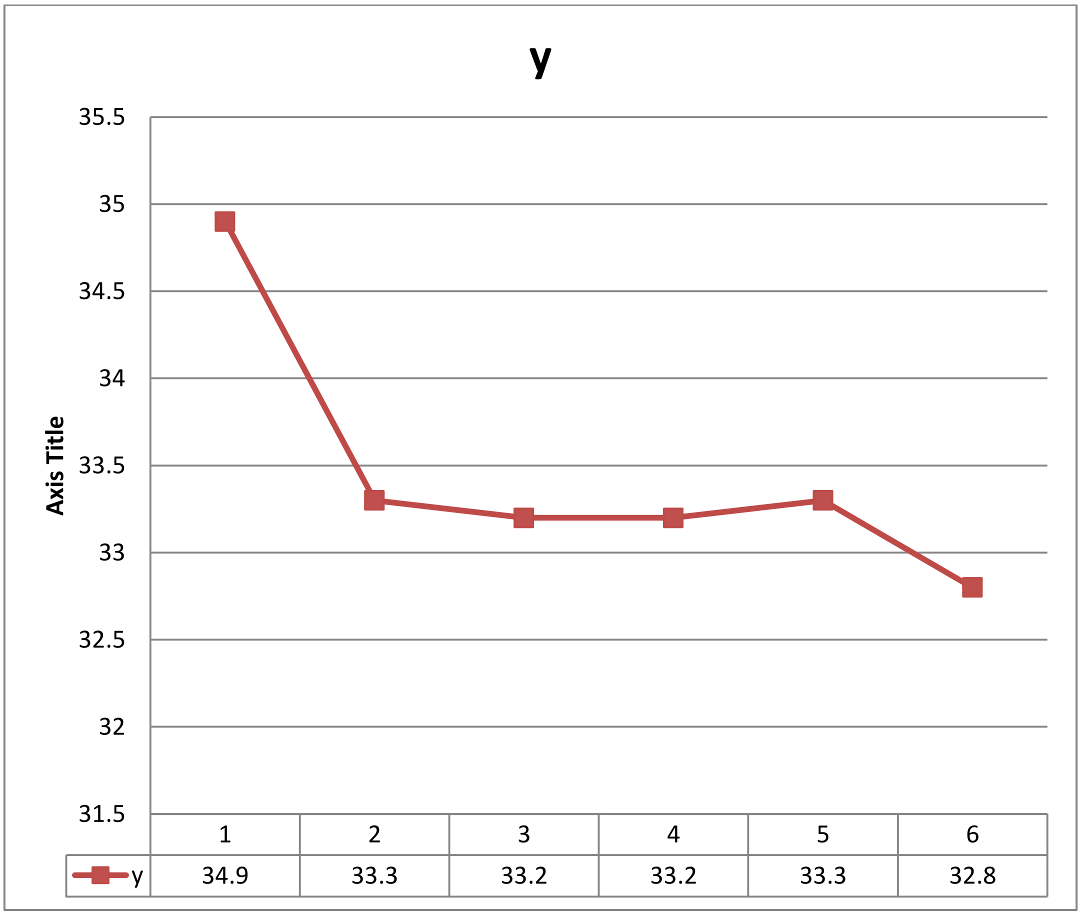


Healthy environment should always be comfort environment. Room temperature is the key factor to accommodate thermal comfort. In this study, it was intended to check the thermal comfort level in the kitchen. Figures show the temperature distributions at all three lines passing through the breathing zone. A peak temperature of 307.6K was observed for the case of close vent. The maximum change of temperature in lateral direction (X-breath) was 3^0C-4^0C. In the longitudinal direction (Y-breath), case 1 showed the highest temperature of 307.8K. However, the change of temperature still remained within 3^0C-4^0C. the upper portion of the room was identified as the heat accumulation zone where the temperature reached up to 310K for case 1.on the other hand for case 4 it reached up to 314K.

TEMPERATURE VARIATIONS ALONG X WITH NATURAL VENTILATION



TEMPERATURE VARIATIONS ALONG X WITH FORCED VENTILATION



CONCLUSION

A typical kitchen has been modeled with two heat sources and one cooling fan. The results were tested for grid independence to obtain an optimum grid resolution. The results are represented for temperature field, velocity field. The predictions are discussed under the effect of ventilation (natural and forced) and no ventilation system. The following conclusions can be drawn from this study.

1. For the gas stoves located in the kitchen corner, the flow shifted towards the corner side and exhibited high temperature zone at all levels above the cooking bench.

2. Flow structure within the kitchen space was observed almost identical in all cases. The breathing zone acted like a source point.

3. Forced ventilation system can lower the temperature by around 6^0C. Within the breathing zone, the temperature is about 6^0C higher than the comfort level of temperature.

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[5] Rahman, M H, Islam, A K M Sadrul, and Amin, Ruhul M, "Numerical Study of Carbon Dioxide Gas Emission From an Urban Residential Kitchen In Developing Countries" ASME 2012 International Mechanical Engineering Congress & Exposition, November 9-15, 2012, Houston, Texas, USA.