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RESEARCH ARTICLE

ON THE NATURE OF THE FLAME EMISSION SPECTRUM OF CRUDE OIL BLAZE AT BAGHJAN

R. Konwar[1], R. Mahanta[2], J. Saikia[3], S. Konwar[4], M. Konwar[5] and G.D Baruah[6]

1. Department of Physics, Tinsukia College, Tinsukia-786125(India).
2. Department of Physics, Dibru College, Dibrugarh-786001(India).
3. Department of Physics, J B College, Jorhat- 785001(India).
4. Department of Petroleum Technology, Dibrugarh University,Dibrugarh-786004(India).
5. Principal, Moran College, Moran- 785670(India).
6. Centre for Laser & Optical Science, New Uchamati, DoomDooma- 786151.

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Abstract

A large of flame occurred at Baghjan (27.58309^0 N,95.4018^0 E) as a result of oil well blow out. The present work reports the spectra of the blaze which have been recorded with the help of a Mini USB Spectrometer with spectral range of 200 – 1200 nm. Assignments of the prominent emission and absorption peaks have been made. Apart from the absorption bands of water vapour and atmospheric oxygen the presence of sodium emission line has been identified. On the basis of the assumption that Baghjan flame qualifies as a black body the surface temperature of the flame has been estimated to be approximately 4140^0 K. Whispering gallery made in atmosphere has been proposed to explain the roaring sound that can be heard from a distance of 15 Km from the blaze.

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Introduction:-

Flames are sources of many band system of diatomic and polyatomic origin. Some bands are observed by the direct combustion of inflammable substances, others by the introduction of additional substances into a flame already established. Flame bands have been found to belong to molecules which are electrically neutral, but very frequently the molecules are not stable in a chemical sense thus combinations such as CH, NH, CN and OH are very common occurrence [1,2]. The general characteristics of the band systems obtained in this way arise from transitions between a few of the lowest levels of the molecules concerned. The energy of the upper levels involved nearly exceeds 5 eV while the lower level is in most cases the ground state. The 4300 Å and 3900 Å band of OH and Swan band of C_2 appear readily enough in the flames of hydrocarbons. Different systems occur most strongly in different parts of the flame. The OH bands are spread through the blue outer cone of a Bunsen flame using coal gas, but the Swan bands are restricted to the greenish inner core of the roaring flame which owes its colour mainly to the presence of these bands. The red and violet systems of CN are given by a flame of moist cyanogens. The 3360 Å band of NH is also obtained strongly from the oxy-ammonia flame, but the systems arising from more excited levels, which are known from other sources, do not appear as well.

From the descriptions as given above it would follow that flames are well known sources of many diatomic radicals. The aim of the present work is to describe the nature of the spectrum in the visible sector originating from a huge flame of fire that engulfed Well No 5 at Baghjan oil field (27.58309^0 N, 95.4018^0 E). Such gas and crude oil blow

Corresponding Author:- R. Konwar
Address**:-** Department of Physics, Tinsukia College, Tinsukia-786125(India).

out is believed to be rare event and its second of its kind in recent years in India, the earlier one took place in the year 2005 at Dikom (94.6^0 E , 27.3^0 N) [3] which is about 50 Km away from Baghjan. In the present work we will have occasion to make a comparative study of the spectra of the blazes which occurred at different places and at different times.

Experimental:

Origin of the blaze: On June 9, 2020 an oil well under Oil India Limited at Baghjan (27.58309^0 N, 95.4018^0 E) located close to the Maguri Beel (wet land) a huge flame of fire occurred as a result of sudden and accidental outburst. The blaze at the well is so massive that it can be seen from a distance of 30 Km with the flame with black smoke going up about 100 meters high endangering local biodiversities in the Dibru- Saikhowa National Park which is adjacent to Baghjan. The spectra of the blaze have been recorded with the help of a Mini USB Spectrometer with spectral range of 200 – 1200 nm. The nearest distance from the blaze to the spectrometer is about 120 meter. Light from the blaze is allowed to fall on the objective of a small telescope and is collected at the eyepiece. The opening end of the optical fiber is kept in close proximity of the eyepiece and the other end of the optical fiber is connected to the spectrometer. A lap-top where an appropriate software is installed to record the spectrum is connected to the spectrometer (Mini USB Spectrometer, Model: SP2 (V 2.1) (LISUN GROUP http:www.lisungroup.com). Fig: 1 shows the spectrum of the blaze recorded on the spectrometer. It is worthy of remark that the experiment is carried out at night and at 20 Hrs. to avoid any extra radiation from the sun which is present during day time. For consideration of comparison a solar spectrum has also been recorded on the same spectrometer. This is exhibited in Fig: 2.

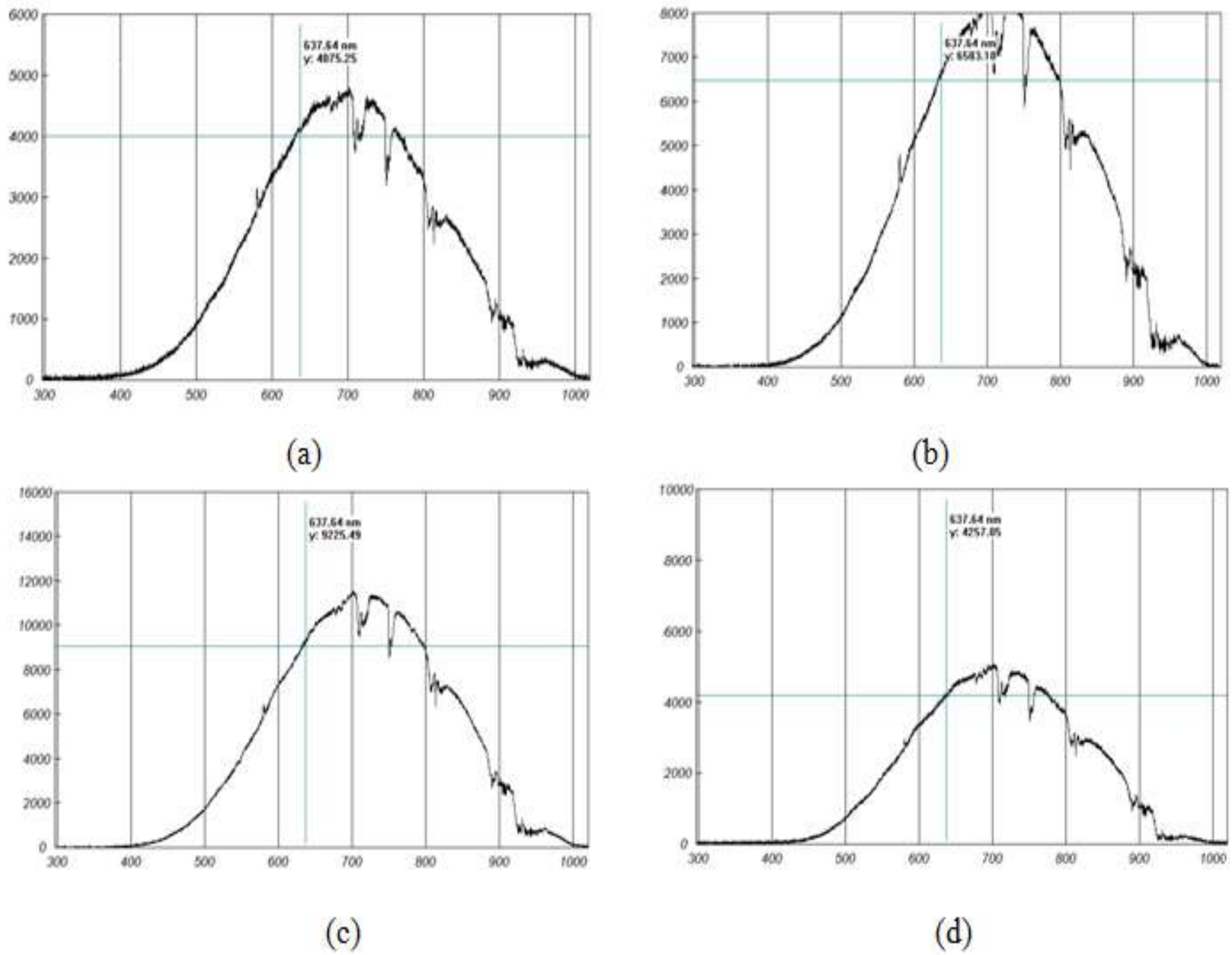

Fig: 1(a, b, c, d): Spectrum of the Baghjan blaze recorded on a Mini Spectrometer (Model SP2 V2.1) on June 16, 2020

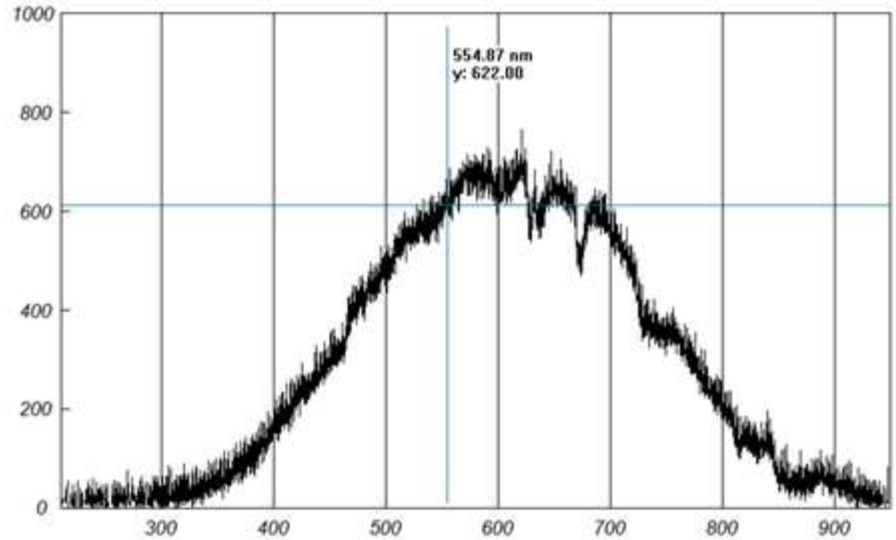

Fig. 2:- Spectrum of the sun recorded on the Mini spectrometer (Model SP2 V 2.1).

Results and Discussion:-

Let us first try to estimate the surface temperature of the flame from a consideration set forth above. From Fig 2 we have an estimate of the surface temperature of the sun as follows. The sun emits radiation over a wide range of wavelengths. We assume that sun is a black body. In this case the radiation is given by the Planck's equation

$$I(\lambda)\Delta\lambda = \frac{2\pi hc^2}{\lambda^5}\frac{1}{e^{hc/\lambda kT} - 1}\Delta\lambda$$

where $I(\lambda)\Delta\lambda$ is the emitted energy per unit area of black body per unit time within the range of wavelength $\Delta\lambda$, measured at absolute temperature T and k is Boltzmann's constant.

Graphs for several temperatures can be drawn. From these curves one can see that the peak wavelength is given by Wien's displacement law

$$\lambda_{\max} = \frac{2.898\times 10^{-3} mK}{T}$$

Taking 5778^0 K as the surface temperature of the sun the peak wavelength is about 501 nm. This is the blue green part of the visible spectrum, or the range of frequencies that our eyes can see. It is worthwhile to note that solar spectrum as shown in Fig:2 shows few well known Fraunhofer intense absorption lines at 6276 – 6278 Å known as α line due to atmospheric O_2, at 6867 – 6884 Å known as B line due to atmospheric O_2 and at 7594 – 7621 Å, the A line due to atmospheric Oxygen. As may be inferred Fig: 1 the spectrum of Baghjan flame shows the peak wavelength at 700 nm which is shifted towards red considerably as compared to the solar spectrum. However, on the basis of the assumption that the Baghjan flame qualifies as a black body the peak wavelength is given by the equation as given above and we have as a surface temperature of the flame

$$T = \frac{2.898\times 10^{-3} mK}{700} = 4140^0 K$$

There are additional characteristics which may be seen in the emission profile of the Baghjan flame. The emission line of sodium appears at 5893 Å. This is however, is weak as compared to the emission line of sodium which is the most intense line in the emission profile of Dikom fire [3, 4]. The presence of a very intense line of Na in the crude oil blaze at Dikom and also in the Baghjan blaze where the Na line appears rather weakly indicates some geophysical characteristics of the region far below the surface. In addition to the Na lines there are other spectral characteristics which may be observed in the spectrum of the Baghjan flame. The atmosphere around the blaze is surrounded by an envelope of hot gases which are product of the combustion processes. The emission from the from the blaze has to pass through this blanket of gases and vapours before it is recorded by the spectrometer. This results in absorption features in the spectral profile. It is possible to make assignment to the absorption bands and as well as to the emission peaks. It may be added that the CN red system of bands which was present in the spectrum of Dikom fire is not observed in the spectrum of Baghjan flame. Table: 1 has been prepared to exhibit the prominent lines and appearing in the Baghjan spectral profile.

Table 1:- Spectral profiles of Baghjan flame and assignment of the prominent emission and absorption peaks.

Wavelength (nm)	Intensity	Emission	Absorption	Assignment
589	w	emission	--	Sodium (Na) D line
676	ms	emission	--	N_2 1st positive
682	ms	emission	--	CO
688	ms	emission	--	O_2, atmosphere
694	ms	emission	--	H_2O
709	s	--	absorption	H_2O
718	s	--	absorption	H_2O
753	s	--	absorption	O_2, atmosphere
806	s	--	absorption	H_2O
815	s	--	absorption	H_2O
827	s	--	absorption	H_2O
899	ms	--	absorption	H_2O
900	ms	--	absorption	H_2O
938	ms	--	absorption	H_2O
950	ms	emission	--	H_2O

w = weak, ms = medium strong, s = strong

As may be inferred from Table:1, most of the spectral features have been identified as belonging to H_2O and atmospheric O_2 molecules. In assigning the bands we taken help from the classic books of Pearse and Gaydon [1, 2] and other references [5, 6, 7]. It is well recognized that atmospheric and infrared absorption (vibration – rotation spectrum) by H_2O molecules in vapour appears especially in solar spectrum. The bands are complex and shows fairly open rotational structure, but no obvious heads. Visible and infrared emission is a part of the vibration – rotation spectrum of H_2O. The infrared and red bands appear readily in flames but the visible bands are very weak and are given by a flame of oxygen burning in hydrogen. The system is complex and in the visible the maximum of intensity are due to bunching of lines of complex rotational structure and the heads are not very definite; to the longer wavelengths, however, some of the bands show sharp heads and are degraded to the longer wavelengths. It is worthy of remark that liquid water shows infrared absorption bands at about 7750Å and 9850 Å. All these characteristic features are present in the spectrum of Baghjan blaze. We may note here that the CN – red system which was present in Dikom flame [3,4] is conspicuous by its absence in Baghjan flame. We may appropriately conclude this section with a comment that Baghjan flame spectrum is quite analogous to the Fraunhofer spectrum or the solar spectrum with a difference that the peak wavelength in Baghjan spectrum is shifted to the red as compared to the solar spectrum. We have also considered the Baghjan flame as a black body.

Whispering gallery mode:

In this section we discuss the whispering gallery mode associated with the Baghjan blaze. This is for the first that whispering gallery mode has been linked with any flame. It is worthwhile to note that the roaring sound of Baghjan blaze can be clearly heard from a distance of fifteen kilometers from the source. It is also observed that this particular sound is not audible to an observer who is in close proximity of the blaze (say about 500 meters from the blaze). This is curious but the phenomenon may be explained if we take into account the whispering gallery mode to operate in the atmosphere. We note here that in a cloudy weather the sound of the Baghjan blaze is more prominent than in a clear weather. It naturally prompts us to identify that the atmosphere is the key factor.

Whispering gallery waves or whispering gallery modes are a type of waves that can travel around a concave surface. A whispering gattery is usually a circular, hemispherical, elliptical or ellipsoidical enclosure often beneath a dome or vault in which whispers can be heard clearly and loudly in other parts of the gallery. Such galleries can also be set up using two parabdolic dishes. Sometimes the phenomenon is also detected in caves. In fact there are numerous instances that exhibit such modes. Lord Rayleigh developed the wave theories for the whispering gallery in St.

Paul's Cathedral London in 1910 and 1914[8]. Fitting sound waves inside a cavity involves the physics of resonance based on wave interference. Sound can exist only at certain pitches as in the case of organ pipes. Whispering gallery waves are guided by the effect of the wave curvature. Raman and Sutherland [9] performed an extensive series of experiment and observed multiple bands. Rayleigh's theory predicted only one band, whereas Raman's experiment revealed the existence of many Rayleigh's theory obviously needed an extension which Raman did not attempt. The acoustics of Baghjan blaze gives us an opportunity to investigate it from the point of view of whispering gallery mode.

Conclusions:-

We now sum up the results which have emerged in this work and also draw appropriate conclusions. The huge blaze of Baghjan flame which occurred as a result of blow-out of a oil well at Baghjan in upper Assam has caused damage to the environment and loss of human life including loss of rig and equipments. We have recorded the spectra of the flame with the help of a mini spectrometer and with the help of the spectrum the surface temperature of the flame has been estimated to be 4140^0 K. Apart from the absorption bands of water vapour and atmospheric oxygen the presence of sodium emission indicates some geophysical characteristics of the region lying deep inside the surface. A comparison of Dikom blaze, a similar event that occurred at Dikom about fifteen year back, showed spectral characteristics which are different from those of Baghjan flame. But the emission line of Na is extremely strong in Dikom flame. An unexplained sound with occasional tremor associated with Baghjan oil well fire that can be heard even from a distance of fifteen kilometers can be linked with atmospheric whispering gallery mode. We may appropriately conclude this section with a remark that though nature has given us an opportunity to make scientific investigation of hazardous oil well blaze at Dikom and Baghjan, we should be equally concerned with the loss of human life and with the damage to the environment.

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