Detection of Underground Spontaneous Combustion of Coal With Surface-Based Radon Technique at Dartbrook Mine

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ABSTRACT

Underground coal heating is a significant hazard in some coal mines. The broad principles of how underground coal heatings occur is reasonably known, however the technique for locating the heatings in often inaccessible goaf has been proved to be difficult. Since 2002, CSIRO, with the support of the Australian Coal Association Research Program (ACARP) has been undertaking investigations to apply and develop innovative surface-based radon technique for locating the underground heatings in Australia. This paper presents the progress of the investigation.

RADON TECHNIQUE

The surface-based radon technique was initially developed by Taiyuan University of Technology, China in 1992. The technique was then commercially used to locate underground heatings in 1995. Since then, it has been used to locate more than 30 underground heatings in China, and great success has been claimed.

Principles

Radon-222 (Rn-222) gas occurs naturally as a decay product of the long-lived uranium-238 that is a common rare element in rock/coal/soil strata. Rn-222's emanation ratio from strata is influenced by many factors such as its lithology, mineral particle size, porosity, surrounding stress, ground hydrology, and temperature. However the degree of the influence by these factors is quite different on different types of rocks/coal/soils. Limited experimental investigations indicate that the temperature has a significant influence on Rn-222's emanation ratio from coal. Figure 1 shows the experimental results of temperature dependence on the emanation ratio from coal for the range of 20°C to 260°C.

The transport of radon and other gases through the earth is a well documented phenomenon. For example Kristiansson and Malmqvist (1982), demonstrated that a radon anomaly could be located at the surface above a strong radium source placed in a mine some 150 m vertically below with intermediate strata of quartzite and shale. Since then many studies have demonstrated that the earth is continuously exhaling gases, including short-lived radon (t1/2 = 3.8 days). Mineral exploration makes use of the gas transport by looking for weakly adsorbed trace metals in soils which are carried by the gas to the earth's surface.

More contentious has been the determination of the mechanism that permits and drives this gas transport. The most widely recognised theory considers that the flow takes places as microbubbles driven by gas pressure differences. These gas bubbles, comprising mainly CO_2 and CH_4 could then carry other rare gases (eg radon) as well as Au, Cu, Pb, Zn, etc (Zhou *et al*, 2003). Several laboratory tests have been reported to confirm that small gas bubbles can in fact act in the proposed manner (Varhegyi *et al*, 1992; Etiope and Lombardi, 1996).

Many authors still report the transport of gas over large distances through seemingly impervious rock layers as 'strange'. Radon, in particular is the most puzzling as its transport must happen very rapidly and the driving force for such rapid flow is difficult to imagine. An alternative model has been recently proposed to explain rapid movement which is based on quantum mechanics and models the behaviour of a particle bound in a potential well (Holub and Smrz, 2002). Deformation of the well

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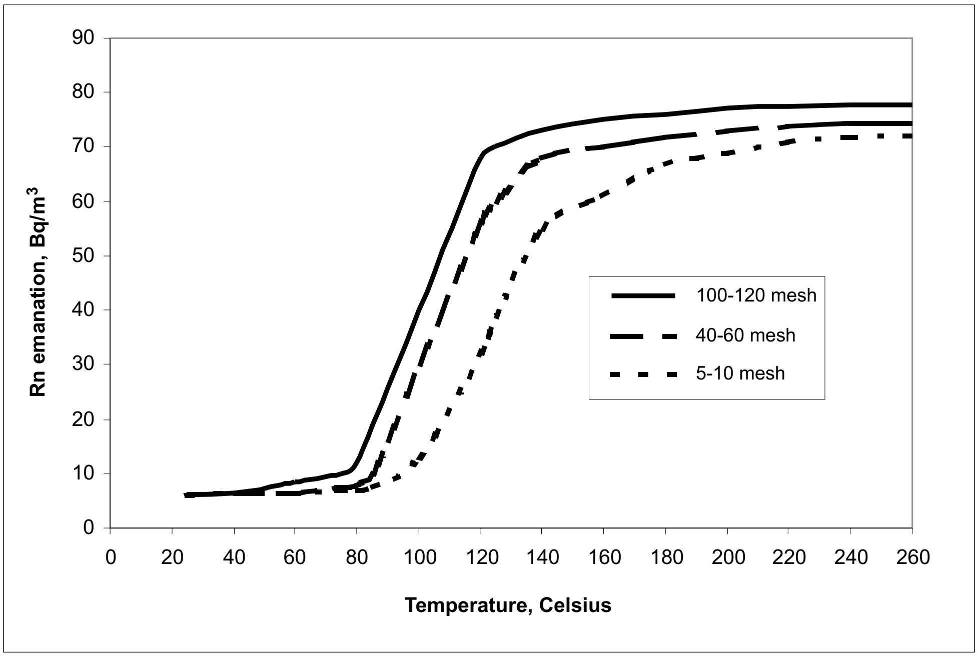

FIG 1 - Temperature dependence of radon emanation from coal (Wu, 1995).

within impenetrable walls of a microcrack leads to the probability of localisation of the particle near the end of the crack. These authors have also identified the common occurrence of geoaerosols (Holub *et al*, 2001) in gases emanating into caves. These aerosols carry both radioactive and inert elements into the air space. One aspect of these geogases is that radioactive decay and radon play a fundamental role in their formation and release. Suggestions have been made that it is radioactive decay that causes the nucleation centres in formation waters, supersaturated with gases.

Operation

The technique employs an alpha detector and alpha cups. The detector is a portable, battery powered 'alpha counting' detector with an ionisation chamber for detecting alpha radiation of radon and its daughters. The cup, also called 'alpha cup', is an open-end plastic cup with a sorbent coating on its internal surface. Radon and its daughters are adsorbed and deposited on the internal surface of the cup. The working principle of the detector is shown in Figure 2, and the alpha cup and radon detector are shown in Figures 3 and 4 respectively.

The operational aspects of the technique is fairly simple. The operation steps include:

1. select the detection area and design surface grids of measurement points;
2. dig holes at the points (about 30 cm in diameter and 40 cm in depth) and place alpha cups upside down;
3. bury the cups for at least four hours and then recover them for on-site measurement with the detector; and
4. process the measurement data with a specially developed software.

DEMONSTRATION OF THE RADON TECHNIQUE IN AUSTRALIA

In 2002, the Australian Coal Association Research Program (ACARP) sponsored a project C12005 to investigate and demonstrate the radon technique. The main objectives of the project were to:

1. investigate the technique and gain a detailed understanding of the technique and its applications; and
2. demonstrate the technique at Dartbrook mine.

The project was successfully completed in September 2003 and the details and results of work carried out under the project were reported to ACARP (Xue, Balusu and Worrall, 2003). The main conclusions are summarised below:

1. The specific principle of the radon technique for locating underground heatings from surface needs to be further investigated.
2. The radon technique was demonstrated in two areas of suspected heatings at Dartbrook mine. The first one covers the surface area of 103 395 m^2 above LW7 goaf. The cover depth in the area was about 340 m. The second area of 10 000 m^2 was centred at CDH003 hole above LW2-3 goaf. The cover depth in the area was about 200 m. Five heating zones were identified with radon technique in the areas. Figure 5 shows the surface area above LW7 and Figure 6 shows the corresponding underground heating zones identified with the radon technique within the area. The results were consistent with those based on analyses of gas monitoring data and mining sequences.
3. It was also identified from the study that to apply the radon technique in the Australian coal mines with a greater

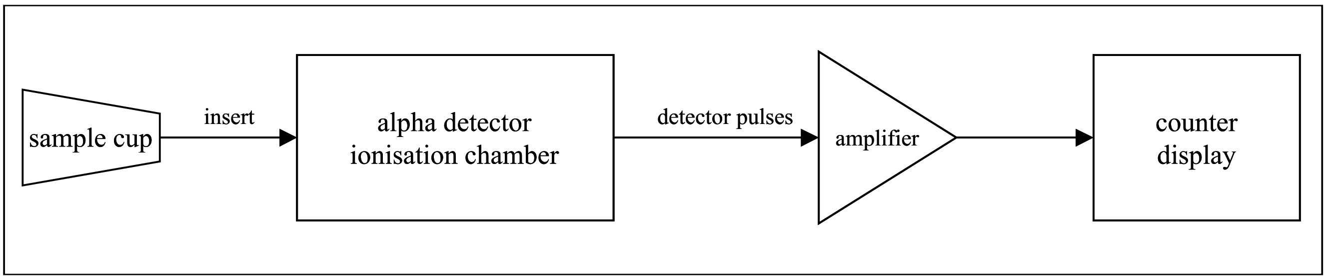

FIG 2 - Working principle of 'alpha cup' method.

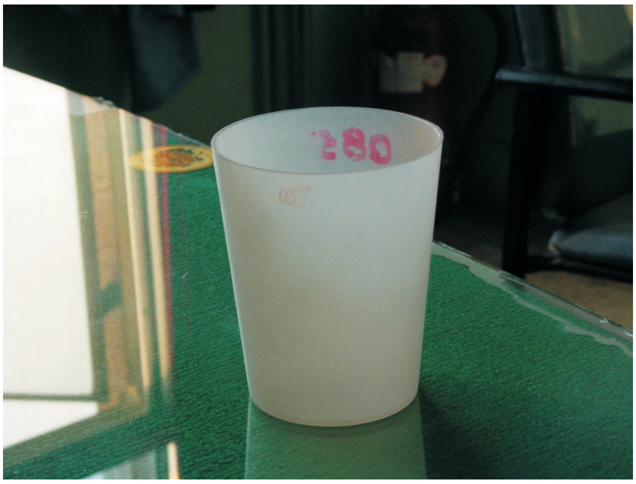

FIG 3 - Alpha cup.

FIG 4 - Alpha detector.

confidence, the detailed studies on the temperature dependence of radon emanation ratio from coal and its upright movement in overlying strata should be undertaken in the future research projects.

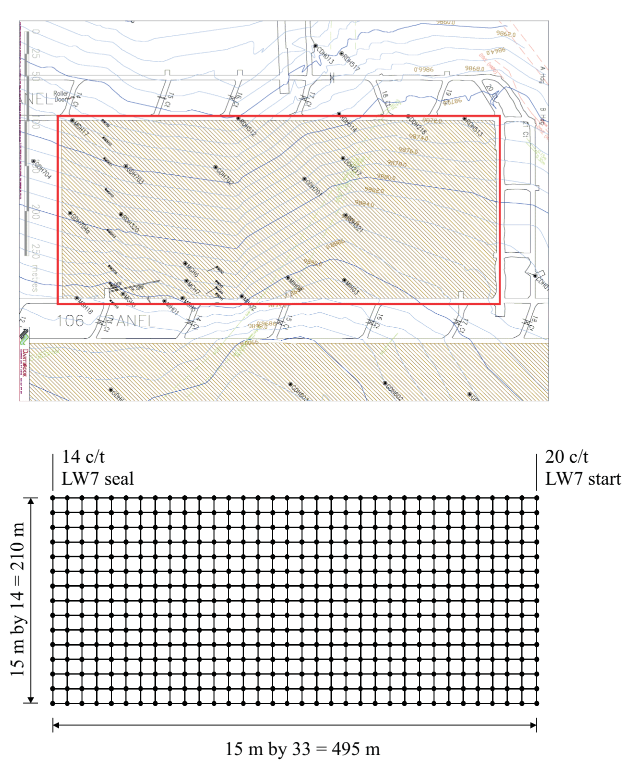

FIG 5 - Surface survey area at Dartbrook mine.

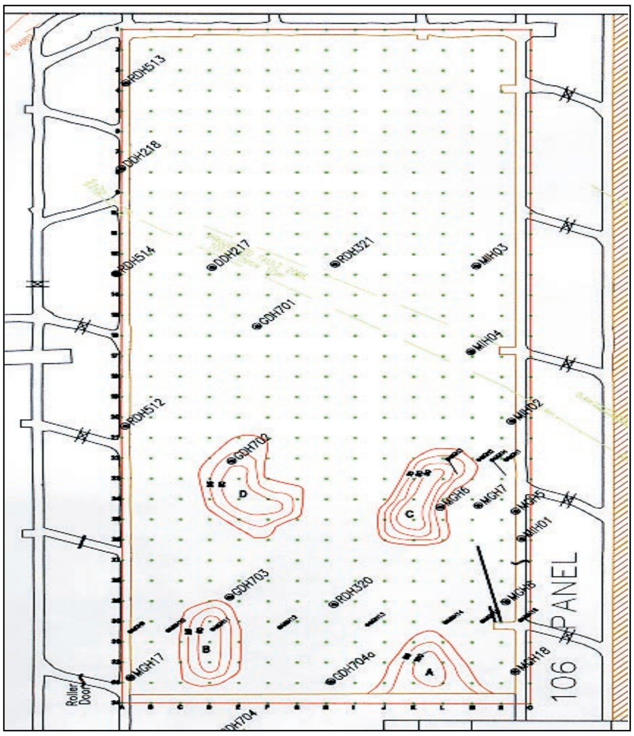

FIG 6 - Underground heating zones identified with radon technique.

FUTURE APPLICATION OF THE RADON TECHNIQUE IN AUSTRALIA

In recognising the importance of the recommended studies, ACARP is funding a current radon project C13021. The project aims to:

1. Investigate temperature dependence of radon emanation from coal and effect of heatings on radon vertical movement in overburden strata. The dependence and effect are the core science upon which the radon technique for locating coal heating is based. Bench-scale testing will be carried out for the study.
2. Develop a portable prototype of radon detector and collector suitable for field measurement of radon measurement in mines.
3. Evaluate the prototype by re-surveying the surface radon flux over the goaf at Dartbrook mine and one other heating event if the opportunity arises.

The project commenced in April 2004 and is progressing well. A bench-scale test rig is being set up. The rig includes test apparatus, controlling system (temperature and air flow) and data sampling system. The portable prototype of radon collector and detector has been designed and ordered for manufacturing. The literature review of the radon movement theories is also underway. The project is scheduled to be completed in December 2005 and the details and results of work to be carried out under the project will be reported to ACARP by then.

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