Methods for Detection of Heating in Coal Mines – Current Scenario

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ABSTRACT

Most of the fires in Indian mines are detected at an advance stage by smell or sight as other sophisticated methods of detecting mine fires by continuous monitoring are yet to be popular in Indian mines. Early detection is the most important step in combating a mine fire. This paper deals with recent advances made in the methods of early detection of mine fires in India as well as other parts of the world.

INTRODUCTION

Fires in coal mines may be categorized into two groups, viz., a) fires resulting from spontaneous combustion of coal b) open fires, which are accidental in nature, caused as a result of ignition of combustion materials.

Spontaneous combustion of coal is one of the important factors, which may endanger the safe operation of underground and open cast coal mines. In India, statistical data indicates that about 70 percent of mine fires / heating are caused due to spontaneous combustion of coal which may lead to huge loss of property and some times precious lives. The delay in control of spontaneous heating can cause serious effect in terms of the risk to human life and huge loss of coal. The situation becomes more difficult due to the confined nature of mine workings. The belated action may sustain the fire due to spontaneous heating, which many a time spread to adjacent properties and it requires much skill and resources to control such fires. With the large scale availability of combustion materials a small fire soon becomes a blazing one. Therefore, early detection of heating is an important aspect in coal mines. Further, an early and reliable detection of heating in a mine helps in taking effective counter measures. This paper addresses recent advances made in the methods of early detection of mine fires in India as well as other parts of the world.

PHYSICAL SYMPTOM

During initial stage of heating the moisture is released from coal and it comes in contact with ventilating air and thereby condenses making haze like formation. In the advance stage of heating, water droplets form on the roof walls and timber supports of the mine. Gob stink or fire stink or tarry smell is considered a very useful warning for recognizing the onset of incipient heating or the advancement of fire in a coal mine. Gob stink cannot detect heating at a very early stage at least not up to 120°C or so (Banerjee, 2000).This calls for temperature measurement as well as compositional studies of mine air.

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TEMPERATURE MEASUREMENT

Heating in any part of the mine can very easily realized by temperature measurement of that area; be it a pillar or sealed area. Before the actual fire occurs in a mine, the underground temperature tends to show some rise due to spontaneous heating. Temperature should be measured in places vulnerable to heating like old working in mines, depillared areas, crushed pillars with cracks and fissures, near gate roads in longwall panels and in return airways. Digital temperature recorder is extensively used in Indian mines for measuring temperature in sealed area. Recently some researchers have utilised infrared thermal gun and thermovision camera for thermal scanning of pillar (Panigrahi and Bhattacherjee, 2004). It has been experienced that IR thermometer provided with scanner can locate hot spots with more accuracy.

GAS INDICES/FIRE RATIOS

Graham's Index, also called index of carbon monoxide (ICO), is widely used in Indian mines to know the status of heating/detection of fire in the early as well as later development stages. Increasing value of CO/O_2 deficiency ratio is normally used for detection of onset of incipient or active heating, which is confirmed by appearance of smoke. This index is temperature dependent. Many fire ratios like Young's Ratio, Willet's Ratio, CO/CO_2 Ratio, Jones and Trickett Ratio, C/H Ratio etc. are available to know the status of fire/detection of heating in a mine. An account of all these have been described elsewhere (Ray et al., 2004). Some researchers (Bhowmick et al. 1995) feel that the early detection of heating system for Indian mines can be improved in the following direction:

- Use of infrared sensors for detection of hot spots in pillar, stopping, airways etc.
- Continuous monitoring of CO in return and other segments of mine airway.

SMELL SENSOR

As there are some detectable odours, which are generated before CO, CO_2 and other gases in the spontaneous heating of coal, detection system using various smell sensors can be employed. Researchers of Hokkaido University, Japan (Kiyoshi et al., 1997) have developed a smell sensor, which not only can detect heating by smell like a human nose but also measure the degree of smell. The sensor component employs a synthetic bilateral membrane like human lipid membrane. For quantifying the odorants a piezo-electric crystal device that can oscillate several million per second is used. Upon absorbing the odorants the weight of the membrane increases and the frequency of the oscillator are changed. The magnitude of the frequency changes as an electrical signal, which enables measurement of the frequency.

The detection depends upon two factors:

- Right detection equipment.
- Placing the equipment in the right place.

Since early detection of incipient heating provides for easier fire fighting and evacuation of personnel, it is important to ensure that fire detection equipment is placed closed to the potential fire sources for maximum effect (Hambleton et al., 1997). Early detection shall give sufficient time to take appropriate action.

TELE-MONITORING SYSTEM

This system essentially comprises of temperature sensors, toxic and combustible gas analysers placed in the underground workplace environment and other fire prone areas and connected to the pit top computer through a data acquisition system. Needless to mention, that it always gives first hand information regarding the heating status of the area concerned.

Environmental tele-monitoring system suitable for underground coal mines have also proved advantageous all over the world for detection of heating. In our country it has been used in Kotadih Coliery, ECL, New Majri Colliery, WCL etc. While reopening a sealed off area in BG panel at VK7 incline, SCCL this system worked successfully.

PATROL ROBOT

Coal Mining Research Centre, Japan, has developed a patrol robot for belt conveyor. The robot is equipped with camera, mike, and infrared thermometer to know the condition of belt conveyor. It is controlled by a computer program or manually. It can be suspended from a monorail, which is extended to the route to be patrolled. It can move at a rate of 100 m/min. on a horizontal route and climb up to 8 degree. The robot will traverse the route at a particular interval of time and transmit the data to a central computer. Analysis of the data will reveal the status of heating of the mine (Mitsumasu et al., 1997). In fact the patrol robot is self running and has visual, audio and thermal sensors that substitute human senses of sight, hearing and touch.

SUB-MICROMETER PARTICLE DETECTOR

The development of sub-micrometer particle detector (SMP's) by USBM shows promise for early detection of heating even earlier than from CO detection (Litton, 1981). Along with CO and CO_2, large quantities of sub-micrometer particles are produced during a combustion process. Initially, the particles produced are in low concentration and are too small to be visible by human eye (0.10 m in diameter). With the increase in intensity of combustion, larger concentrations of particles are produced that are visible. Particulate fire detectors are designed to detect both invisible and visible particles.

It is worth mentioning that sub-micron sized particulates are produced at a temperature much lower than they can produce even CO. With the tube bundle system of sampling and continuous monitoring device fitted with suitable sub-micrometer particulate detector, these particulates are detected at the onset of heating.

FIRE LADDER

SIMTARS (Safety in Mines Testing and Research Station), Queensland, Australia, on the basis of the experiments undertaken on Australian coals, has developed fire ladder (Dent, 1997). This has enabled a hierarchy of gas appearance to be determined, where the temperature of a heating can be determined from the gases present. This hierarchy is different for different types of coal. In one of the fire ladder they have shown the hierarchy of gases like carbon dioxide, carbon monoxide, methane, ethylene, hydrogen and propylene. SIMTARS has also developed 'SPLUS' package which enables the gas analysis data to be interpreted with respect to a potential mine heating.

THERMAL OXIDATION OF COAL

Recently a facility has been developed at Central Mining Research Institute, Dhanbad to assess the spontaneous heating behaviour of coal in the laboratory by thermo-decompsitional analysis. The study also helps to assess the status of fire in the sealed off area. For thermo-decompsitional analysis, coal sample of 40-mesh size, 40 gm in weight is placed in a reaction vessel. The reaction vessel is 150 mm long, 37.5 mm internal diameter and 4 mm thick, made of brass. The reaction vessel is kept in an air oven, temperature of which can be measured with a thermocouple and regulated through a progammable temperature controller. The lower portion of the vessel is connected with 6 mm diameter copper tube fitted with U-tube manometer to supply required quantity of fresh air through the coal sample. The upper portion of the vessel is connected to another copper tube of same diameter, which is connected with a suction pump fitted with a two-way stop cork to regulate the air flow and for collection of gas samples. Samples are collected by water displacement method. After fitting the vessel filled with coal sample in the heating chamber and establishing the airflow to the extent of 90-cc/ min through the vessel, heating is started at the rate of 1°C/min. The complete system is shown in figure 1. The gases emitted during heating of coal at the interval of 20°C is collected in sampling tubes and analysed in Chromatograph. Carrier gases used for the chromatographic analysis are nitrogen, zero air and hydrogen. Different gases viz., O_2, CO_2, CO, H_2, CH_4 and other hydrocarbons are emitted at different temperature starting from 40°C to 300°C at 20°C interval. This gives a clear-cut idea of spontaneous combustion characteristics of a particular coal seam for which experiments are carried out.

From the laboratory study the following points are emerged.

- The study reveals that CO is the best indicator for early detection of heating of coal and hydrocarbons appear at more advance stage of heating.
- Emission of various hydrocarbons at varied temperature range may be helpful in assessing the temperature and status of fire in the fire affected sealed off areas.
- Size of the coal is a very important aspect in respect of spontaneous heating behaviour of coal. Smaller the size more susceptible is the coal towards spontaneous heating.

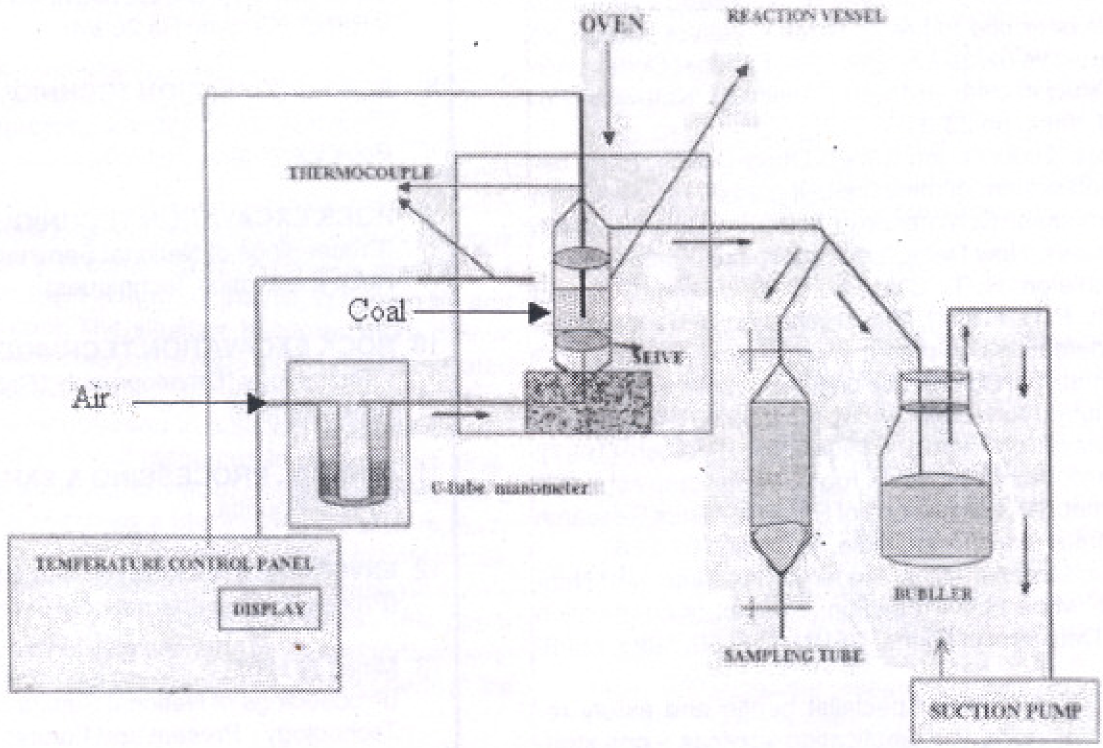

Figure 1 - Set up for thermal oxidation of coal

CONCLUSIONS

Many developments have taken place all over the world for early detection of heating in coal mines. Some of them have already practiced in mines and some are in experimental stage. Indian mines should utilise some of the modern methods for early detection of heating. Some of the methods, which can be implemented in Indian mines, are furnished below:

- Environmental tele-monitoring system should be there in all fire prone mines or seams susceptible to spontaneous heating.
- In depillaring areas where spontaneous heating prevents safe operation of coal winning operation, it should be mandatory to monitor the area by installing temperature and gas sensors and connect them through a data acquisition system. Arrangements for reducing the oxygen concentration in the goaf area

should also be made by infusing inert gas. This minimizes the chances of spontaneous heating.

- Thermal oxidation of coal has proved to be advantageous before reopening of sealed fire area. This should be practiced in Indian mines.
- Carbon Monoxide continues to be best indicator for early detection of heating. A systematic and continuous monitoring of CO always helps the mine management to detect heat much earlier than eruption of fire. Presence of hydrocarbons indicates advance stage of heating.

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