A. K. MUKHOPADHYAY
JITENDER KUMAR SAINI
and
UTKARSH SINGHAL

Generation of electricity from coal fire

Fire in coal mines is a global problem which started due to numerous reasons. Thousands of coalfield fires are burning globally in every continent except Antertica. Jharia coalfield in India is one such place where number of coal reserves are under fire. The fire is spreaded over a vast area. The first coal fire in Jharia coalfield was reported in 1916 and are still burning inspite of best efforts to extinguish them.

1.0 Introduction

Coal seam fire has huge energy potential. Throughout the coal fire area the temperature is not equally distributed. It usually varies from 217°C to 731°C. Globally thousands of inextinguishable mine fires are burning. The enormous amount of heat energy can be utilised by converting it into electricity.

2.0 Heat energy from coal fire

Heat energy released from coal fire from a large area can be measured by thermal infrared remote sensing data. In situ energy released varies linearly with the spectral radiance observed at the thermal satellite sensor. The heat energy released depends on the coal fire area and depth. Also, it may vary on daily basis depending on climate changes and changes in ventilation conditions through new cracks and vents.

Heat is radiated by conduction and convection processes. Fire at greater depth transmits heat by conduction process which is relatively slow heat transfer process. From fire at shallower depth heat transfer takes place by convection mechanism which is a faster process. Thus, fire at greater depth might lead to a weaker signal than shallower fire, even if the amount of coal burning inside is equal. Thus, there is every possibility that the remotely sensed heat energy release may not be the true energy release.

The intensity of the infrared radiation which is a form of electromagnetc radiation, emitted by objects is a function of temperature. Temperature above absolute zero (i.e 0ºK) emits infrared radiation. Infrared measuring devices acquire infrared radiation and transform it into electronic signal. For a larger area, a cluster of sensors are required to produce a detailed infrared image.

Messrs. A. K. Mukhopadhyay, Professor and Jitender Kumar Saini and Utkarsh Singhal, B Tech Final Year Students, Deptt. of Mining Machinery Engg., IIT (ISM), Dhanbad

The wavelength at which elctromagnetic radiation is emitted depends on the temperature of the object. The higher the temperature is, shorter is the wavelength. Peak wavelength for a specific temperature can be calculated by Wein's Law given in equation 1.

$$A_{peak} = 0.0029/T \quad \ldots \quad (1)$$

The relation between peak wavelength and temperature is graphically presented in Fig.1

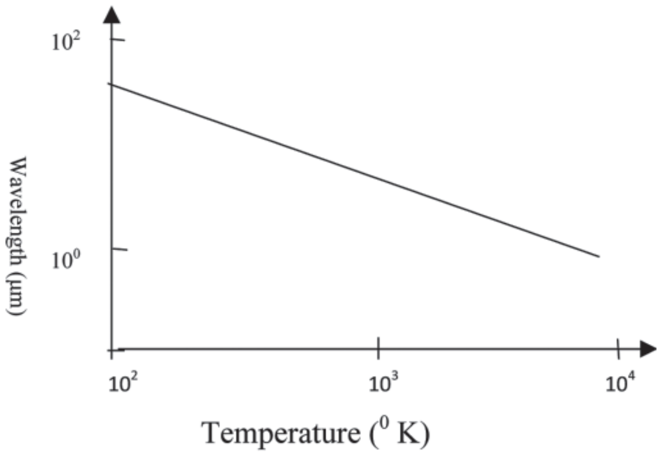

Fig.1 Relation between wavelength vs temperature

Total radiation over an area can be obtained from Stefen-Boltzman formula :

$$W_b = \sigma T^4 \quad \ldots \quad (2)$$

where W_b is the radiation from the body, σ is constant and T is the temperature .

3.0 Conversion of heat to electricity

Thermo-electric generator (TEG) is a solid state device that converts heat flux directly into electrical energy through Seebeck effect. The device can be used in order to convert heat into electric power. It is made of thermo-electric material which posses high electric conductivity and low thermal conductivity properties. Low thermal conductivity ensures that while one side of the TEG will remain hot the other side will stay cool. This temperature gradient will generate voltage.

The solid state device shown in Fig.2 consists of two dissimilar thermo-electric materials joined at their ends: an n-type (negatively charged) and a p-type (positively charged) semiconductor. When there is a temperature difference between the two materials, electric current will flow through the circuit. A thermo-electric circuit composed of materials of different Seebeck coefficient (p-doped and n-doped semiconductors), configured as a thermo-electric generator, is

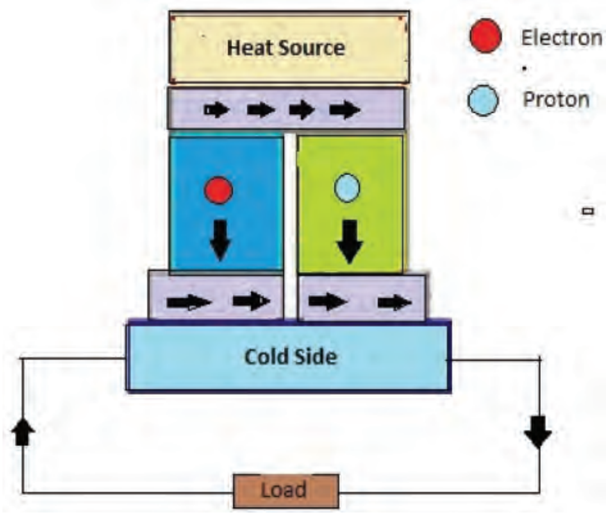

Fig.2 Seebeck effect

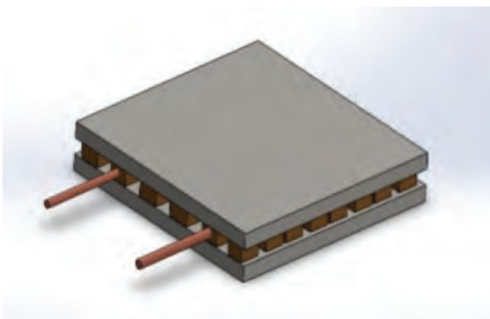

Fig.3 Thermo-electric generator (TEG)

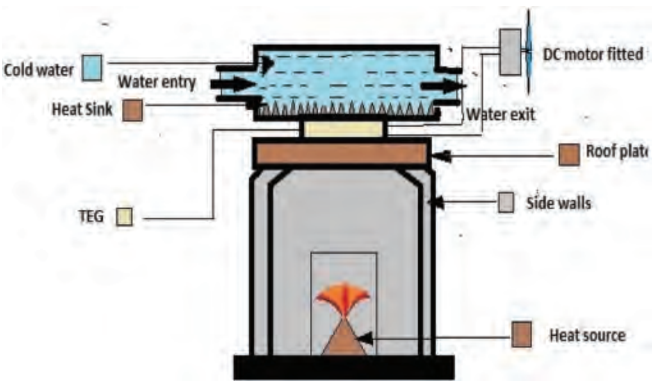

Fig.4 Experimental set up

shown in Fig.3. The selection of thermo-electric materials in the device will be based on the temperature range. For low temperature range, alloys bismuth (Bi) in combination with antimony (Sb) is used. For intermediate temperature range alloys are lead (Pb) and for high temperature range material fabricated from silicon germanium (SiGe) are used.

Solid state thermoelctric generators have no moving component, therefore, recovery of thermal energy is possible with high reliabilty and least maintenance.

4.0 The experimental set up

In the set up as shown in Fig.4, a steel chamber was fabricated. For maximum transfer of heat walls of the chamber were insulated with asbestos sheets. Heat source was placed inside the chamber. The cold side temperature is kept at 0^{o}C and the hot side temperature is kept upto 54^{o}C to keep the temperature gradient within the permissible limit of the TEG used in this study. One side of the TEG is fixed with ice cold water filled container and the other side on the top of the heating chamber. A fan connected with a dc motor (1.5V, 0.15A) was fitted to complete the circuit. The temperature gradient in TEG results in generation of voltage and current. The fan starts rotating as current starts flowing through the circuit.

5.0 Experimental result and discussion

As the temperature of hot side water increases, the generated voltage and the current simultaneously increases. At one stage the power becomes sufficient to drive the fan. Multimeter was used to measure current and voltage. Temperature was measured by a multimeter (Mastech MAS830L Digital Pocket Multimeter). And RPM of the fan by non-contact tachometer.

The experimental data are shown in Table 1. The data are used to draw the graph between generated voltage and temperature difference, generated power and temperature difference. Figs.5 and 6 are the graphical representation of the data from Table 1.

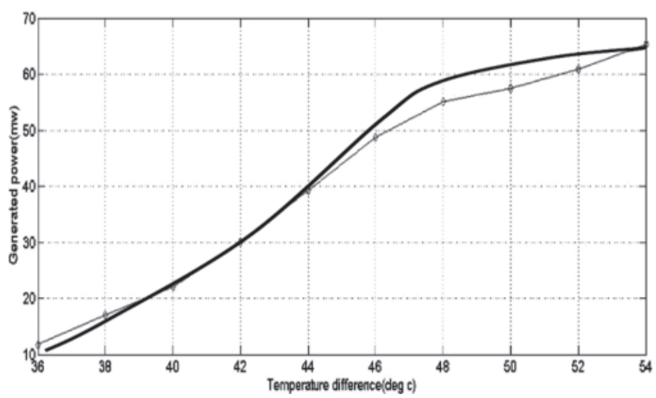

Fig.5 Power vs temperature difference

TABLE 1: EXPERIMENTAL DATA

	ΔT (°C)	Voltage (mV)	Current (mA)	Power (MW)	Contact area (mm^2)	Fan rpm
1	36	545	22.1	11.7	1600	570
2	38	696	25.3	17.1	1600	660
3	40	786	28.2	22.0	1600	760
4	42	907	33.5	30.0	1600	910
5	44	1063	37.7	39.2	1600	1001
6	46	1180	41.2	48.7	1600	1134
7	48	1224	42.3	55.1	1600	1145
8	50	1335	43.6	57.4	1600	1176
9	52	1373	44.5	60.9	1600	1200
10	54	1488	46.1	65.2	1600	1225

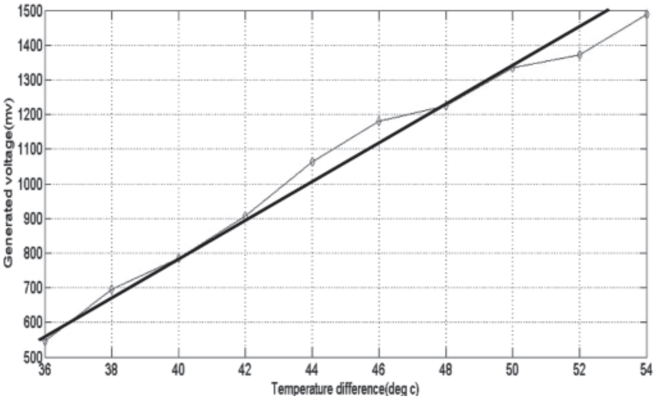

Fig.6 Voltage vs temperature difference

6.0 The proposed scheme

The coal fire is a source of heat but its availability remains uncertain for a prolonged time at a particular area. The TEG needs to be shifted throughout the area where coal fire is existing. The entire fire zone is proposed to be covered by a stationary steel or concrete structure. On the top of the structure, aspiration holes would be made so that air is available for buring of coal. On the top of the structure, horizontal grids are to be fitted to enable the TEG to slide over

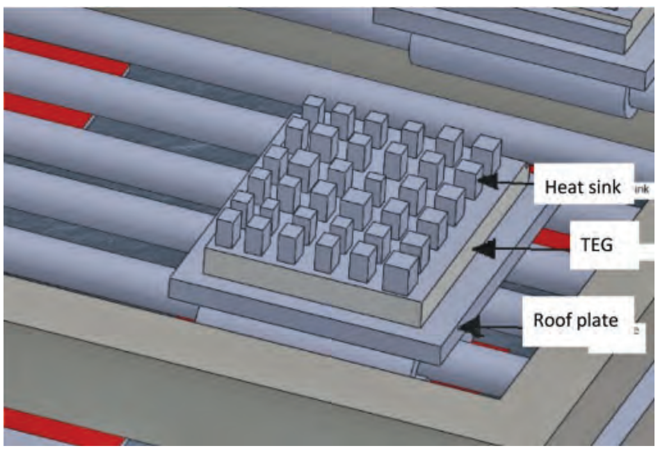

Fig.7 Arrangement of TEG over coal fire

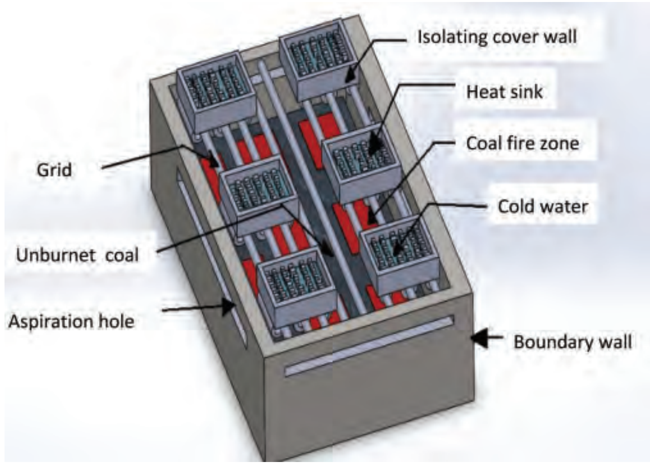

Fig.8 Power generating unit over a coal fire zone

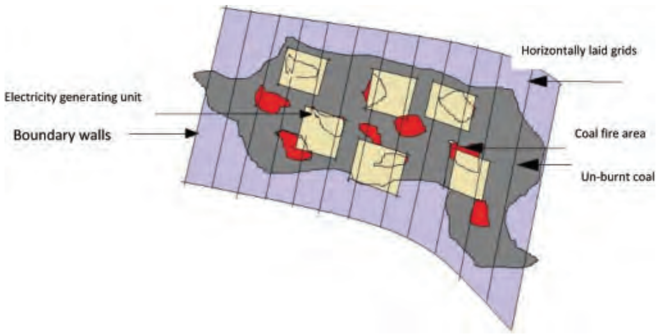

Fig.9 View showing boundary of coal fire zonegrids and TEG units

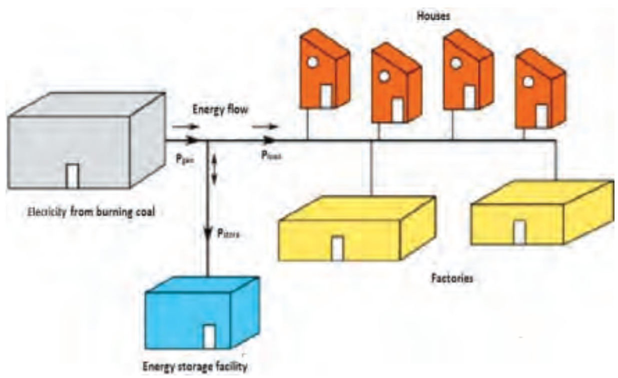

Fig 10.The arrangement of electricity generation, storage and distribution scheme

it to position itself on the source of fire. The TEGs are to be suitably positioned to avoid direct contact with fire.

TEG would be sliding over the grid. The top part of the TEG with its heat sink remain in contact with the cooling arrangement. The hot part and the cold part of TEG are separated by heat insulating layer. Fig.7 shows the conceptual arrangement of TEG over a coal fire zone. Fig.8 shows the power generating unit with the multiple number of TEGs over coal fire. Fig.9 shows the view of a fire zone with TEG units. Fig 10 shows the arrangement of electricity generation, storage and distribution scheme.

Continued on page 471