Available online at www.scholarsresearchlibrary.com

Scholars Research Library

European Journal of Applied Engineering and Scientific Research, 2012, 1 (4):122-133
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041

Radiation effect on flow of a radiating gas in a vertical channel

[1]E.O. Ogbaji, [2]M.O. Ibrahim

[1]Department of Mathematics/Statistics/Computer Science, Kwararafa University, Wukari-Nigeria
[2]Department of Mathematics,Usmanu Danfodiyo University, Sokoto-Nigeria

---

ABSTRACT

Fluid motion caused by a convective flow of a radiating gas was studied. Numerical solution for temperature, velocity and flow rate were obtained and graphs are presented for temperature, velocity and flow rate of gas. The results obtained showed that an increase in radiation parameter shows an increase in velocity, the temperature decreases as radiation parameter increases and lastly the flow rate increases as the radiation parameter increases.

Key words: Radiation, Temperature distribution, Velocity, and flow rate

---

NOMENCLATURE

U	Velocity of Gas
V	Axial velocity
T_W	Wall temperature
g	Acceleration due to gravity
qR	Radiative flux
y	Co-ordinate axis normal to the channel
x	Co-ordinate axis horizontal to the channel
T	Temperature of the fluid near the channel
α	Thermal diffusivity
σ	Stefan –Bolzman constant
μ	Permeability
u	Axial velocity on x-direction
P	pressure in a gas
ρ	Mass density of a gas
β	Volumetric coefficient of thermal expression
c_p	Specific heat capacity
γ	Optical depth
Q	Temperature distribution of a gas
K	Thermal conductivity of a gas
τ	Shear stress
R	Radiant energy
b	width of the channel
r	Radius of the vertical channel

INTRODUCTION

Radiation is the process by which energy can be transferred from one body to another through electromagnetic waves in absent of intervening medium. If intervening medium is present, it must be at least partially transparent in order for radiant energy transfer to take place. There are several kinds of radiation namely, Eletromagnetic, Visible light, Ultraviolet (UV), Radio waves, Microwaves, X-ray, Gamma ray, Alpha and Beta Radiation[1].

In everyday life, we recognize three states of matter; solids, liquid and gases. Although liquid and gases have a common characteristic in which they differ from solids; they are fluids lacking the ability of solid to offer permanent resistance to a deforming force fluids flow under the action of such forces, deforming continuously as long as the force is applied. A fluid is unable to retain any unsupported shape; if flows under its own weight and takes the shape of any solid body with which it comes into contact. Fluids are distorted by action of shear stress.

The interaction of radiation with mass transfer past an accelerated isothermal vertical plate with uniform mass diffusion in the presence of magnetic field and heat source has been studied. The effects of thermo physical parameters on velocity, temperature and concentration are analyzed and the following

Observations were noticed. An increase in the radiation parameter results in decreasing velocity and temperature within the boundary layer. Increasing

Magnetic parameter decreases the velocity. The presence of heat source raises the temperature[2].

The unsteady free convection flow with radiative heat transfer of a viscous incompressible fluid past an impulsively started infinite vertical plate with Newtonian heating was investigated. It is found that the fluid velocity decreases near the plate and it increases away from the plate with an increase radiation parameter. The fluid velocity increases with an increase in time□. It is also found that the fluid temperature decreases with an increase in radiation parameter. Further, it is found that the shear stress □□at the plate (□□= 0) due to the flow decreases with an increase in radiation parameter. The rate of heat transfer decreases with an increase in radiation parameter while it increases with an increase in time [3].

An exact analysis is performed to study thermal radiation effects on flow past an impulsively started infinite isothermal vertical plate in the presence of a chemical reaction of first order. The dimensionless governing equations are solved by the usual Laplace -transform technique. The effect of different parameters such as the radiation parameter, thermal Grashof number, mass Grashof number Schmidt number, chemical reaction parameter and time are studied. It is observed that the velocity increases with decreasing the chemical reaction parameter or radiation parameter. The velocity increases with increasing the thermal Grashof number or mass Grash of number[4].The flow of an unsteady MHD free-convection past an infinite vertical plate with time-dependent suction under the simultaneous effects of viscous dissipation and radiation is affected by the material parameters was study. In addition, an increase temperature profile is a function of an increase in viscous dissipation. Whereas an increase in radiation and magnetic field parameters led to a decrease in the temperature profile on cooling. Equally, cooling of the plate by convection currents with increases in the radiation, magnetic field and Darcy parameters led to a decrease in the velocity profile. Finally, increased cooling of the plate and viscous dissipation resulted in an increase in the velocity profile[5].

Radiation absorption increases the flame speed and extends the flammability limit. This enhancement effect also increases with pressure. The spectral dependent radiation absorption needs to be included in any quantitative predictions of flame speed and flammability limit with CO2 addition. The present radiation model can well reproduce the theoretical radiation flux at hollow sphere boundaries and the measured flame speed. The radiation absorption effect increases with flame size and pressure. The theory based on gray gas model over-predicts the radiation absorption by two-orders. The effective Boltzmann number is extracted from the present radiation modeling and can be applied to flame let modeling in turbulent flow. Effects of radiation absorption on flame speed at different pressure and equivalence ratios[6].

When a fluid is at rest, there can be no shearing forces acting and therefore all forces in the fluid must be perpendicular to the planes upon which they act. Although there can be no shear stress in a fluid at rest, shear stresses are developed when the fluid is in motion, if the particles of the fluid move relatives to each other, so they have different velocities, causing the original shape of the fluid to become distorted. If, on the other hand, the velocity of the fluid is the same at every point, no sheer stresses will be produced, since the fluid particles are at rest relative to each other. Usually, we are concerned with flow past a solid boundary adheres to it and will, therefore, have the same velocity as the boundary [7].

When a force on a fluid, the fluid continues to flow for as long as the force is applied and will not recovered its original form when the force is removed.

Fluids are in two states of matters; that is liquid and gas. Gas is one accept of fluid which will be the main focus in this work.

A gas is comparatively easy to compressed, changes of volumes with pressure are large and cannot normally be neglected and are related to changes in temperature. A given mass of gas has no fixed volume and will expand in a containing vessel. It will completely fill any vessel in which it is place and therefore, does not form a free surface [7].

Gas had known fixed volume but occupy the volume of its container. Gas had low density and viscosity; value of a gas will change with change in temperature or pressure. A gas had a characteristic that it will diffuse readily, spreading uniformly to fill the space of any container. There are various kinds of gases, namely ideal gas, liquidified petroleum gas, syngas, trace gas, toxic gas, noble gas[2].

There are some gas which are not stated in above such gases are nitrogen, oxygen, carbon (IV) oxide, carbon (ii) oxide and hydrocarbon gases.

The transport of energy by radiation can occur between surfaces that are separated by vacuum [8].

2.0 FORMULATION OF THE PROBLEM AND ITS SOLUTIONS

In this study, velocity, temperature distribution and flow rate model of gas are formulated. These models had been solved by using Newton's fourth order scheme .It is also expected that the same result will be obtained if finite difference, trapezoidal rule and computer programme are applied in the models. We analyzed the models in relation to radiation effect on a radiating gas in a vertical channel.

2.1 MATHEMATICAL FORMULATION

Radiative Flux

$$\frac{\partial qR}{\partial y} = -\frac{16}{3\alpha}\sigma T^3 \frac{dT}{dy} \qquad (2.1.)$$

Momentum Equations

X-component equation

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial x^2}\right) \qquad (2.2)$$

Y-component equation

$$u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) \qquad (2.3)$$

Energy equation

$$u\frac{\partial T}{\partial x}=\alpha\frac{\partial^2 T}{\partial y^2}-\frac{1}{\rho c_p}\frac{\partial qR}{\partial y} \qquad (2.4)$$

Continuity Equation

$$\rho\frac{\partial u}{\partial x}+\rho\frac{\partial v}{\partial y}+\frac{\partial \rho}{\partial t}=0 \qquad (2.5)$$

$\Rightarrow$

$$\frac{\partial u}{\partial x}=0,\ \frac{\partial v}{\partial y}=0,\ \frac{\partial \rho}{\partial t}=0 \qquad (2.6)$$

Wall Temperature

$$T_w=T_0+\left(\frac{\tau}{b}\right)x \qquad (2.7)$$

Temperature gradient

$$\frac{\partial T}{\partial y}=\frac{\tau}{b} \qquad (2.8) \qquad \frac{\Delta p}{\Delta T}=-\beta\rho$$

$$\Delta P=-\beta\rho\Delta T$$

As $\Delta P \to P, \Delta T \to T, \Delta T = T_w - T$ (2.9)

Body force

-Pg= $\beta\rho(T_w-T)g$ or -Pg= $\beta\rho$ Tg (2.10)

2.2 ASSUMPTIONS

In order to treat the problem already state above properly, we assume the following,

(i)The velocity field is fully developed on y-axis, that is v=0.
(ii)The flow field and the temperature field are symmetrical about the central of the channel.
(iii)The temperature of the walls is the same and maintained at a constant temperature gradient.
(iv) The viscosity, the thermal conductivity and specific heat capacity are independent of temperature and the essential is included in the body force term.

VERTICAL PLATE

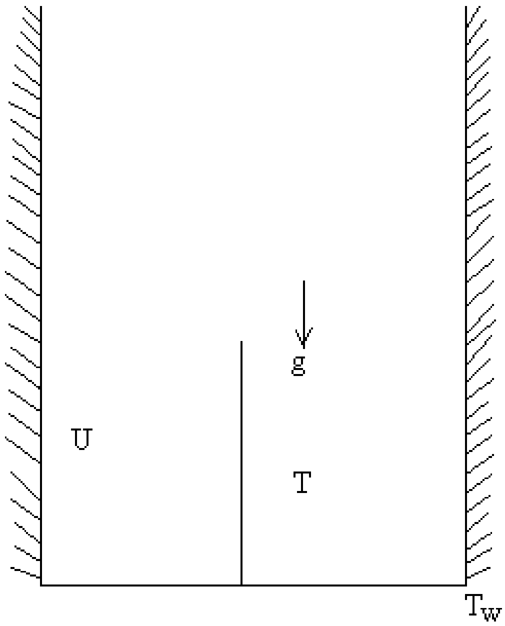

Fig2.1: Diagram showing the flow of a radiating gas in a vertical channel[9]

Where,
U=velocity of gas
g=acceleration due to gravity.
T=Temperature near the channel
T_W=Temperature of the wall.

2.3 Formulation of Model Equation

2.3.1 The velocity model

We formulated a model equation for velocity of gas, we used momentum equation (2.2) and (2.3), since momentum is define as mass*velocity. We shall test for pressure gradient in equations (2.2), to enable us to use appropriate equation, since pressure gradient is vital in discussion of fluid.

Since velocity field is fully developed on y-field direction, that is v=0 and v$\neq$0 on x-field direction.

$$\frac{\partial p}{\partial y}=0, \frac{\partial p}{\partial x} \neq 0 \text{ , respectively.} \quad (2.12)$$

Since

$\frac{\partial p}{\partial x} \neq 0$, in equation (2.2), we shall use this condition to obtain a model equation for velocity of a gas. We will introduce an appropriate body force term into equation (2.2), in negative direction. That is –pg.It represent the body force exerted on a gas in negative x-direction.

By substituting (2.10) in equation (2.2), we have

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}\right)=\rho g\beta-\left(\frac{\partial p}{\partial x}\right)+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)\rho \quad (2.13)$$

Divide through by ρ to obtain

$$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=\beta gT+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\left(\frac{1}{\rho}\frac{\partial p}{\partial x}\right)$$

Recall from (2.1.4b)

$$\frac{\partial u}{\partial x}=0$$

Since at the wall v=o,

$$v\frac{\partial u}{\partial y}=0,\quad \frac{\partial^2 u}{\partial x^2}=0$$

Then, we have

$$\beta gT+\mu\frac{\partial^2 u}{\partial y^2}-\left(\frac{1}{\rho}\frac{\partial p}{\partial x}\right)=0 \qquad (2.14)$$

Let

y=by, u= $\alpha\frac{U}{b}, T=-\tau Q, \frac{\partial}{\partial y}=\frac{d}{dy}, \frac{\partial}{\partial x}=\frac{d}{dx}, \frac{\partial^2}{\partial x^2}=\frac{d^2}{dx^2}, \frac{\partial^2}{\partial y^2}=\frac{d^2}{dy^2}$ (2.15)

To transform equation(2.14), we will use transform (2.15)

$$\beta gT+\mu\frac{d^2 u}{dy^2}=\left(\frac{1}{\rho}\frac{dp}{dx}\right)$$

$$-\beta g\tau Q+\mu\frac{d^2\left(\frac{\alpha U}{b}\right)}{b^2dy^2}=\left(\frac{1}{\rho}\frac{dp}{dx}\right)$$

Multiplying through by $\frac{b^3}{\mu\alpha}$ to obtain,

$$\frac{d^2U}{dy^2}-\beta g\tau Q\,\frac{\mathrm{b}^3}{\alpha\mu}=\left(\frac{1}{\rho}\frac{dp}{dx}\right)\frac{b^3}{\mu\alpha}$$

Take

R= $\beta g\tau\frac{\mathrm{b}^3}{\alpha\mu}$ and $\gamma=-\left(\frac{1}{\rho}\frac{dp}{dx}\right)\frac{b^3}{\mu\alpha}$

$$\frac{d^2U}{dy^2}=RQ-\gamma \qquad (2.16)$$

2.3.2 The temperature distribution model

Base on definition of temperature, that, it is the degree of hotness or coldness of a body. It is the property of a body, which determines the direction in which heat will flow when in contact with another body. Heat is a form of energy, which flows as a result of temperature differences. Then we used energy equation to formulate temperature distribution of gas.

$$u\frac{\partial T}{\partial x} = \alpha\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho c_p}\frac{\partial qR}{\partial y} \tag{2.17}$$

Substitute equation 2.1 and 2.8 in equation 3.6

$$u\frac{\tau}{b} = \alpha\frac{\partial^2 T}{\partial y^2} - \frac{1}{\varphi_p}\left(-\frac{16}{3\alpha}\sigma T^3\frac{dT}{dy}\right) \quad , u\tau = \alpha b\frac{\partial^2 T}{\partial y^2} + \frac{1}{\rho c_p}\left(\frac{16}{3\alpha}\sigma T^3\frac{dT}{dy}\right)b \tag{2.18}$$

Take

K= $\frac{1}{\rho c_p}\left(\frac{16}{3\alpha}\sigma\right)b$,

$$u\tau = \alpha b\frac{\partial^2 T}{\partial y^2} + KT^3\frac{dT}{dy}$$

Divide through by b α to obtain

$$\frac{u\tau}{b\alpha} = \frac{\partial^2 T}{\partial y^2} + LT^3\frac{dT}{dy} \tag{2.19}$$

Since

L= $\frac{K}{\alpha b}$

By using transformation 2.16 in equation 2.19, we will have

$$\frac{\alpha\frac{U\tau}{b}}{b\alpha} = \frac{\partial^2(-\tau Q)}{\partial(by)^2} + L(-\tau Q)^3\frac{d(-\tau Q)}{d(by)} \tag{2.20}$$

Further simplification of 3.9 gives

$$\frac{U\tau}{b^2} = -\frac{\partial^2(\tau Q)}{b^2\partial y^2} + LQ^3\tau^4\frac{dQ}{bdy} \tag{2.21}$$

Multiplying each term in 2.21 by $\frac{b^2}{\tau}$

$$U = -\frac{\partial^2 Q}{\partial y^2} + bLQ^3\tau^3\frac{dQ}{dy}$$

Take

R=bL τ^3

$$U = -\frac{d^2 Q}{dy^2} + RQ^3\frac{dQ}{dy}$$

$$\frac{d^2 Q}{dy^2} = RQ^3\frac{dQ}{dy} - U \tag{2.22}$$

2.3.3 The flow rate model

$$F=\frac{2}{r}\int_0^1 U dy \qquad (2.23)$$

3.0 . MATHEMATICAL ANALYSIS

Numerical methods is used to solve equation (2.16,2.22.2.23) to find temperature distribution, velocity and flow rate of gas. The numerical methods used are trapezoidal and finite difference method. Computer programmed is written.

3.1 Finite Difference Method

$$\frac{dQ}{dy}=\frac{Q_{i+1}-Q_{i-1}}{2h} \qquad (3.1)$$

$$\frac{dU}{dy}=\frac{U_{i+1}-U_{i-1}}{2h} \qquad (3.2)$$

$$\frac{d^2U}{d\ y^2}=\frac{U_{i+1}-2U_i+U_{i-1}}{h^2} \qquad (3.3)$$

$$\frac{d^2Q}{d\ y^2}=\frac{Q_{i+1}-2Q_i+Q_{i-1}}{h^2} \qquad (3.4)$$

The finite difference method is used to solve to equation (2.22) and (2.16) simultaneously. Since equation (2.16) and (2.22) are system of two second order ordinary non-linear differential equation then we have two sets of initial condition one on U and Q and the other on the derivatives. That is, $U_0=0, Q_0=0, Q_1=0, U_1=0,$ h=0.1

To find value for Q

We rearranged and substituted equation (3.1) and (3.4) in equation (2.22), we have

$$RQ^3\frac{dQ}{dg}-\frac{d^2Q}{dy_2}=\text{U}$$

$$Q_{i+1}=\frac{hU_i-2Q_i+Q_{i-1}\left(\frac{h}{2}RQ_{i-1}^3-1\right)}{\frac{h}{2}RQ_{i-1}^3-1} \qquad (3.5)$$

To find U

Substitute equation (3.3) in equation (2.16)

$$U_{i+1}=(RQ_i-\gamma)h^2+2U_i-U_{i-1} \qquad (3.6)$$

To find F

$$F=\frac{2}{nr}(U_1+U_2+\ldots+U_{n-1}) \qquad (3.7)$$

$$F=\frac{2}{nr}\sum_i^{n-1}U_i \qquad (3.8)$$

Computer program was written using Pascal programming language to solve the numerical equation for temperature distribution, velocity and flow rate model of gas .The result are also presented in a tabular form and graphically.

RESULTS AND DISCUSSION

The numerical results obtained from the computer program are presented in table 1.The corresponding graph obtained from these tables are presented in figure 1-3 below.

Table 1: Numerical values showing the pattern of effect of radiant energy (R=1 to 30) on temperature distribution, velocity, flow rate of gas at optical depth= -1, r= 0.3m, h= 0.1

RADIANT ENERGY (KJ)	TEMPERATURE DISTRIBUTION (KELVIN)	VELOCITY (M/S)	FLOW RATE (CUBIC METRE/SECOND
1	0.0000000	0.0000000	0.00000
2	0.0000000	0.0100000	0.06667
3	-0.0001000	0.0300000	0.20000
4	-0.0005000	0.0599970	0.39998
5	-0.0015000	0.0999740	0.66649
6	-0.0034997	0.1498760	0.99917
7	-0.0069981	0.2095680	1.39712
8	-0.0125923	0.2787702	1.85847
9	-0.0209741	0.3569649	2.37977
10	-0.0329255	0.4432720	2.95515
11	-0.0493092	0.5362866	3.57524
12	-0.0710531	0.6338771	4.22585
13	-0.0991252	0.7329413	4.88628
14	-0.1344864	0.8291191	5.52746
15	-0.1780046	0.9164689	6.10979
16	-0.2302822	0.9871180	6.58079
17	-0.2913239	1.0309220	6.87281
18	-0.3599498	1.0352009	6.90134
19	-0.4329819	0.9846888	6.56459
20	-0.5046987	0.8619101	5.74607
21	-0.5677139	0.6481917	4.32128
22	-0.6158553	0.3252534	2.16836
23	-0.6469026	-0.1231730	-0.82115
24	-0.6622686	-0.7103871	-4.73591
25	-0.6644235	-1.4465456	-9.64364
26	-0.6548375	-2.3388100	-15.59207
27	-0.6332450	-3.3913322	-22.60888
28	-0.5974216	-4.6048305	-30.69887
29	-0.5426070	-5.9756068	-39.83738
30	-0.4598941	-7.4937392	-49.95826

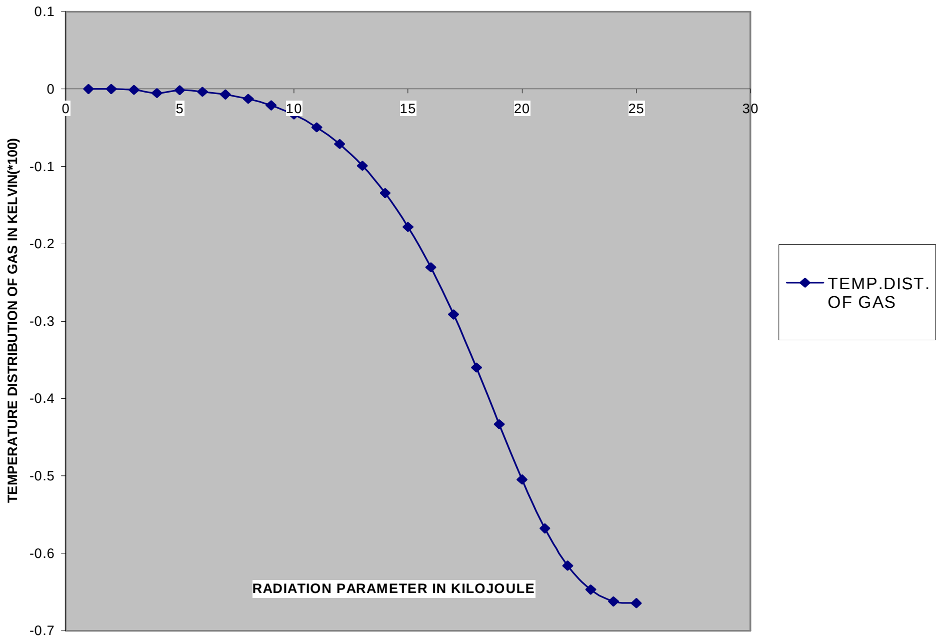

Fig.1 GRAPH SHOWINGTEMPERATURE DISTRIBUTION OF GAS AND RADIATION PARAMETER

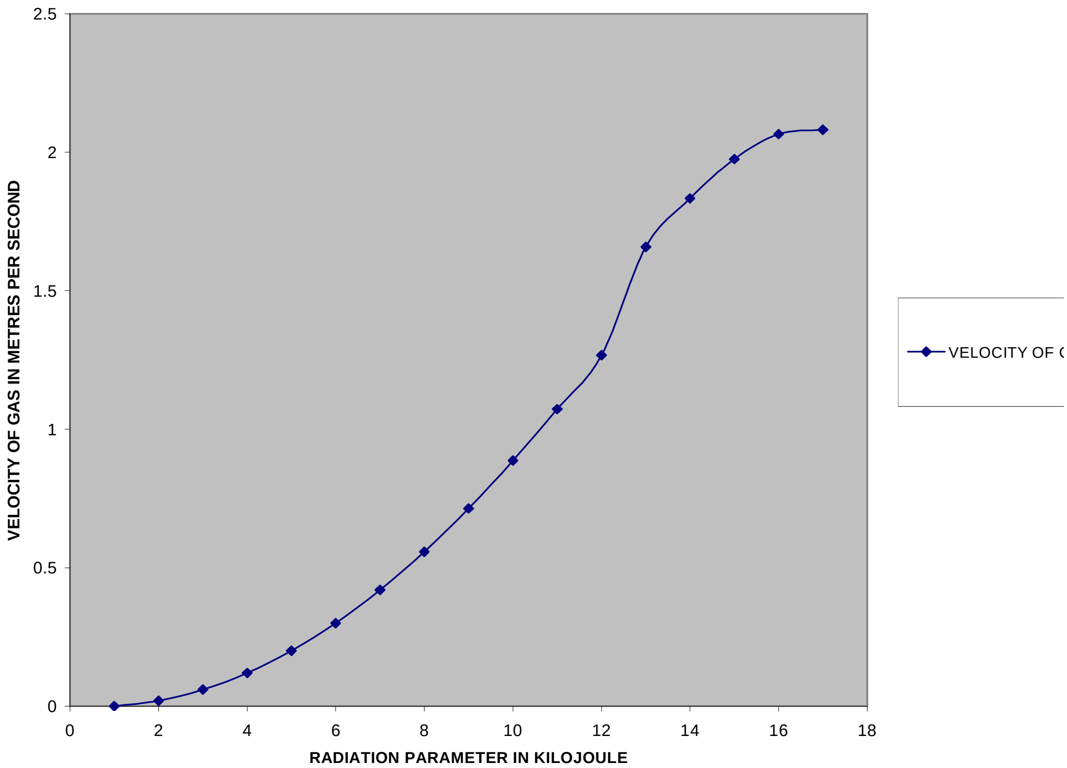

Fig.2 GRAPH SHOWING VELOCITY OF GAS AND RADIATION PARAMETER

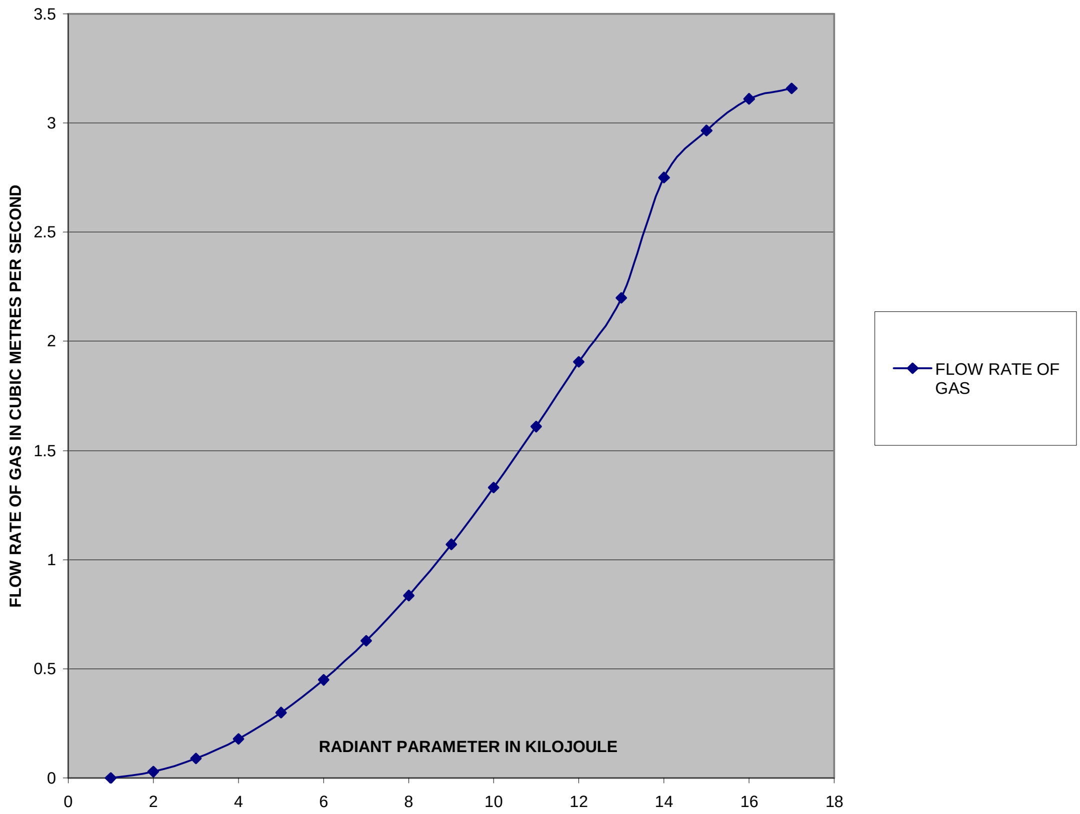

Fig.3 GRAPH SHOWING FLOW RATE OF GAS AND RADIANT PARAMETER

The temperature distribution of gas decrease as radiation parameter increase as in figure (1).The velocity of gas increase as radiation parameter increase as in figure (2).Here as seen from figure (3), flow rate of gas increase as radiation parameter increases.

CONCLUSION

We conclude that an increase in radiation parameter shows an increase in velocity, the temperature distribution decreases as radiation parameter increase and lastly the flow rate increases as the radiation parameter increases.

REFERENCES

[1] Bala Anki Reddy, P., Bhaskar Reddy, N. and Suneetha , S. ,(**2012**), *Journal of Applied Fluid Mechanics*, Vol. 5, No. 3, pp. 119-126
[2]Beatty, W.J. (**2007**) Recurring Science misconception in K-6 Textbook http://.www Wikipedia. Org/Wiki/gas.
[3]Das, C. S. Mandal, R. Jana, N.(**2012**), *International Journal of Computer Applications (0975 – 8887) Volume 41– No.13*
[4]Muthucumaraswamy, R.Chandrakala, P. and Antony Raj, S.(**2006**), *Int. J. of Applied Mechanics and Engineering*, **2006**, *vol.11, No.3, pp.639-646*
[5]Israel-Cookey, C., Ogulu, A., Omubo-Pepple, V.B.(**2003**), *International Journal of Heat and Mass Transfer* 46 (2305–2311)

[6]Zheng Chen , Xiao Qin , Bo Xu a, Yiguang Ju ,and Fengshan Liu, (**2007**) , Studies of radiation absorption on flame speed and flammability limit of CO2 diluted methane flames at elevated pressures Proceedings of the Combustion Institute 31 2693–2700
[7]Douglas, G.F (**1995**), Fluid Mechanics, Longman Singapore Publisher, Limited, Singapore, U.K.
[8]Luis B.Y.H and jorrdon R.C. (**1957**), Availability of solar Energy for flat plate. Solar Collections, in low Temperature. Engineering Application of solar energy. ASHRAE, New York.
[9]Ibrahim,M.O.(**2000**),Radiation effect on laminar convective flow of a gas in heated channel proceeding of nig.National mathematical centre,Abuja.vol.2 pp175-192.