Journal Homepage: - www.journalijar.com
INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)
ISSN NO. 2320-5407
Article DOI: 10.21474/IJAR01/4477
DOI URL: http://dx.doi.org/10.21474/IJAR01/4477

RESEARCH ARTICLE

ANALYSIS OF TEMPERATURE DISTRIBUTION ALONG ELEVATION OF FURNACE BOILER FOR POWER PLANT WITH TANGENTIAL CORNER UTILIZE NATURAL GAS FUEL FOR COMBUSTION IN TILT ANGLE $\Phi = 0^{O}$.

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Manuscript Info

Manuscript History

Received: 13 April 2017
Final Accepted: 15 May 2017
Published: June 2017

Key words:-
Furnace, Non premix combustion, Temperature, Turbulent flow, CFD Fluent

Abstract

Using natural gas fuel combustion with tilt angle $\Phi = 0^{o}$ to predictions the features of systems such as furnaces and/or boiler the working in high temperatures are made for three dimension which adopted tangential corner fire .The present study utilizing available packages including CFD FLUENT ANSYSIS. The turbulent kinetic energy with dissipation rate (K-ε) for non premixed combustion model will be solve the turbulent flow procedure, aims to study the aerodynamics of this flow and it is effect on the temperature distribution ,and show how the flame looks like fire ball in the centre of furnace effecting heat uniformly furnace walls.

Introduction:-

The power plants are one of worldwide subjects that had been studied along time they were considered as an important factor for development of national economics and the furnace is an important component of the boiler unit that has two functions ,meaning it works as combustion chamber and also radiant heat transfer surface .The furnace boiler of power plant is used to provide steam or hot water .There are two types of boiler, fire tube boiler by which the fire passes through the tubes and water tube boiler by which the fire surroundings the tubes that contain water.

Natural gas fired boilers have combustion and heat transfer characteristics somewhat different from those of coal or oil fired boilers, thus careful additional consideration become necessary in designing gas fired burners.

The type of fuel that is combust determine the great extent over all plant design ,such as fuel handling and preparation ,combustion ,recovery of heat ,fouling of heat transfer surface ,corrosion of materials and air pollution control ,the use of oil and gas as fuels for new benefit ,boilers has reduce expect for certain areas of world where these fuels are ready available and low cost [1].In natural gas fired boiler ,there is minimum need for fuel storage and handling because the gas usually comes directly from pipeline to the boiler.

Boiler of power plant as present case study is radiant reheat out door type ,with 12 burners in three levels tangential corner furnace and it is configuration is called “Box type” as shown in (Fig.1) work in manner called natural circulation[2] .

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Review:-

Theoretical Studies of Tangential Combustion in Thermal Industrial Boiler Furnaces:-

In last two decades and until the present years theoretical studies of many researchers in the field of combustion in industrial thermal furnaces have evolved for their development .Thermal industrial furnaces differ in terms of engineering design and the ability which supply for different industrial uses. Hence there are three main methods of firing based on their orientation in the furnace; 1-Down shot firing where the fuel mixture is injected downwards, 2-Horizental (opposed jet or front firing) where fuel mixture is injected horizontally, 3- Corner type firing where the fuel mixture is injected tangentially towards a single combustion zone, all these construction see in (Fig. 2).

All above technologies mentioned above , are good for combustion but there is suitable design can be choose depend on designer and operating condition availability of raw materials in place of construction and several necessary requirements for cost minimization ,maximum combustion rate that must be accomplished in a small space ,this can be achieved by a turbulent swirling flow or by tangential corner flow that has minimum advantage to keep the flame stable.[3].

Fuels used in industrial applications such as gaseous type normally described as clean combustion give low rates of soot and nitric. To achieving optional level in combustion region for mixing is describe as main problem. Stability limits depending on mixing rate ,that the narrow stability is produce when there is too high mixing rate, but when it be too low mixing rate ,the system go downward slope or direction to combustion induced pressure oscillations. The traditional combustion chambers including swirl, nozzles, plain orifices slots and venture, they are work with different methods to inject gas in such devices [4].

Azazi [23] present study for power plant furnace with tangential corner firing utilize (2 - D) aerodynamics and thermal aspects by using FORTRAN computer program. In his study he deduced that inside the fire – ball and in the furnace the pressure amount with the design value is agreement. That losses were 14.5% in the furnace to get 1500^{o}C inside temperature and the tangential velocity played a great role for keeping the stability of the fire ball.

Ben - Mansour *et al.* [5] In Tangentially fired furnace, their study done by varying the mass flow rate for air in parallel of changing excess air factor at various operating conditions , for maximum furnace temperature and furnace average temperatures ,they provided correlations for NO concentration ,through the simulation, their The results show that gases close to the walls in the regions of high temperature that lead to tripping one or two burners either adjacent or opposite o tripping four burners, and tripping any of the burners lead to significantly distorted for temperature distribution .

Wagh *et al.* [6] their numerical work as investigation study deal with thermal tangentially fired boiler of 600MW pulverized coal and validated with experimental data , the study how to be characteristics shape flow inside the burner through it impact by changing the mass flow rate and firing angle.

Optimization is executed for different design such as firing angle and burner velocity with objective function in order to enhancement efficiency of mixing in the furnace. From that optimum design and operating parameters with simulation can be possible.

Munisamy *et al.* [7] They present CFD investigation in comparing between the off-design burner angle -30° and design condition of 0° burner firing angle with for 700 MW Tangentially fired furnace boiler using coal fuel, then can be reduce rear pass temperature un-balance by boiler operation by tilting burner angle -30° ,hence their conclusion illustrate, this effect back to reduce the turbulence fire ball inmixing inside the furnace to reduce the pass temperature shifted the fire ball position. However reducing the burner tilt angle, lead to decreasing the efficiency of the furnace.

Their results for -30° burner tilting angle, the velocity profile explain that fire ball is shifted below than the plane so as the design condition the fire follows not clear as that of 0° burner firing angle.

The effort of Wisam *et al.* [8] was on the 120MW natural gas - fired industrial boiler on combustion process by computational fluid dynamic simulations. The boiler is of tangential system at three different elevation from its four corners by which air nozzles and fuel burners can be tilted with ± 30ºin the range, then air and natural gas with intense mixing of natural gas and air, are fired into the furnace The flow in the furnace is highly swirling, hence results obtained as compared to practical observation, show good prediction of temperature profile and distribution.

Towards the exit of furnace there is helical shape in anti-clockwise direction for combustion gas flows in the turbulence levels extremely high. When the burner is tilted up to -10º in negatively value, at re-heater the average temperature level lead to reduces, so the change in firing angle will interrupt the temperature slightly and flow contour at furnace re-heater. Where inside the furnace the overall flow pattern is dominated by these sources, however, this is true for air nozzles only. By their study they concluded the following factors [8]:

1. Along the furnace height temperature profile exhibited a lower temperature at the bottom furnace , a drastic increase at the combustion region, but at the upper furnace remained approximately constant .
2. Displayed the highest average temperature when + 10° burner tilt at the re-heater entrance among all tilt configurations .The configuration likewise provides good symmetrical temperature distribution at the furnace re-heater.
3. The lowest average temperature indicated (when - 10° burner tilt) at the re-heater entrance among all tilt configurations.
4. Reasonably good symmetrical temperature distribution at the entrance of the furnace for all negative burner tilts has been display.

Case study:-

In this study it was required certain specifications as follows:

The requirements of implementation furnace as:-

The furnace for high pressure steam production by natural gas and fuel oil firing is intended as box type design construction shown in (Fig. 1) which is suitable for capacity around 200MW.Tangential corner firing is adopted with following dimensions are; X=10.810m,Y=22.500m,Z=9.4860m,with capacity 2307.23 cubic meter, schematic furnace chamber shown in (Fig. 2).

The furnace walls are formed by 63.5mm O.D. tubes on 76.5 mm centres fusion welded together into tube panels to provide a complete gas tight seal ,the furnace rear screen tubes are 76.2 mm O.D. Where the tubes are spread out to permit passage of super heater elements, these tubes are made of carbon steel. The spaces between the tubes are closed with fins to form a complete metallic surface. The ends of the tubes are welded in straight rows to the water wall upper and lower headers. These wall tubes are supported by the buck stays through the tie bars or the tension plates against the pressure differential between the furnace inside and outside .

On to outside of the walls insulating material (mineral wool blankets)is set and covered with outer casing of corrugated steel plate . In oil and natural gas firing ash formation are negligible, so the furnace has been design with completely closed "V" type bottom to ensure the gas –tightness . That is the front and rear water walls bend toward the furnace bottom header sloping downward 15 degrees from the horizontal [2].

Present case study Parallelogram Furnace (box type construction design) which is suitable for capacity around 200MW, with dimensions (x, y, z) $(10.81\times 22.5\times 9.486)\ \mathrm{m}^3$, respectively representing (Fig.1).The furnace consist of three levels with 12 burners , four corners at each level , one burner for each corner ,where level 1 at height (y_1=6.248m) , level 2 at height (y_2=7.765m) and level 3 at height(y_3= 9.282m)). The type of burners(gas) are mounted with entrances of primary and secondary air in wind box arrangement ,the burners have titling tangential corner (Tilit angle ,$\Phi = -30^o, 0^o, +30^o$)in present case the design take $\Phi = 0^o$, and angle θ of nozzle position in horizontal plane $\theta = 45^o$ for corner 1,3 and $\theta = 36^o$, $\theta = 54^o$ for corner 2 and 4 ,represented in the (Fig.2) [2]. The inlet boundary conditions can be define by properties of entering fluid (Gas) such as temperature, velocity, mass flowrate , density and viscosity and air properties for simulation is listed in table **-I ,**the simulation is done under design condition for different load operation The fuel (Gas) [2].

Table I:- Boundary conditions for Gas Fuel (Natural Gas)

Item	**Unit**	**Gas firing**				
Load	-	100%MCR	70%MCR	60%MCR	40%MCR	30%MCR
			Natural Gas			
Mass flow rate($\dot{m}$)	Nm^3/h	4870				
	Kg/s	0.9036	0.63252	0.54216	0.36144	0.27108

Temperature(T)	K	300	-	-	-	-
Density(ρ)	Kg/m^3	0.668	-	-	-	-
LHV	J/kg	50×10^6	-	-	-	-
			Primary Air			
Mass flow rate($\dot{m}$)	Kg/s	4.545	3.1815	2.727	1.818	1.3635
Temperature(T)	K	300	-	-	-	-
Density(ρ)	Kg/m^3	1.183	-	-	-	-
			Secondary Air			
Mass flow rate($\dot{m}$)	Kg/s	1.51515	1.06	0.90909	0.60606	0.34545
Temperature(T)	K	300	-	-	-	-
Density(ρ)	Kg/m^3	1.183	-	-	-	-

Where, Nm^3/hr, is denoted Normal Cubic Meters per Hour = 1.25 l/hr.

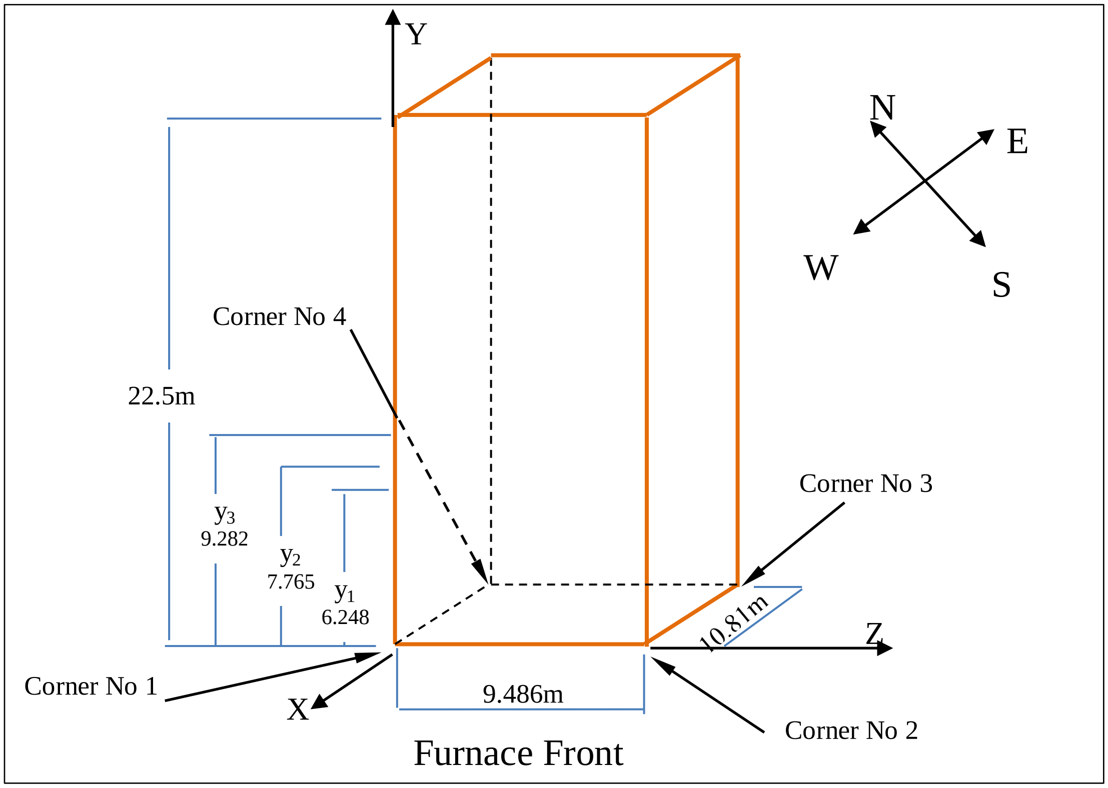

Figure 1:- Schematic Furnace chamber (wind box)

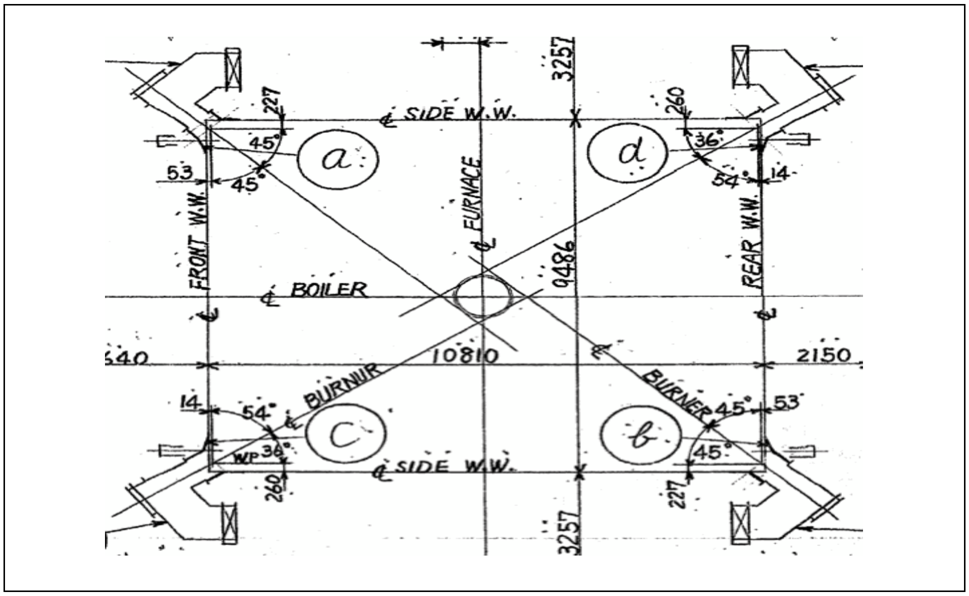

Figure 2:- Tilit angle , Φ and angle θ of nozzle position in horizontal plane [2]

Gas burners:-

Initially burners are installed at each corner of the furnace in 3 elevations ,A,B,C,(level 1at y_1=6.248m, level 2 at y_2=7.765m, and level 3 at y_3= 9.282m)as previously represented in (Fig. 1) ,12 sets in total. Each burner has 2 spud type gas nozzle The fuel gas is supplied to each burner through a gas burner valve as shown in (Fig.3).The gas supply pipe for each burner divides into 2 lines at the front of the burner wind box and these lines run into the wind box and are connected to two gas nozzles respectively. Each gas nozzle (spud) is fixed in position and has a tilting nozzle so located as to cover its tip. The gas is injected into the furnace from the gas nozzle though this tilting nozzle including tilting nozzle including air though the inlet opening of the tilting nozzle and mixing with that air in the nozzle.

As for the primary air and secondary air nozzles. The Operating gas pressure ranges from 0.08kg/cm^{2}g to 1.5 kg/cm^{2}g at the burner inlet and is controlled automatically to suitable for burner load and number of burners in service by the burner control systems .However the gas supply pressure at the outlet of the gas control valve various in the range of 0.2kg/cm^{2}g (trip pressure) to 3.0 kg/cm^{2}g to complete the pressure loss in the line from the control

valve to each burner .The alarm for "Burner inlet pressure low" , is set at 0.5kg/cm^{2}g. The Natural Gas analysis mole and volumetric present given table -II:

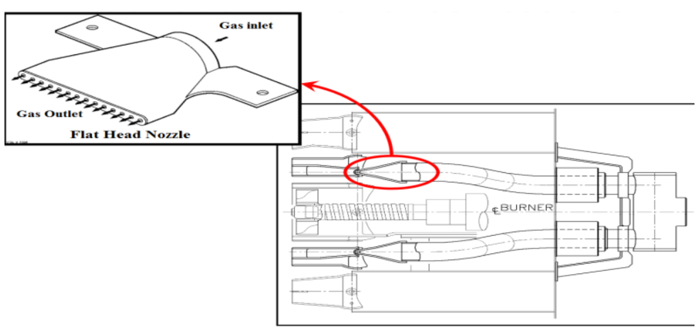

Figure- 3:- Schematic gas burner (nozzle) [2]

Theoretical Analysis:-

In the analysis of flow and combustion inside furnace, the following equations must be considered:
Continuity equation

$\frac{\partial}{\partial x}(\rho U) + \frac{1}{r}\frac{\partial}{\partial r}(\rho r V) + \frac{1}{r}\frac{\partial}{\partial \theta}(\rho r W) = 0$ (1)

Equation of Motion (Momentum)[9,10]

In z - direction:

$\frac{\partial}{\partial z}(\rho UU - \mu_{eff}\frac{\partial U}{\partial z}) + \frac{1}{r}\frac{\partial}{\partial r}(\rho r VU - \mu_{eff}\, r\frac{\partial U}{\partial r}) + \frac{1}{r}\frac{\partial}{\partial \theta}\left(\rho WU - \mu_{eff}\frac{1}{r}\frac{\partial U}{\partial \theta}\right) = source$ (2)

Where :

Source $= -\frac{\partial \rho}{\partial z} + \frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial U}{\partial z}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left[r\mu_{eff}\left(\frac{\partial V}{\partial z}\right)\right] + \frac{1}{r}\frac{\partial}{\partial \theta}\left[\mu_{eff}\left(\frac{\partial W}{\partial z}\right)\right]$

In r – direction :

$\frac{\partial}{\partial z}(\rho UV - \mu_{eff}\frac{\partial V}{\partial z}) + \frac{1}{r}\frac{\partial}{\partial r}(\rho r VV - \mu_{eff}\, r\frac{\partial V}{\partial r}) + \frac{1}{r}\frac{\partial}{\partial \theta}\left(\rho WV - \mu_{eff}\frac{1}{r}\frac{\partial V}{\partial \theta}\right) = source$ (3)

Where :

Source $= -\frac{\partial \rho}{\partial r} + \frac{\partial}{\partial z}\left(\mu_{eff}\frac{\partial U}{\partial r}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left[r\mu_{eff}\left(\frac{\partial V}{\partial r}\right)\right] + \frac{1}{r}\frac{\partial}{\partial \theta}\left[\mu_{eff}\left(r\frac{\partial(\frac{W}{r})}{\partial r}\right)\right] + \rho\frac{W^2}{r} - \frac{2\mu_{eff}}{r}\left(\frac{1}{r}\frac{\partial W}{\partial \theta} + \frac{V}{r}\right)$

In θ – direction :

$\frac{\partial}{\partial z}(\rho UW - \mu_{eff}\frac{\partial W}{\partial z}) + \frac{1}{r}\frac{\partial}{\partial r}(\rho r VW - \mu_{eff}\, r\frac{\partial W}{\partial r}) + \frac{1}{r}\frac{\partial}{\partial \theta}\left(\rho WW - \mu_{eff}\frac{1}{r}\frac{\partial W}{\partial \theta}\right) = source$ (4)

Where :

Source $= -\frac{1}{r}\frac{\partial \rho}{\partial \theta} + \frac{\partial}{\partial z}\left[\mu_{eff}\left(\frac{1}{r}\frac{\partial U}{\partial \theta}\right)\right] + \frac{1}{r}\frac{\partial}{\partial r}\left[\mu_{eff}\left(\frac{\partial V}{\partial \theta} - W\right)\right] + \frac{\mu_{eff}}{r}\left(r\frac{\partial(\frac{W}{r})}{\partial r} + \frac{1}{r}\frac{\partial V}{\partial \theta}\right)\Big] - \frac{\rho WV}{r} + \frac{1}{r}\frac{\partial}{\partial \theta}\left[\mu_{eff}\left(\frac{1}{r}\frac{\partial W}{\partial \theta} + \frac{2V}{r}\right)\right.$

Equation of Energy

$\frac{\partial}{\partial z}\left(\rho UT - \frac{\lambda}{C_p}\frac{\partial T}{\partial z}\right) + \frac{1}{r}\frac{\partial}{\partial r}\left(\rho r VT - \frac{\lambda}{C_p}\frac{\partial T}{\partial r}\right) + \frac{1}{r}\frac{\partial}{\partial \theta}\left(\rho WT - \frac{\lambda}{C_p}\frac{1}{r}\frac{\partial T}{\partial \theta}\right) = source$ (5)

Where:

Source$=\frac{q_{c.v.}}{C_p} = \frac{\dot{m}_f H_{c.v.}}{volume\ C_p}$

Boundary Conditions at the wall

Tangential velocity:-

The fluid velocity in θ direction, in the immediate vicinity of furnace wall, must be equal to that of wall it self Thus Z equal zero at all points on the surface. The same is for axial velocity U and radial velocity V both of this equal zero at wall.

Boundary Conditions at the inlet:-

In most problems the conditions of the entering fluid is known the temperature, velocity , viscosity and density may be given or calculated, this just when flow coming out from nozzles. Velocity is given from the equation of mass flow rate for both types of fuel used in thermal power station.

$\dot{m}_{\text{fluid}} = \rho . A . V_{\text{ref}}$ (6)

Where ; $\dot{m}_{\text{fluid}}$: is the mass flowrate of fluid in(kg/s): $\dot{m}_{\text{gas}}$ for gas fuel, $\dot{m}_{\text{oil}}$ for liquid fuel, $\dot{m}_{\text{air}}$ for air flow rate (either primary air $m_{p.a}$, or secondary air $m_{s.a}$)

ρ: density of fluid(gas, oil, air)in (kg/m^3).

A : Area of nozzle (gas, oil, air) in (m^2).

$V_{\text{ref}} = (V_{gas}, V_{oil}, V_{p.a}, V_{s.a}) = V_{nozzle}$

$V_{nozzle} = \frac{\dot{m}}{n\rho A}$

Where; n: No. of nozzles

The analysis of velocity components illustrated in (Fig. 4):

X = U = V_{ref} sin θ cos Φ

Y = V= V_{ref} sin Φ

Z = W = V_{ref} cos θ cos Φ

Natural Gas:-

The third-most widely used energy source in the world Natural gas is a combustible, gaseous fossil fuel that is accounting for approximately 21 percentage of total ,primary energy demand in 2012.Natural gas can be produced either on its own or alongside oil production(the latter referred to as ("associated gas").Natural gas has the following analysis by south oil Refinery Company (Iraq)[2].The analysis in terms of mole and volumetric percentage, given in the table –II:

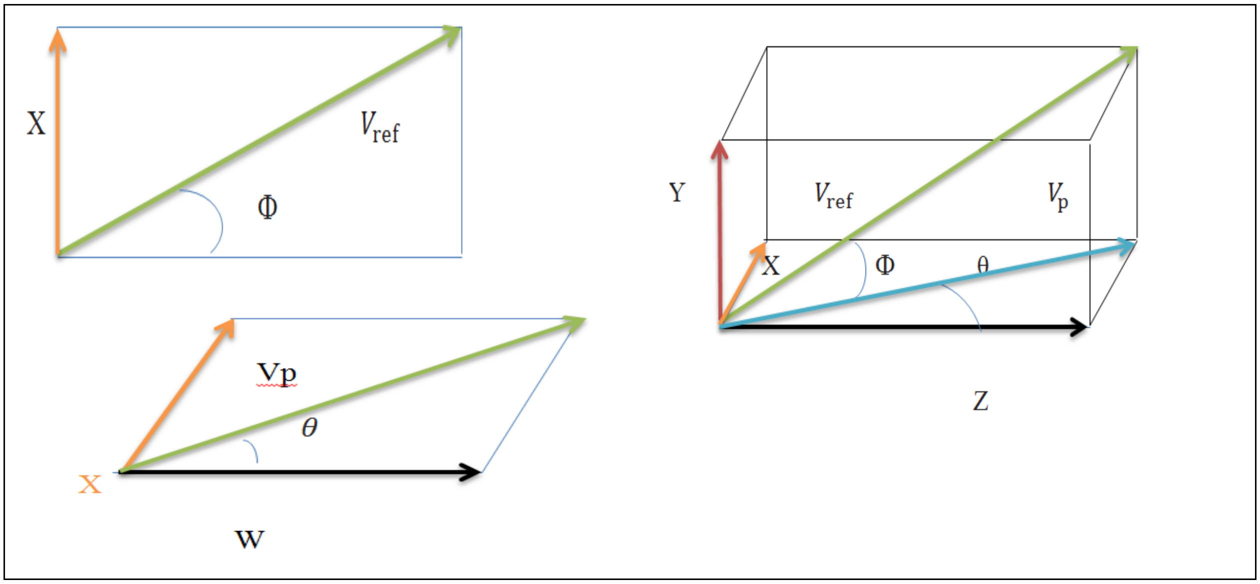

Figure 4:- Velocity components

Stoichiometric of combustion:-

The equation of stoichiometric equation of combustion for fossil fuels are mainly compounds of carbon and hydrogen (hydrocarbons – $C_m H_n$).The reaction of its oxidation can be written by the equation of stoichiometry. It is important for one mole of fuel ($C_m H_n$) necessary exactly ($m+\frac{n}{4}$) mole of oxygen for complete combustion.

$$C_m H_n+(m+\frac{4}{n})O_2\rightarrow{}_mCO + \left(\frac{n}{2}\right)H_2O \quad (7)$$

This is illustrated in the following as balanced equation [11]:

$$CH_4 + 2 O_2 \rightarrow CO_2 + 2H_2O \quad (8)$$

1 mole of CH_4 +2 mole of $O_2\rightarrow$ 1 mole CO_2 +$2H_2O$

Combustion and chemical reactions:-

The combustible of the fuel elements and compounds in the fuel with all the oxygen as combination that requires high temperatures enough to ignite the constituents, mixing or turbulence to provide intimate oxygen-fuel contact, and sufficient time to complete the process [12].The total mass of oxygen required per kg of fuel as shown in table-III:

$$m_{ox} = C\% \times \frac{W_{O_2}}{W_c} + H_2\% \times \frac{W_{O_2}}{2W_{H_2}} + S\% \times \frac{W_{O_2}}{W_S} \quad (9)$$

Most gaseous involved in combustion calculations can be approximated as ideal gases, the reacting substance can be modelled by equation of state [13].Analysis process neglecting ash value because it is not entering combustion.

$$\rho_{mix} = \frac{\frac{P}{\overline{R}T}}{\frac{m_{fu}}{W_{fu}} + \frac{m_{ox}}{W_{ox}} + \frac{m_{pr}}{W_{pr}}} \quad (10)$$

Where;

m_{fu}: the mass of fuel used kg.W_{fu}:the molecular weight of fuel.m_{ox}:the mass of oxygen used kg/kg of fuel

m_{pr}:the mass of products per kg =(m_{co_2}+m_{H_2O}+m_{so_2})W_{pr} : molecular weight of the products.

$$\rho_{co_2} = \frac{P_{co_2} / \overline{R}T}{m_{co_2}/W_{co_2}} \quad (11)$$

$$\rho_{H_2O} = \frac{P_{H_2O} / \overline{R}T}{m_{H_2O}/W_{H_2O}} \quad (12)$$

$$\rho_{so_2} = \frac{P_{so_2} / \overline{R}T}{m_{so_2}/W_{so_2}} \quad (13)$$

Table II:- Natural Gas analysis mole and volumetric percentage (where the high heat value and low heat value where 52.225MJ/kg,47.141MJ/kg respectively at 32^{o}F and 1 atm.)

Element	Symbol	Mol. %	Vol.%
Nitrogen	N_2	0.46	0.46
Methane	CH_4	72.71	72.9
Carbon dioxide	CO_2	2.65	22.08
Ethane	C_2H_6	22.25	2.64
Propane	C_3H_8	1.67	1.64
I-Butane	I-C_4H_{10}	0.08	0.08
N-Butane	N-C_4H_{10}	0.17	0.17
I-Pentane	I-C_5H_{12}	0.02	0.02
N-Pentane	N-C_5H_{10}	0.01	0.01
N-Hexane	N-C_6H_{14}	0.0	0.0
Heptane	C_7H_{16}	0.0	0.0

Table III:- Oxygen total mass required per kg of fuel

	Fuel Content	%Content by weight of the fuel	Combustion Equation	Theoretical O_2 Required per kg of Fuel	Product per kg of Oxidant
1	C	0.855	$C+O_2\rightarrow CO_2$	$C\%\times\frac{W_{O_2}}{W_C}$	$CO2=C\%\times\frac{W_{CO_2}}{W_C}$
2	H	0.115	$2H_2+O_2\rightarrow 2H_2O$	$H\%\times\frac{W_{O_2}}{W_{H_2}}$	$H_2O=H_2\%\times\frac{W_{H2O}}{W_{H_2}}$
3	S	0.025	$S+O_2\rightarrow SO_2$	$S\%\times\frac{W_{O_2}}{W_S}$	$SO_2=S\%\times\frac{W_{SO_2}}{W_S}$

Mathematical Modelling:-

Physical Model and Assumptions:-

By considering the physical problem and it is geometry as shown in (Fig.1)to (Fig.5),represented schematic diagram of investigation domain ,all dimensions required to create the model obtained from plant power manual[2].The furnace is divided into y- planes through the elevation of the furnace, the location of three levels for fuel burners and three air ducts(one primary air duct + two secondary ducts)for each burner located in each corner.

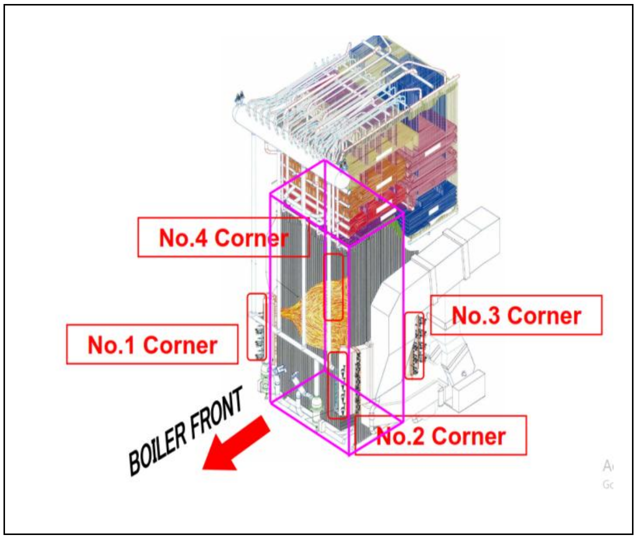

Figure 5:- Schematic diagram of furnace with four wind box [2]

K-epsilon turbulence model (k-ε):-
The turbulence model [14] is used to simulate the turbulence flow and combustion process. In present study standard K-epsilon model and radiation model p1 and non-premixed species model have been chosen, the turbulence viscosity is expressed as:

Turbulence kinetic energy(k):-

$$\rho\bar{u}\frac{\partial k}{\partial z}+\rho\bar{v}\frac{\partial k}{\partial r}+\frac{1}{r}\rho\overline{w}\frac{\partial k}{\partial \theta}=\frac{\partial}{\partial z}\left(\frac{\mu_t}{\sigma_{k,t}}\frac{\partial k}{\partial z}\right)+\frac{1}{r}\frac{\partial}{\partial r}\left(\frac{\mu_t}{\sigma_{k,t}}r\frac{\partial k}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial \theta}\left(\frac{\mu_t}{\sigma_{k,t}}\frac{\partial k}{\partial r}\right)-\rho\varepsilon+\mu_{t\,G} \quad (14)$$

Energy dissipation(ε):-

$$\rho\bar{u}\frac{\partial \varepsilon}{\partial z}+\rho\bar{v}\frac{\partial \varepsilon}{\partial r}+\frac{1}{r}\rho\overline{w}\frac{\partial \varepsilon}{\partial \theta}=\frac{\partial}{\partial z}\left(\frac{\mu_t}{\sigma_{\varepsilon,t}}\frac{\partial \varepsilon}{\partial z}\right)+\frac{1}{r}\frac{\partial}{\partial r}\left(\frac{\mu_t}{\sigma_{\varepsilon,t}}r\frac{\partial \varepsilon}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial \theta}\left(\frac{\mu_t}{\sigma_{\varepsilon,t}}\frac{\partial \varepsilon}{\partial r}\right)+C_1\frac{\varepsilon}{k}\mu_t\,G-C_2\frac{\varepsilon^2}{k} \quad (15)$$

Where (G) is referred to the generation term and is given by [45]and[46].

$$G=2\left[\left(\frac{\partial\overline{u}}{\partial z}\right)^2+\left(\frac{\partial\overline{v}}{\partial r}\right)^2+\left(\frac{v}{r}\right)^2+\left(\left(\frac{1}{r}\frac{\partial w}{\partial \theta}\right)^2\right)\right]+\left[\left(\frac{\partial\overline{u}}{\partial r}\right)+\left(\frac{\partial\overline{v}}{\partial z}\right)+\left(\frac{\partial\overline{w}}{\partial \theta}\right)\right]^2+\left(\left(\frac{\partial u}{\partial z}\right)^2+\left(\frac{1}{r}\frac{\partial\overline{v}}{\partial \theta}\right)^2+\left(\frac{\partial\overline{w}}{\partial r}-\frac{\overline{w}}{r}\right)^2 \quad (16)$$

$$\mu_t = C_o\,\rho k^{0.5} l \quad (17)$$

Where: Co is a constant ,when assuming high Reynolds number, the value to be proportional to ($k^{3/2}/l$) ,so the previous equation becomes , μ_t is a hypothetical property of the flow and must be modelled, and it varies with position, so the pervious equation become[15].

$$\mu_t = C_\mu\,\rho\,\frac{K^2}{\varepsilon} \quad (18)$$

Where C_μ : is a constant.
Some adjustable constants are included in equations also consist of. By numerous iterations of data fitting for a wide range of turbulent flows, the values of these constants have been arrived .The values of coefficients illustrated in table – IV:

Table IV:- Turbulent Model constants.

C_1	C_2	C_μ	$\sigma_{k,t}$	$\sigma_{\varepsilon,t}$	σ_c	k	ε
1.44	1.92	0.09	1	1.3	0.7	0.4	0.9

Numerical Computation:-
The present study deals with combustion process, therefore, there is heat transfer between the burnt gas and furnace walls, while the gas have been experiencing few transitions during entry from nozzles until the furnace region. Numerical analysis is perform by using commercial software ANSYIS FLUENT 15.The set of governing equations represent in present study are set of convection equations .The analysis as physical or engineering problems based on the finite volume method that FLUENT code based on this technique.

Finite volume method (FVM):-
It is a method for representing and evaluating partial differential equations in the form of algebraic equations values at discrete places on a meshed geometry are calculated. "Finite volume" refers to the small volume surrounding each node point on a mesh, the volume integrals in a partial differential equation that contain a divergence term are converted to surface integrals, using the divergence theorem, then such terms are evaluated as fluxes at the surfaces of each finite volume. These methods are conservative where the flux entering a given volume is identical to that leaving the adjacent volume, it is easily method to formulate that allows for unstructured meshes, and many computational fluid dynamics packages used this method.

SIMPLE Algorithm:-
In computational fluid dynamics, SIMPLE algorithm is a widely used numerical procedure to solve the Navier - Stokes equations. SIMPLE is an acronym for Semi-Implicit Method for Pressure Linked Equations, uses to get relationship between velocity and pressure correction to impose mass conservation and obtain the pressure field .

It is also important to confirm whether or not the CFD code FLUENT is able to simulate data such heat transfer, fluid flow through furnace region. Combustion regime choose in this process is non-premixed where gas and air entered the reaction zones separately [16].

Design Modeler **(DM):-**

ANSYS version 15 was used to for drawing all parts of domain with high accuracy using the data documents given by manufacture company in manual [2] to draw such design as represented in (Fig. 6).

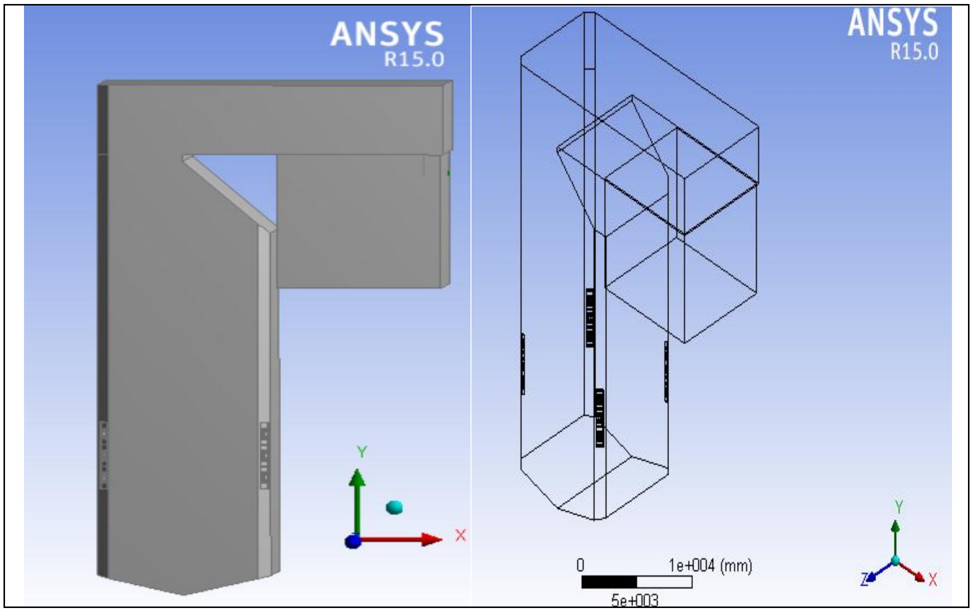

Figure 6:- Design model

The Mesh:-

The discrete representation of the geometry that is involved in the problem,in computational solutions of partial differential equations, can be defining as meshing . Essentially, it partitions space into elements (or cells or zones) over which the equations can be approximating. To create computationally best shaped zones, the zone boundaries can be free, or for represent internal or external boundaries within a model they can be fixed.

Polygonal or polyhedral mesh it is the practice of generating that approximates a geometric domain. Grid generation is the term often used interchangeably ,typical use for computational fluid dynamics as physical simulation . Created three-dimensional meshes for finite element analysis need to consist of tetrahedra, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedra with flat polygonal faces, straight edges and sharp corners or vertices.

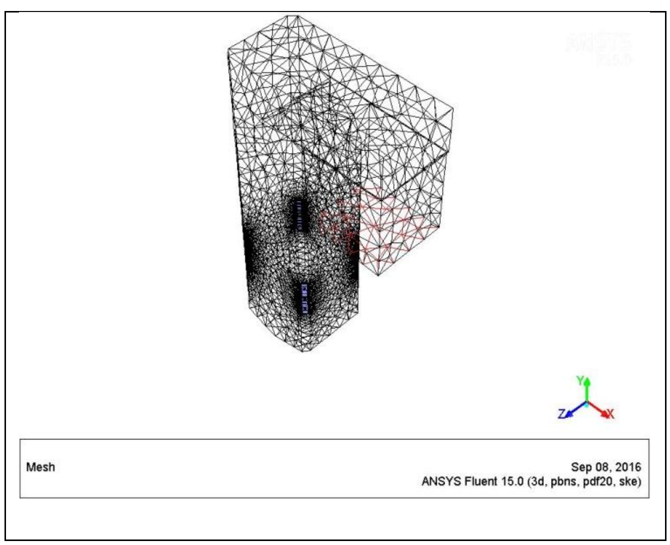

Figure 7:- Mesh for specifird geometry

Solution Set up:-
k- epsilon model **(K-ε)** and radiation model p1 and non-premixed species model have been chosen.

Results and Discussion:-
Temperature Distribution:-
The furnace temperature distribution in the y- cutting plane is shown clearly in (Fig.8). For the natural gas combustion, a uniform temperature scale is applied to assure the analysis is achieved consistently. Temperature distribution in this region of high and low temperature becomes non-uniform due to the combustion process which is resulted from mixing of fuel and air in the wind box.

The presence of tangential fired system generates a swirling fire ball at the centre of the combustion zone which is shown in (Fig.8) and (Fig.9), the swirling flow is stronger in the upper level at 9.282 m, approximately, from ground level with respect to the entire height 22.5m of the furnace. The maximum temperature of 2060 K, 2180K is found to exist at the central part for (static temperature and total temperature) of the furnace. The flow and its effect on the temperature distribution, shows how the flame looks like fire ball in the centre of furnace, which enhance the heat distribution uniformly in the furnace walls.

The temperature of pre-heated air entering the tangential burners is found to be at 555K ,while the flue gases leave the boiler furnace with an average temperature of 1631K. The temperature variation along the elevation inside combustion zone and the peak temperature is noticed at approximately in centre fire of fire ball.

The variation of temperature along the elevation inside the combustion zone , it is found that gas temperature increase steadily with elevation and a peak temperature notice approximately at 9.282m where the burners level 3 restricted up to this elevation and the temperature is found to drop gradually therefore the furnace outlet gas temperature is 1631K, and air preheater outlet gas 628K as shown in(Fig. 11).This can concluded as the flue gas move up word ,the temperature of gas decreases due to the heat transfer to the surrounding water walls.

J. Himachandra and L. Prasad [17], made the CFD analysis on 210 MW, type of boiler tangential fire pulverize tower utilized coal fuel for combustion. At different positions temperature are estimated. In their results the tangential fired system generates a swirling fire ball at the centre of the combustion zone which is shown in Fig10. The swirling flow is stronger at the lower level approximately13 m from ground level as compared at 30m from the ground level .The maximum temperature of 1850 K is found to exist at the central part of the furnace.

Their study showed there is variation of temperature inside the combustion zone, there is an increasing occurred steadily with elevation and notice that the peak temperature approximately at 25 where the burners are restricted up to 25 m inside furnace ,therefore with induced turbulence strong swirl motion is observed up to 25m,as shown in (Fig. 12).

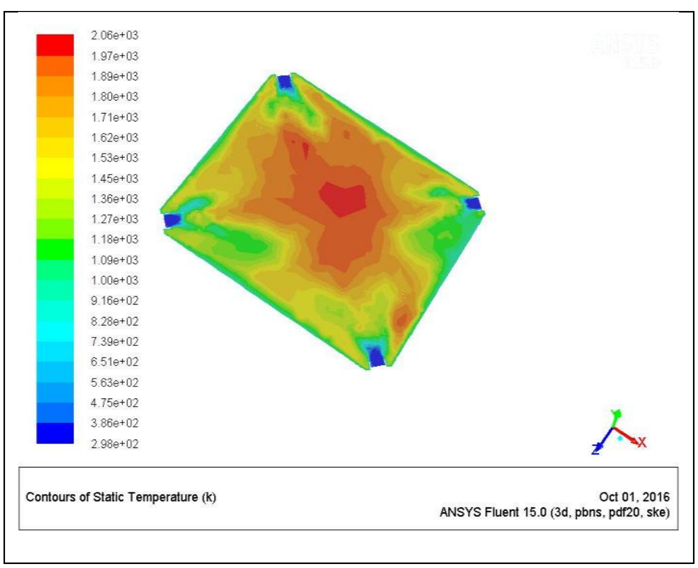

Figure 8:- Contours of Static Temperature (K)

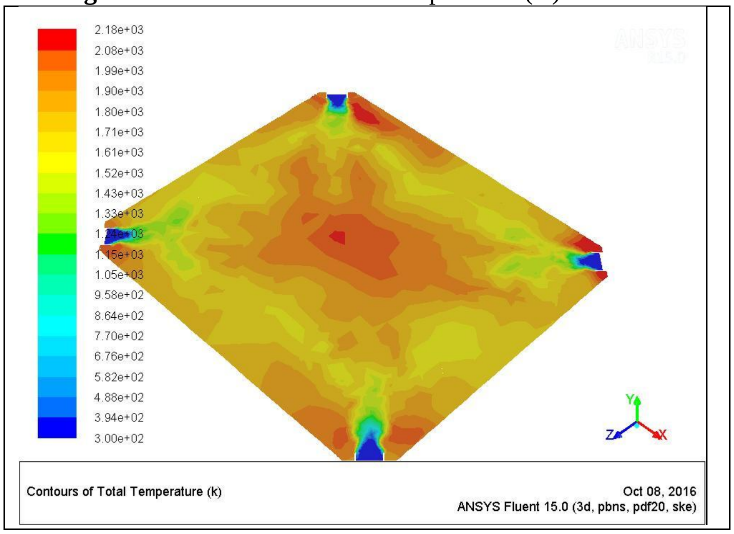

Figure 9:- Figure :- 8 Contours of Total Temperature(K)

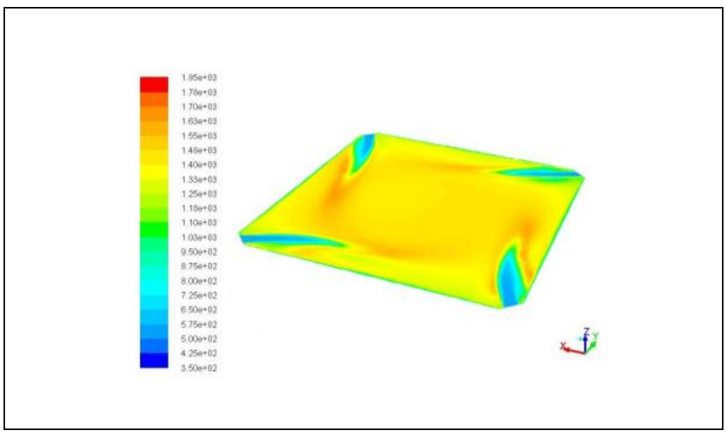

Figure 10:- Contour of Static Temperature(K).

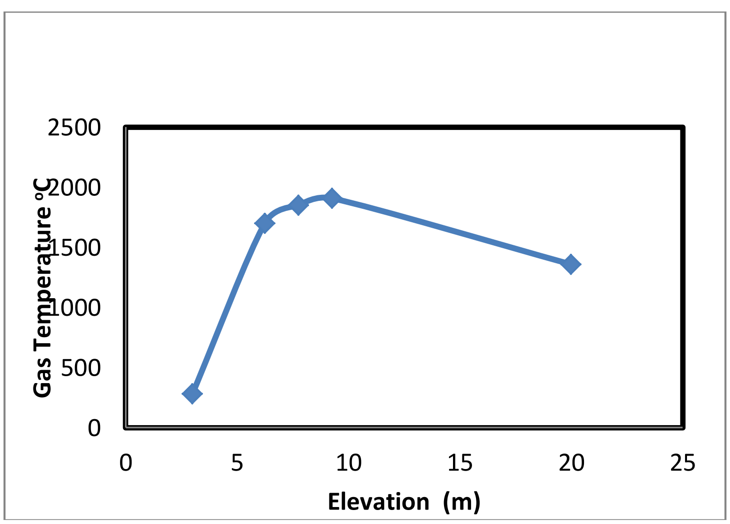

Figure 11:- The average temperature along the elevation

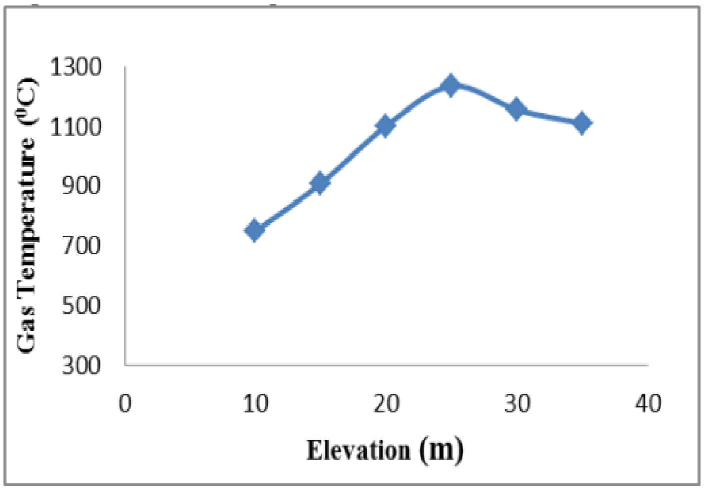

Figure 12:- The average temperature along the elevation

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