# MODELING AND SIMULATION OF LPG VAPORIZER

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# MODELING AND SIMULATION OF LPG VAPORIZER

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April -2011

# CERTIFICATE

This is to certify that the work contained in this thesis titled "**Modeling and Simulation of LPG Vaporizer**" has been carried out by P Praveen Kumar under my supervision and has not been submitted elsewhere for a degree.

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# ABSTRACT

LPG is liquefied petroleum gas and is stored in the form of liquid. The upper part of the tank is filled with gas form. When it is released the there is drop in the pressure, gas at the top part of tank will release to burning area. In order to increase efficiency of combustion, vaporizing by electricity heating is common used. While the energy is concerned, the idea of using heat from ambient air to vaporize gas is introduced in this thesis. Copper tube is considered as heat exchanger. Size and length of tube were selected to be the parameters in the mathematic model.

So this study mainly involves the modeling of a horizontal helical coil which acts as a heat exchanger made of copper. Copper is selected because of its ductility and thermal conductivity. The parameters to be decided in this modeling are the radius of copper tube and length of the copper tube. In this thesis experimental data is compared with modeling data. The data is obtained from the previously done experiment and the results obtained are compared with the modeling results.

The modeling equations were developed for the flow and these modeling equations were solved using programming language C++. The results shows how there is variation in temperature profile with increase in the tube area. The results are developed for tubes of different diameters and are compared with the experimental results. An excel sheet is also developed which shows step by step calculations of these iterations. At the end the modeling results are compared with the experimental data to check the performance of the modeling equations.

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## NOMENCLATURE:

$\rho$ = LPG density

v = velocity of LPG

P = LPG pressure

$\tau$ = shear stress

$d_i$ =inner diameter

v = velocity

$m_i$, $m_o$ = input and output mass flow rate in control volume respectively,

h =specific enthalpy

Q = heat transfer rate,

U = Overall Heat Transfer Coefficient,

A = heat exchange area.

Ta = ambient temperature.

Ti = LPG temperature

$r_i$ = inner radius

$r_o$ = outer radius

kc = thermal conductivity of the material

$h_i$ = coefficient of convective inside the pipe

$h_o$ = coefficient of convective outside the pipe

# CHAPTER-1

## 1. INTRODUCTION

LPG is liquefied petroleum gas and it is stored in the form of liquid. The upper part of the tank is filled with gas form. When it releases the pressure drops instantly and this goes to the burning area. In order to increase efficiency of combustion, vaporizing by electricity heating is common used. While the energy is concerned, the idea of using heat from ambient air to vaporize gas is introduced in this study. Copper tube is considered as heat exchanger. Size and length of tube were selected to be the parameters in the mathematic model.

The main aim of this project is to develop mathematical model to study the heat characteristics of LPG in a helical coil. Copper tube acts as a heat exchanger taking heat from the surrounding air. The experimental and mathematical modeling results were compared at a fixed temperature and pressure. The change in behavior of LPG when done with tubes of different diameters and lengths is also analyzed. So this project gives a clear picture of the temperature profile behavior of LPG when flowing through a horizontal helical coil.

## 1.1 PROCESS DESCRIPTION

LPG which is stored in the container is made to pass through the horizontal helical copper tube. The flow is regulated with a flow rate meter. LPG passes through the copper tube with a rise in its temperature. This variation in temperature is measured using the thermocouples. These thermocouples are installed at the regular intervals and the temperature values are recorded. This experimental work is done with copper tubes of different diameters and lengths. The experimental set up is shown as follows. The ultimate effect being increase in the temperature of LPG. This idea of using ambient air is used since vaporizing by other means are costlier than this .when compared with the other process this way of vaporizing is economic.

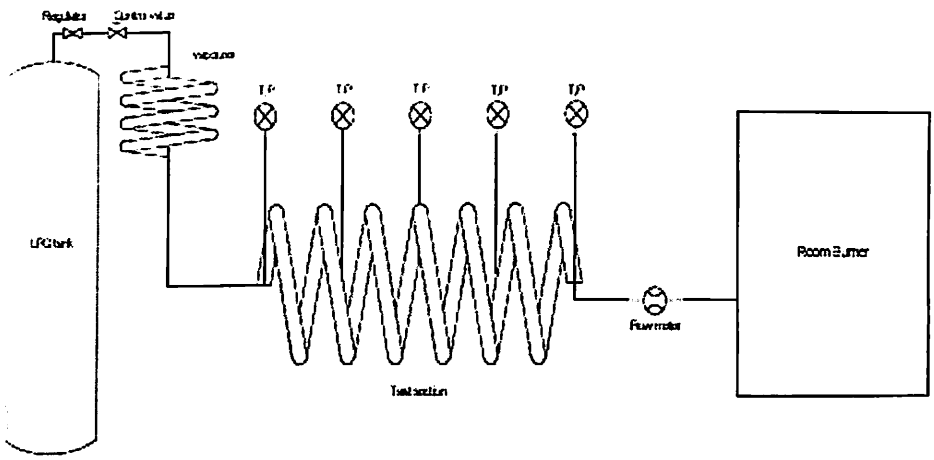



**Figure 1-1 Experimental Installation**

The main components being

1. Helical tube
2. Flow rate meter
3. Thermocouple

# CHAPTER -2

## LITERATURE REVIEW:

The process of vaporizing LPG is done to increase the combustion efficiency. So to maximize its temperature before going to the burner is to select a process which is economic and efficient. So the idea of using copper tube as a heat exchanger is developed. The horizontal coil is used to save the space and copper is used because of its thermal conductivity and ductility. So in a minimum area maximum results can be obtained. The results showed that the length did not affect much the process but the radius had more impact on the heat characteristics of the LPG

The experiment is performed with three different diameters. The results obtained are from the literature and are as follows.

**Table 2-1 Experimental Literature Data : Diameter 0.0127m**

| Area, $m^2$ | Temperature, K |
|---|---|
| 0 | 274 |
| 0.02 | 285 |
| 0.04 | 293 |
| 0.07 | 298 |
| 0.12 | 301 |
| 0.25 | 301.15 |
| 0.37 | 301.15 |
| 0.40 | 301.15 |

**Table2-2 Experimental Data: Diameter = 0.005953m**

| ,Area, $m^2$ | Temperature, K |
|---|---|
| 0 | 274 |
| 0.02 | 285 |
| 0.04 | 295 |
| 0.09 | 299 |
| 0.12 | 300.5 |
| 0.17 | 301.15 |
| 0.20 | 301.15 |
| 0.25 | 301.15 |

**Table 2-3 Experimental Data: Diameter = 0.0063m**

| Area, $m^2$ | Temperature, K |
|---|---|
| 0 | 274 |
| 0.02 | 290 |
| 0.04 | 297 |
| 0.08 | 300 |
| 0.13 | 301.15 |
| 0.18 | 301.15 |
| 0.20 | 301.15 |

This experimental data has been obtained from the previous work by V. Changrue, et.al, 2008.

The main aim of this project is to develop a mathematical model to see the variation in temperature of LPG with area and to compare it from the experimental literature data.

# CHAPTER-3

## THEORY

Helically coiled tubes are effective as heat transfer equipment due to their compactness and increased heat transfer coefficients in comparison with straight tube heat exchangers. Helical coils are used for heat exchange in the fields of air conditioning, nuclear power, refrigeration, and chemical engineering

The increased heat transfer coefficients are a consequence of the curvature of the coil, which induces centrifugal forces to act on the moving fluid, resulting in the development of secondary flow. Fluid from the inside of the tube is thrown through the center of the tube towards the outer wall and then returns to the inner wall via the wall region. This secondary flow enhances heat transfer and temperature uniformity due to increased mixing especially in laminar flow. so this kind of flow helps in increasing the rate at which the heat is transferred and always the uniform temperature is present. The advantage is created by the helical coil mainly due to its orientation and curvature of the coil

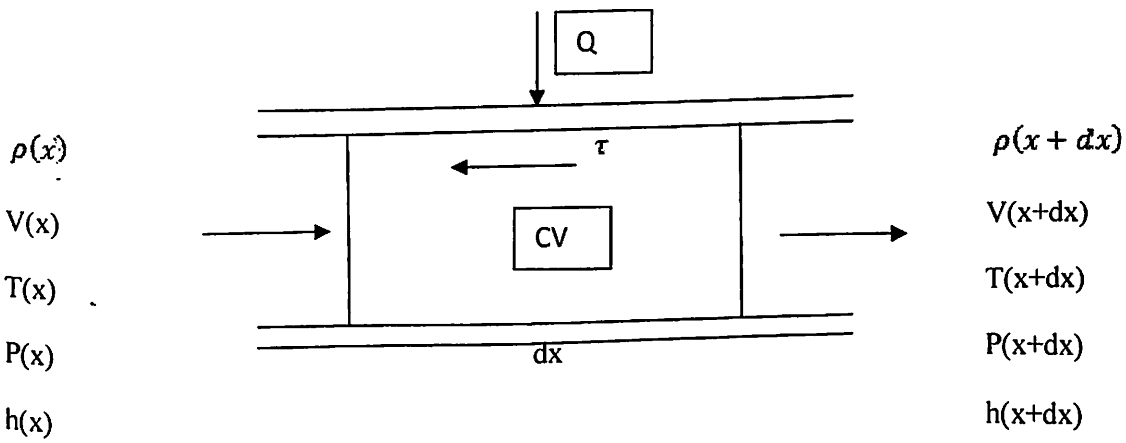



**Figure 3-1 factors in control volume**

# CHAPTER- 4

# MODELING OF LPG VAPORIZER

## CONTINUITY EQUATION:

The flow in control volume is considered as that accumulated mass flow rate in control volume equal to difference of mass flow rate in and mass flow rate out.

$$\frac{d\rho}{dt} + \frac{\partial(\rho v)}{\partial x} = 0 \qquad \text{Eqn. 4.1}$$

Where $\rho$ = LPG density

v = velocity of LPG

## LINEAR MOMENTUM EQUATION:

The total force on control volume is the summation of the different of momentum rate in and out and accumulated momentum rate in control volume.

$$\frac{\partial(\rho v)}{\partial t} + \frac{\partial(\rho v^2)}{\partial x} + \frac{dP}{dx} + \frac{4\tau}{d_i} = 0 \qquad \text{Eqn. 4.2}$$

Where P = LPG pressure

$\tau$ = shear stress

$d_i$ =inner diameter

v = velocity

**ENERGY EQUATION:**

First Law of Thermodynamics is related to energy. In control volume, input energy equal to summation of accumulated energy and output energy which is the following equation.

$$Q + \sum m_i (h(x) - \frac{v^2}{2} + gZ(x)) = \frac{dE_{cv}}{dt} + \sum m_o(h(x + dx) + \frac{v^2(x + dx)}{2} + gZ(x + dx)) \quad \text{Eqn 4-1}$$

Where Q = input energy,

$m_i$, $m_o$ = input and output mass flow rate in control volume respectively,

h =specific enthalpy

**HEAT TRANSFER:**

Heat transfer in the pipe consists of conduction and convection. It was assumed that there is no radiation:

$$Q = UA\ (Ta - Ti) \quad \text{Eqn 4-2}$$

Where, Q = heat transfer rate,

U = Overall Heat Transfer Coefficient,

A = heat exchange area.

Ta = ambient temperature.

Ti = LPG temperature

Overall Heat Transfer Coefficient, U, is calculated form the following equation:

$$\frac{1}{U} = \left(\frac{1}{h_i} + \left(r_i \times \frac{\ln\left(\frac{r_o}{r_i}\right)}{k_c}\right) + \frac{r_i}{(r_o \times h_o)}\right) \qquad \text{Eqn.4.5}$$

Where $r_i$ and $r_o$ are inner and outer radius respectively,

kc = thermal conductivity of the material,

$h_i$ = coefficient of convective inside the pipe

$h_o$ = coefficient of convective outside the pipe

Where hi and ho are calculated from the correlation of Nusselt Number, Nu:

$$h_i h_o = \frac{Nu_{i,o} K_{i.o}}{d_{io}} \qquad \text{Eqn. 4.3}$$

The Nusselt number for the calculation of heat transfer coefficients is important .the correlation relating nusselt number and Rayleigh number for the natural convection heat transfer is

Nu=0.9125×Pow (Ra, 0.301) Eqn. 4.4

$$Ra = \frac{L^3 \rho^2 g \beta \Delta t c_p}{\mu\, k} \qquad \text{Eqn 4.9}$$

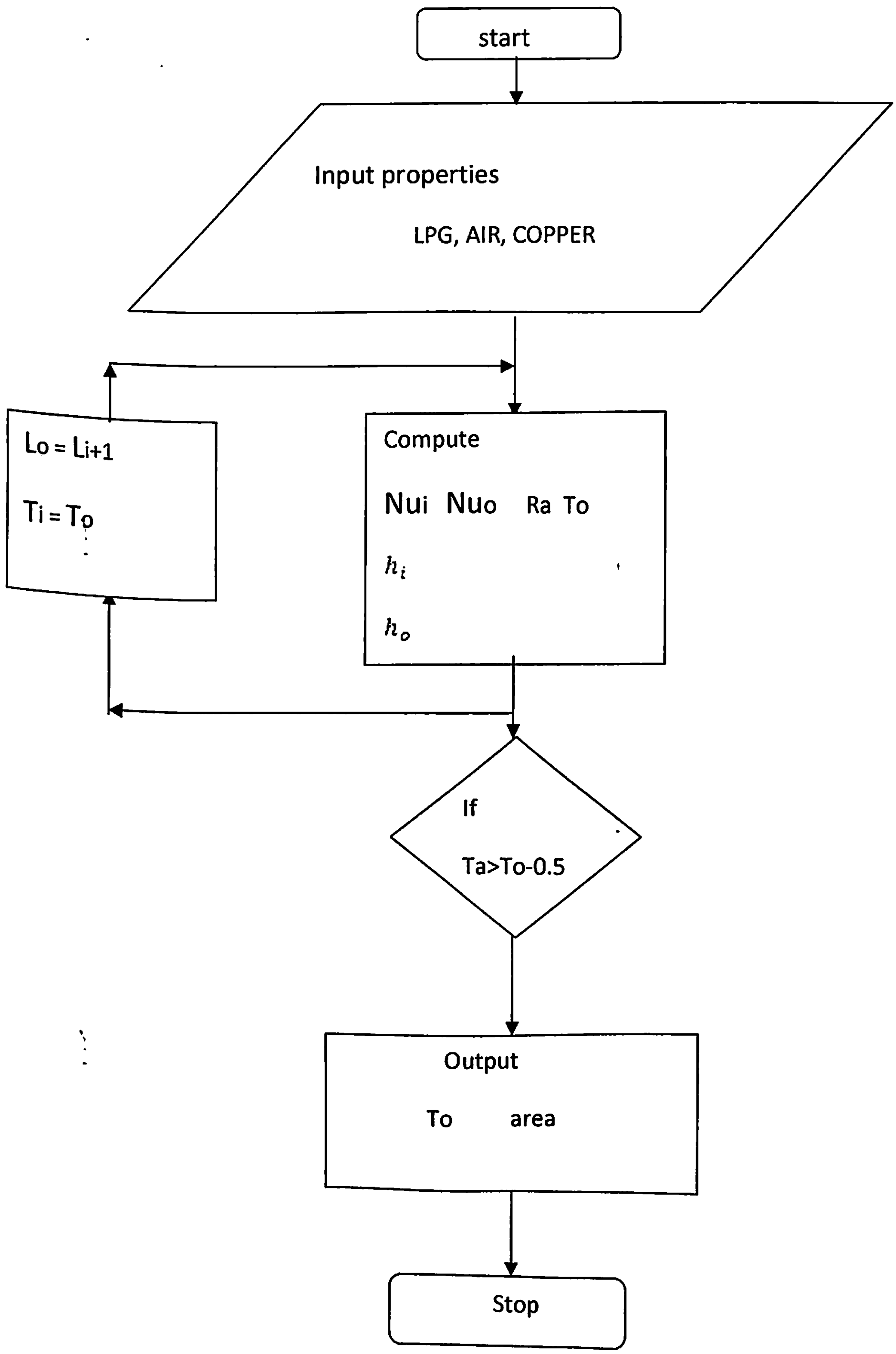
Where L = length

$\rho$ = density

$\beta$ = coefficient of thermal expansion

# CHAPTER -5

FLOW CHART



# CHAPTER -6

## Results and Conclusion:

The modeling equations were solved using the programming language C++ and the results are tabulated as follows.

**Table 6-1 Modeling results for Diameter = 0.00635m**

| AREA, $m^2$ | TEMPERATURE, K |
|---|---|
| 0 | 274 |
| 0.0325 | 285.64 |
| 0.065 | 296.24 |
| 0.097 | 297.94 |
| 0.13 | 299.04 |
| 0.1625 | 299.58 |
| 0.195 | 299.93 |
| 0.227 | 300.17 |
| 0.26 | 300.34 |
| 0.292 | 300.46 |
| 0.325 | 300.56 |

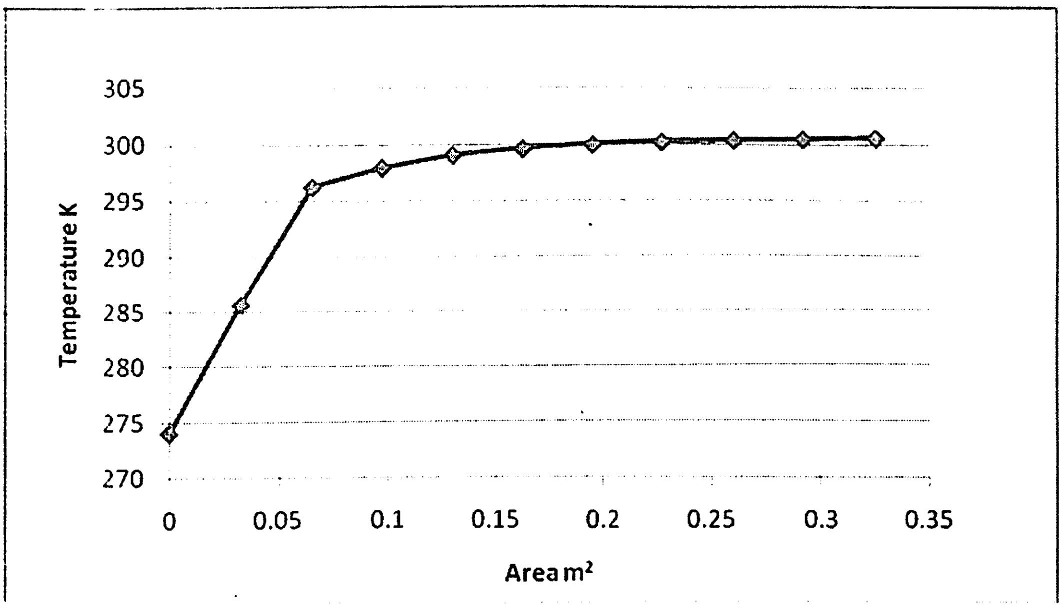



Figure 6.1 Variation of Temperature with area (Diameter = 0.00635m)

**Table 6-2 Modeling results for Diameter = 0.00953m**

| AREA, $m^2$ | TEMPERATURE, K |
|---|---|
| 0 | 274 |
| 0.0424 | 283.35 |
| 0.0849 | 295.74 |
| 0.1274 | 297.57 |
| 0.169 | 298.8 |
| 0.212 | 299.4 |
| 0.254 | 299.8 |
| 0.297 | 300.07 |
| 0.339 | 300.25 |
| 0.382 | 300.39 |
| 0.424 | 300.49 |

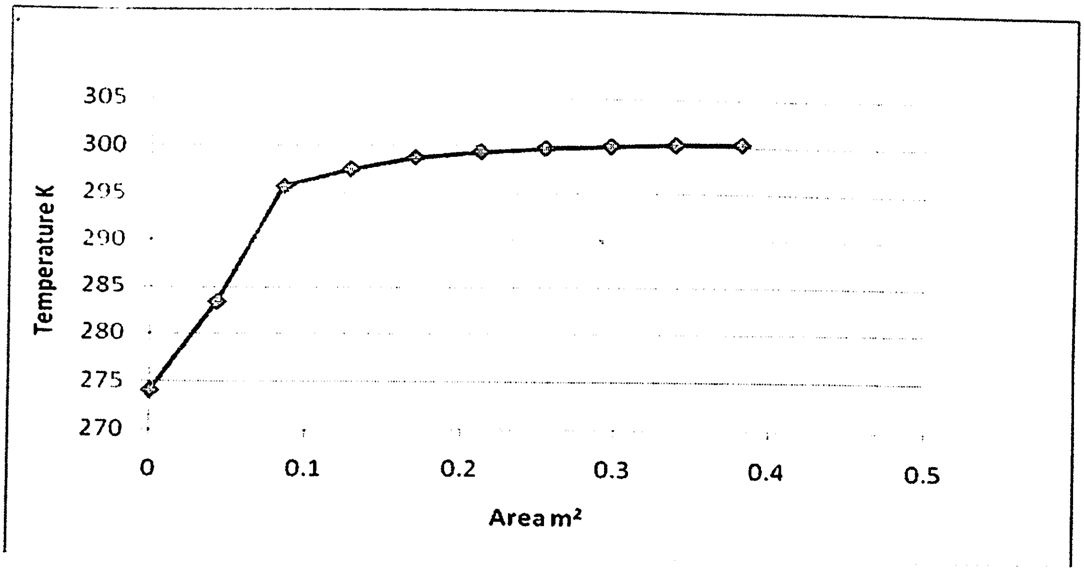



Figure 6.2 Variation of Temperature with area (D = 0.00953m)

**Table 6-3 Modeling results for Diameter 0.0127m**

| AREA, $m^2$ | TEMPERATURE, K |
|---|---|
| 0 | 274 |
| 0.0524 | 281.937 |
| 0.104 | 295.44 |
| 0.157 | 297.34 |
| 0.2098 | 298.66 |
| 0.2622 | 299.303 |
| 0.314 | 299.73 |
| 0.367 | 300 |
| 0.419 | 300.198 |
| 0.472 | 300.344 |
| 0.524 | 300.45 |

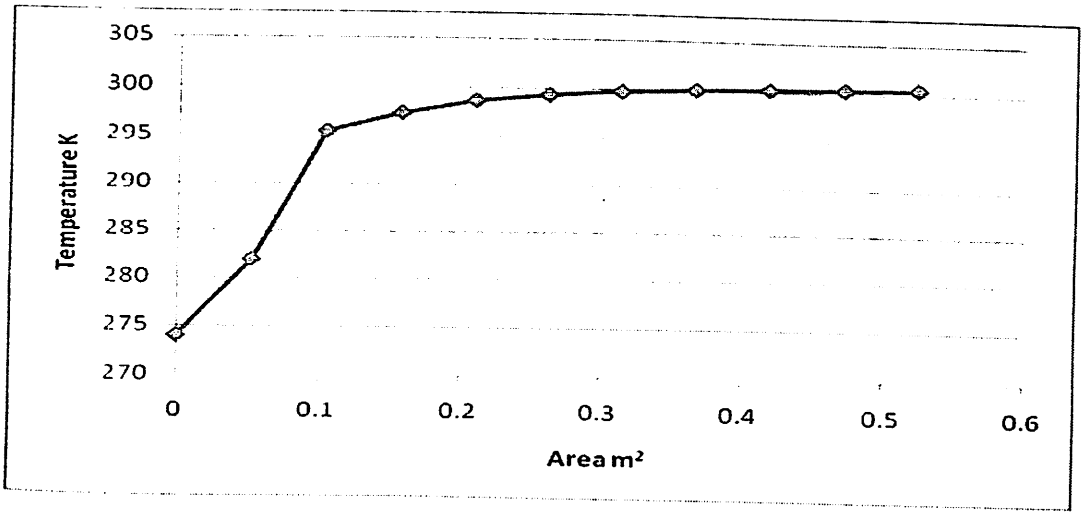



Figure 6.3 Variation of temperature with area (Diameter 0.0127m)

Three different diameters were chosen and the results are obtained. These curves indicate how there is variation in temperature with area. The initial rise in temperature in all the three cases was high and then after certain length there was no variation. Now this data is compared with the experimental data.

Comparison between experimental and modeling results

**Table 6-4 Comparision between Modeling and Experimental results Diameter 0.00635m**

| AREA, $m^2$ | TEMPERATURE, K | |
|---|---|---|
| | Modeling | Experimental |
| 0 | 274 | 274 |
| 0.0325 | 285.64 | 291 |
| 0.065 | 296.24 | 299 |
| 0.097 | 297.94 | 300.5 |
| 0.13 | 299.04 | 301 |
| 0.1625 | 299.58 | 300.12 |
| 0.195 | 299.93 | 300.13 |
| 0.227 | 300.17 | 301.1 |
| 0.26 | 300.34 | 301.15 |
| 0.292 | 300.46 | 301.15 |
| 0.325 | 300.56 | 301.15 |

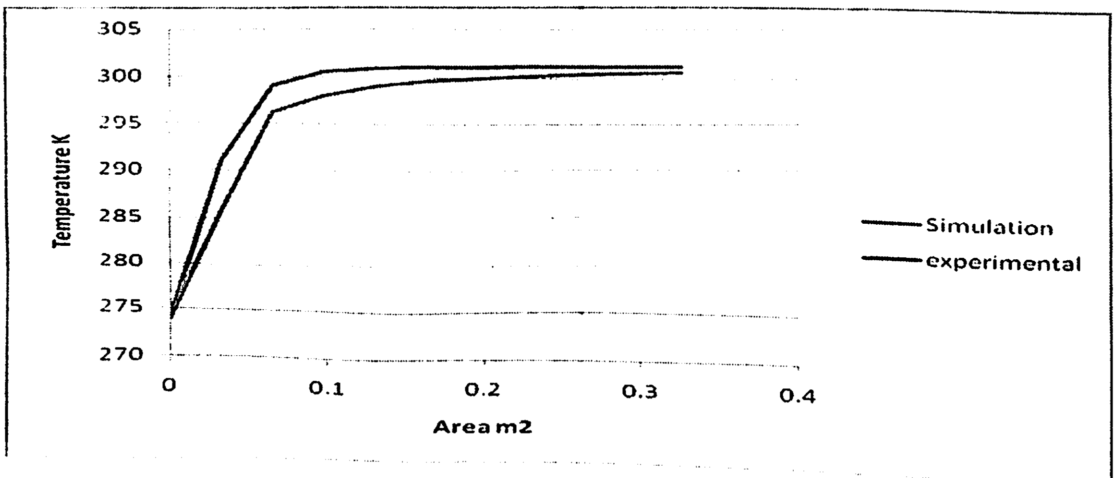



Figure 6.4 Comparision between modeling and experimental data (0.00635m)

**Table 6-5 Comparision between Modeling and Experimental results for Diameter = 0.00935 m**

| AREA, $m^2$ | TEMPERATURE, K | |
|---|---|---|
| | MODELING | EXPERIMENTAL |
| 0 | 274 | 274 |
| 0.0424 | 283.35 | 294 |
| 0.0849 | 294.74 | 298 |
| 0.1274 | 297.57 | 300.5 |
| 0.169 | 298.8 | 300.92 |
| 0.212 | 299.4 | 301.05 |
| 0.254 | 299.8 | 301.1 |
| 0.297 | 300.07 | 300.15 |
| 0.339 | 300.25 | 300.15 |
| 0.382 | 300.39 | 300.15 |
| 0.424 | 300.49 | 300.15 |

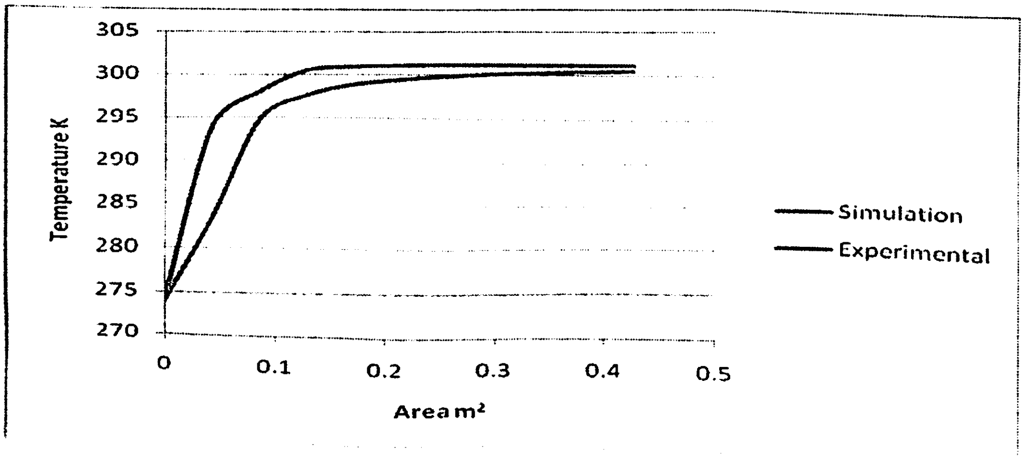



Figure 6.5 Comparision between Modeling and Experimental data for Diameter = 0.00935 m

**Table 6.6: Comparision between Modeling and Experimental results for Diameter = 0.0127m**

| AREA, $m^2$ | TEMPERATURE, K | |
|---|---|---|
| | MODELING | EXPERIMENTAL |
| 0 | 274 | 274 |
| 0.0524 | 281.94 | 292 |
| 0.104 | 295.44 | 298 |
| 0.157 | 297.34 | 300 |
| 0.2098 | 298.66 | 300.5 |
| 0.2622 | 299.303 | 300.9 |
| 0.314 | 299.73 | 301.15 |
| 0.367 | 300 | 300.15 |
| 0.419 | 300.198 | 300.15 |
| 0.472 | 300.344 | 300.15 |
| 0.524 | 300.45 | 300.15 |

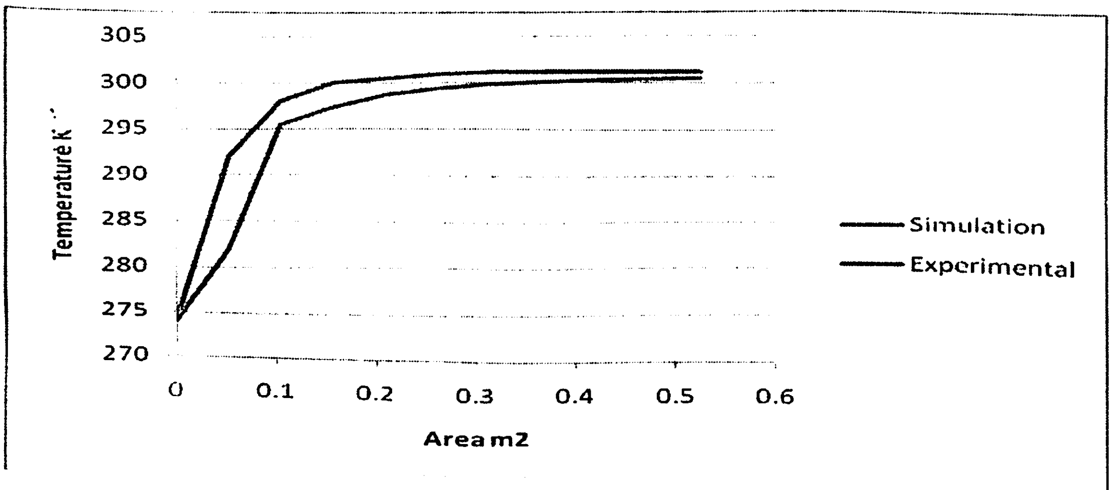



Figure 6.6 Comparision between Modeling and Experimental data for Diameter = 0.0127m

## COMPARISON OF RESULTS

For Diameter: 0.00635m,

| AREA, $m^2$ | TEMPERATURE, K | | |
|---|---|---|---|
| | Experiment | Reference 1 | Present Work |
| 0 | 274 | 274 | 274 |
| 0.0325 | 291 | 285 | 285.64 |
| 0.065 | 299 | 292 | 296.24 |
| 0.097 | 300.5 | 295 | 297.94 |
| 0.13 | 300.9 | 297 | 299.04 |
| 0.1625 | 301.02 | 298.4 | 299.58 |
| 0.195 | 301.07 | 299.6 | 299.93 |
| 0.227 | 301.15 | 300.3 | 300.17 |
| 0.26 | 301.15 | 300.6 | 300.34 |
| 0.292 | 301.15 | 301.06 | 300.46 |
| 0.325 | 301.15 | 301.15 | 300.56 |

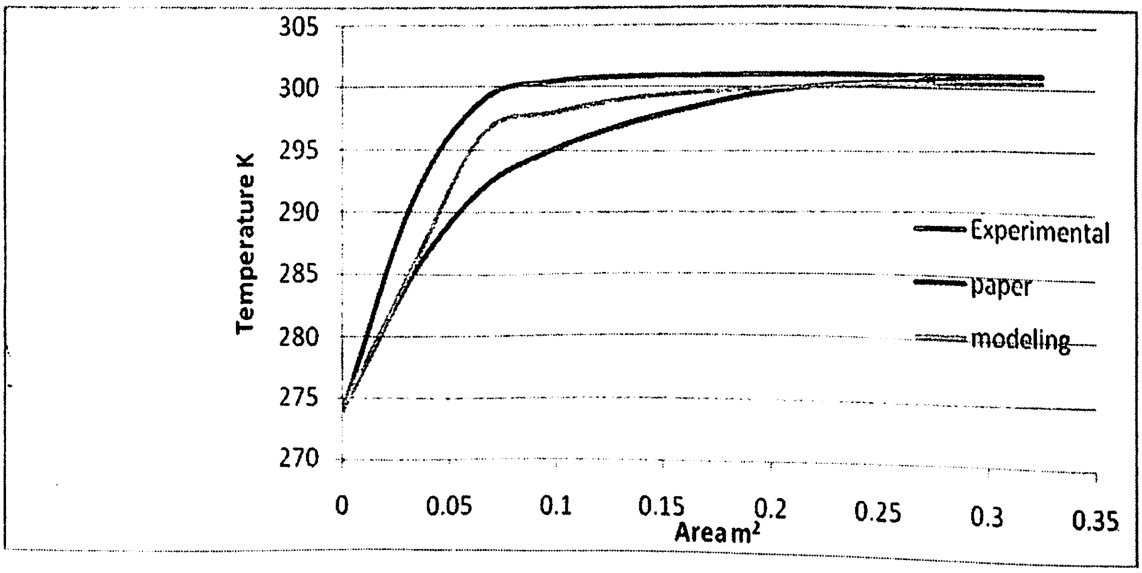



Figure 6.6 Comparision between Modeling and Experimental data for Diameter: 0.00635m

Comparison of modeling results for different diameters

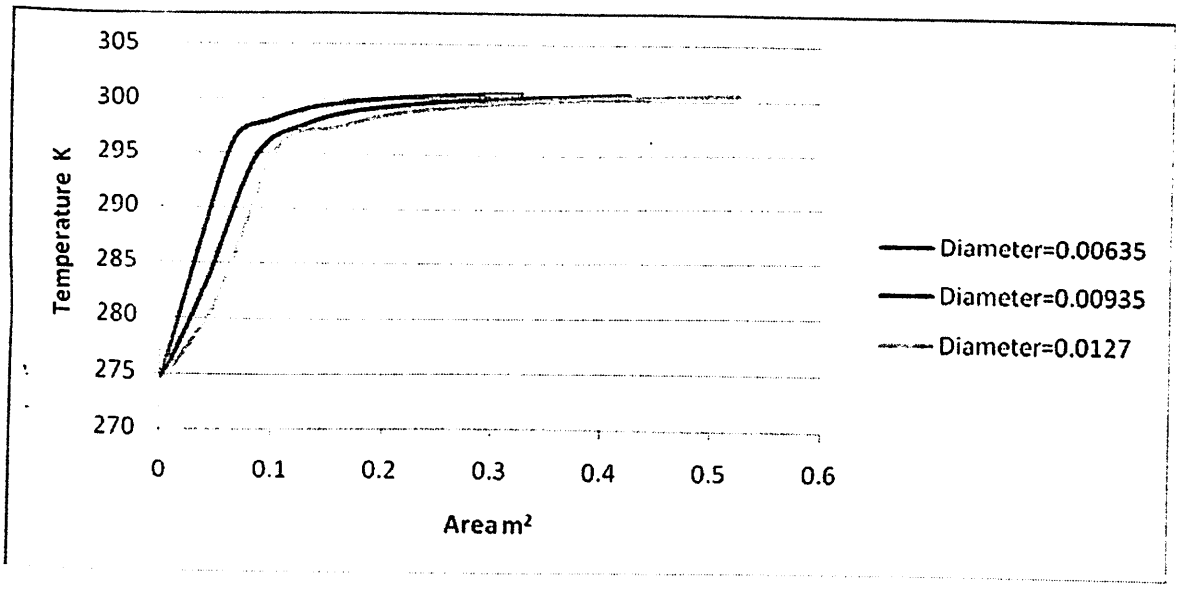



Figure 6.7 Comparison of different diameters of the modeling results.

## DISCUSSION

The length of the copper tube did not significantly affect the temperature profile of LPG. The temperature rise in the initial length was very high and later after certain length it became constant. The main parameter here was the diameter of the tube. The larger diameter of copper tube provided more heat exchange area but the velocity tended to be low. So it influenced the Reynolds number and Nusselt number. The coefficient of convection inside the pipe will be reduced. So the heat transfer from pipe surface to inside fluid is reduced.

In the present project, the expression for overall heat transfer coefficient is been changed which ultimately effected the temperature profile as the earlier one used in the paper was inconsistent in the units.

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