FACTORS AFFECTING GAS RELEASE FROM THE WORKING SEAM

By
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ABSTRACT

The seam gas content at Westcliff Colliery is 12-15m3/tonne of coal.Composition ranges from 99% CH_4 to 52% CO^2 in one area. Desorption rates are proportional to gas contents and CH_4 is preferentially desorbed. A crushed zone of reduced permeability advances with the face - at Westcliff ribside crushed zones are 2.5 to 6.5m wide. Poor strata control widens crushed zones. 12 months of pre-drainage allowed 2 heading development and longer pillars to be used in a virgin area instead of 3 or more headings without drainage. Machined coal may lose as much as 1.6m^3/tonne being conveyed out of Westcliff Colliery. Experience differs from mine to mine. Permeation is affected by time, strata movements, changing water content, and changing stress. Permeabilities vary from 10md for Pittsburgh Seam to less than 1 md for the Bulli Seam. All these data and differences await further investigation.

INTRODUCTION

The emission of firedamp from coal into mine workings is a complex combination of processes. Seam gases flow into mine workings only as a result of the pressure drop between the gas within the coal seam and the atmospheric pressure in workings. As a face advances, the gas pressure in the virgin coal falls and the adsorption equilibrium is disturbed, resulting in the release of some prevously adsorbed gas into the microfractures and cleats in the face area.

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Gas release continues from outbye ribs and from coal already won. The rate and extent of gas release from the working seam depends mainly upon: 1. gas content, 2. gas composition, 3. position of the abutment zone, 4. the degree of breakage of cut coal, and 5. changes in permeability.

GAS CONTENT

The gas content of coal, volume per unit mass, m3/tonne or cm3/g, depends primarily on seam gas pressure, strata temperature, adsorptive capacity and moisture content, and to a lesser extent on permeability and distance from outcrop. The content steadily decreases from the time coal exists in a virgin state to the time of its utilisation. Desorption of gas from coal is proportional to the gas content,providing all other factors remain constant,as shown by the cumulative desorption curve for a Bulli seam sample, Fig 1. If the gas content halves, the gas emission rate should also halve.Predrainage at West Cliff Colliery NSW, of 470 panel by drilling boreholes from an adjacent panel reduced the gas content of 470 panel coal from a virgin value of 12-15 m3/tonne to less than 4m3/tonne in seven months. Within 12 months gas content had reduced to less than 1m3/tonne, with the result that no gas problems were experienced in driving the two-heading development through what was otherwise virgin ground.

GAS COMPOSITION

The 2 principal components of most seam gases are carbon dioxide and methane. Composition can vary from nearly 100% CH_4 to nearly 100% CO_2. Minor constituents include nitrogen, ethane, helium, hydrogen and higher hydrocarbons,

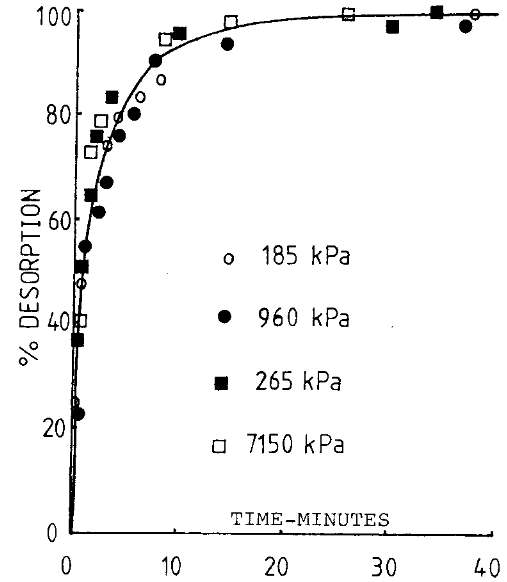

Fig.1 - Desorption of sample E, Bulli Seam, West Cliff Colliery (-53 um) at 30oC for a range of equilibrium methane adsorption pressures.

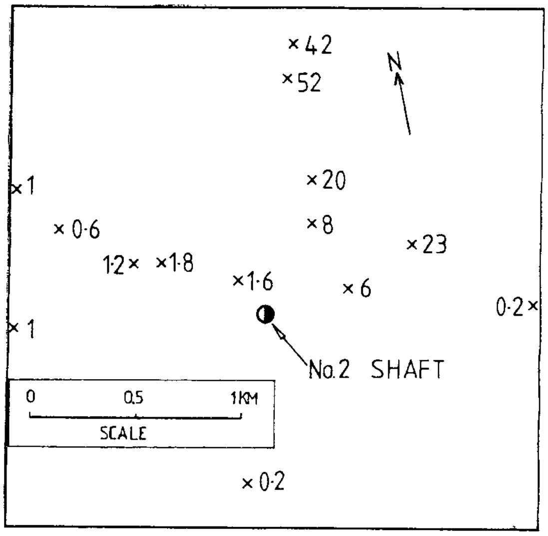

Fig.2. - CO_2 concentration in Bulli Seam gas at West Cliff Colliery, N.S.W. e.g. x 1 = 1% CO_2

For the same seam, large composition variations can occur over relatively short distances. At West Cliff Colliery the CO_2 concentration in the Bulli seam gas, as sampled from in-seam holes, varies from less than 1% CO_2 in the Southern workings to over 50% in the Northern workings, as illustrated by Fig.2. Coal has a higher adsorptive capacity for CO_2 than CH_4. Fig.3 illustrates this by a plot of the dry, 30°C equilibrium desorption isotherms of CH_4 and CO_2 for Bulli seam coal from West Cliff Colliery. The implication is that for any given seam pressure, the greater the porportion of CO_2 in the seam gas, the higher is the combined overall emission rate providing the seam pressure remains the same. At the same adsorbed gas concentration, CH_4 desorbs more rapidly than CO_2, so that for a coal seam district containing both gases, the adsorbed CO_2/CH_4 ratio increases with time. In other words, the Concentration of seam gases as measured from samples from in-seam holes may not be exactly the same as the original adsorbed gas mixture.

ABUTMENT INFLUENCES

The solid coal ahead of the working face can be divided into two sections, one section on the face side of the front abutment and the other beyond the abutment into the solid coal. The region on the face side of the front abutment is called the fractured or crushed zone. Kissell(1972) detailed evidence for the existence of this zone, including its increased permeability compared to the zone beyond the abutment into the solid coal.Due to fracturing within the crushed zone, the permeability is much higher than in the intact zone beyond, which exhibits virgin permeability. As the previous crushed zone is mined, new crushed zone is formed ahead of the face.Calculations of the extent of the crushed zone at West Cliff is shown in Fig. 4.

Fully caved longwall faces exhibit a featis similar in shape to the ground stress profile in the vicinity of longwall workings (Mucke, 1975) and depends on time, roof support method, method of working and face advance rate. The profile of flow rate is also related, although inversely, to the ground stress beyond the abutment zone. Permeability is the controlling factor on the face side of the abutment. The flow profile along a borehole at West Cliff Colliery intersecting a shear zone is shown in Fig. 5. The abutment and crushed zones are clearly evident, as well as the destressed nature of the shear zone.

In a study of the Barnsley seam at Yorkshire Main pit, Richards (1978) found that for one advancing face practising methane drainage, 74% of the gas in the air at the outbye end of the district return originated between the two 10 m statutory intake and return sampling points. Of the gas between the two points, 48% came from the face, roof and floor and 52% from the goaf at the tailgate. Of the gas which originated from the seam, 66% emanated from the major cleats in the face 1.5 m apart. These results implied that about 35% of the total gas make from the district originated from the exposed face of this advancing longwall. Pre-drainage of the seam, if possible, would have resulted in a major contribution to methane control (Richards, 1978, p. 702). Pre-drainage of a retreat longwall block should then significantly reduce gas problems on the face itself, as well as, more importantly, reducing emission into the next developing gate roads to the point where it does not retard advance rates. The usefulness of pre-drainage was illustrated by the driving of a two-heading development through a virgin district at West Cliff Colliery, previously pre-drained for up to 12 months. Without pre-drainage, a minimum of three headings (two outside returns) would have been required, and pillar lengths would have been reduced.

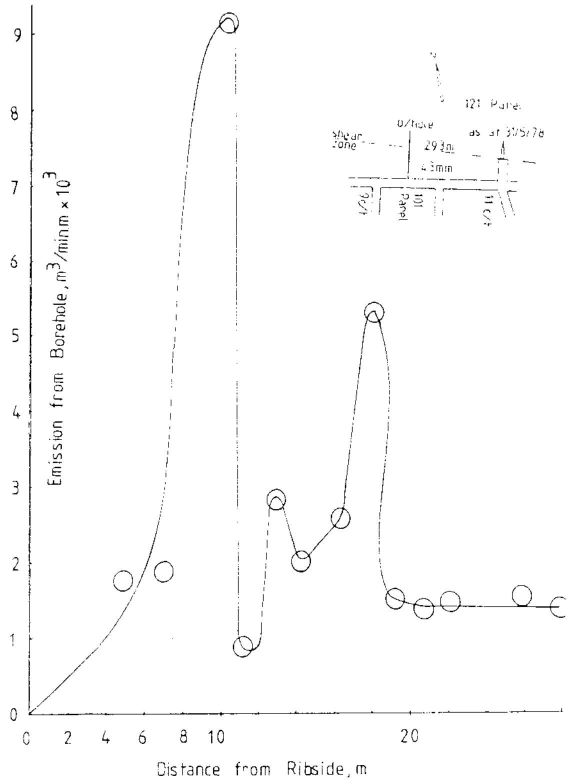

Fig. 5. Flow profile of a borehole in a virgin area of West Cliff Colliery, in the vicinity of a small shear (outburst) zone. Abutment: 10-12 m
Shear zone: 18 m

EMISSION FROM BROKEN COAL

Coal which has been cut and transported out of the mine, or coal spalled from ribs in mine roadways, can contain appreciable quantities of gas in the desorbed state. The Pittsburgh seam, U.S.A., for example, has been recorded to contain up to 80% of its original gas content in lump coal collected at the faces of development workings (Kissell and Deul, 1974)

Possibly the earliest work on residual gas content in mined coal was carried out by Graham (1921). From previous work which indicated that seam gas desorbed very slowly even from small lumps (25 mm), Graham concluded that cut

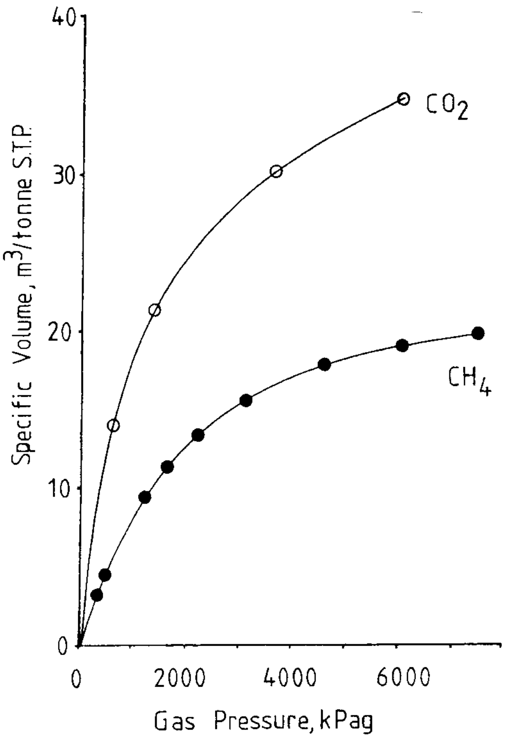

Fig. 3. Equilibrium Desorption Isotherms for Bulli Seam coal, West Cliff Colliery, 30°C, 0% moisture. (Hayes, 1982).

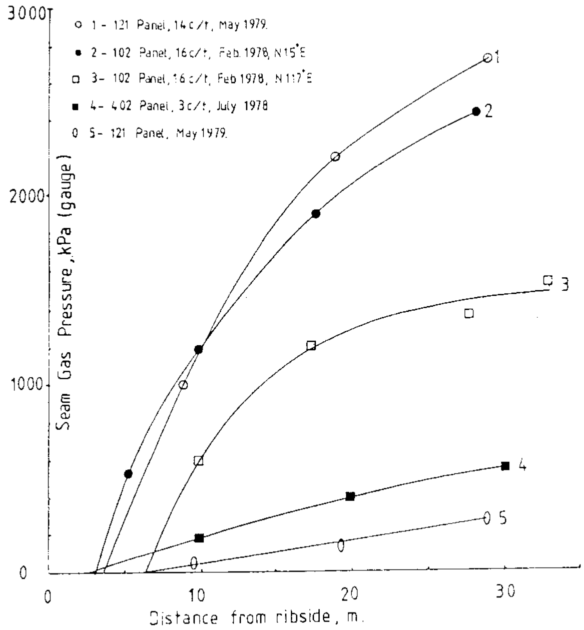

Fig. 4. Variation of seam gas pressure with distance into solid coal, West Cliff Colliery, Appin. The depth of the crushed zone can be calculated where the pressure is zero, and varies from 2.5 to 6.5 m.

ure which Ettinger (1958) called the "gas barrier". The gas barrier is, in fact, the front abutment line, beyond which little gas flows from the coal seam into the workings. Most of the gas from the working seam on longwall faces originates from the fracture zone, which is in most cases 5 - 10 m ahead of the face. The existence of a gas barrier can be justified in terms of the effect of stress on the permeability of coal. Somerton (1975) found that increased applied stress in constrained specimens of coal caused a decrease in permeability of several orders of magnitude up to the point where microfracturing occurs, beyond which permeability increased. This indicates that the abutment stress (which is greater in magnitude than the virgin vertical stress) could decrease permeability to the extent that the region of high vertical stress concentration acts as a gas barrier, discouraging the flow of gas from beyond the abutment zone into workings. Jolliffe (1970) stated that the work done by British M.R.E. found that gas migrated only about 15 m from solid ribs in longwall gates adjacent to goaf areas, and this accords with the concept of a gas barrier. On faces which achieve poor strata control, with excessive abutment loads leading to extensive fracturing ahead of the face, gas emission from the seam into the working area is increased due to the widened crushed zone: poor roof control can lead to increased gas emission.

Gas pressure measurements made in subadjacent seams show that the gas pressure profile coal retains almost all of its original gas for a relatively long time and that residual gas contents are a good index of gassiness. Hinsley's work on samples of face coal (Hinsley, Konda and Morris, 1965) indicated that "unless the coal is permeable and there is much firedamp emission from the roof and floor, the residual firedamp content of the coal should give a rough guide to the likely emission that will occur when the seam is worked". However, no correlation was found between methane emission at the statutory 10 m points and residual methane content and, in contrast to Graham's earlier work, Hinsley did not conclude that mined coal retained most of its original gas content. Later work at the Pittsburgh Research Centre by Kissell and Deul (1974) on the subject of coal breakage and methane emission found that the Pocahontas No. 3 Seam contains less than 10% of its original gas content when sampled from development faces. In this seam, then, 90% of the original gas content has escaped before the coal becomes the working face. If only 10% of the original gas remains on the face, then the size to which it is broken can make little difference to mine gas make. Some coals, however, retain up to 80% of their original gas content when exposed as face coal (Kissell and Deul, 1974, p. 183). Nevertheless, coal breakage still accounts for only a minor percentage of total gas emission. This was shown in studies of the Pittsburgh Seam (Centinbas, 1972) which concluded that breakage accounts for 10-15% of the total gas emission. Pickering (1969) found that gas from coal breakage on a typical British longwall face represented only 8-15% of the gas make between the two statutory 10 m points.

Although complete data are only available for several American and British Seams, it seems reasonable to assume that breakage is a minor contributor to methane emission in other seams as well. In seams like the Pocahontas No. 3, gas release occurs over a relatively short time and little gas remains in face coal to be released during breakage. In seams like the Pittsburgh, gas release occurs over a relatively long time and insufficient time is available from exposure on the face until it reaches the surface to pollute the mine atmosphere with firedamp. With reference to the Bulli Seam, there are several indirect indicators as to the contribution of cut coal to the total methane output of the mine. Firstly Hargraves' work at Metropolitan Colliery (1963) on desorption of gas from coal cuttings from boreholes drilled ahead of the face indicated a residual gas content of not much more than 1.0 m^3/tonne. Work done at West Cliff Colliery by Griffiths, cited by Lama (1980), showed for one panel that the maximum gas released by breakage and rib emission within the immediate face area was less than 1.0 m^3/tonne. In one face sample taken from a rapidly advancing development heading at West Cliff, the total gas content (composition 99% CH_4) was calculated as 10.8 m^3/tonne STP. From the desorption curve of the sample shown as Fig. 6, it can be seen that for the minute or so that the coal would be in the face area after cutting, only 4% of the desorbable gas content would be emitted, and that in the 30 min required to reach the surface, the coal would have emitted less than 15% (i.e., 1.6 m^3/tonne) of the desorbable content. Since the overall mine output of methane is about 40 m^3/tonne (not including drained methane), it is obvious that the major source of gas at West Cliff is the coal ribs, and that the residual gas content of face coal only contributes in a minor way to the total mine gas make. However, even though the gas in face coal contributes little to total mine gas make, it can be a significant factor in pollution of the face area. Emission from cut coal could increase general body gas at the face by 0.1-1.0% CH_4, depending upon residual gas content

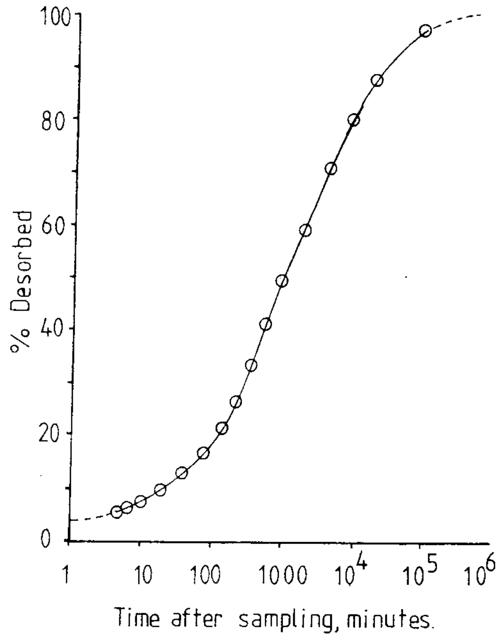

Fig. 6. Desorption of a face sample from West Cliff Colliery: -73 + 3 mm, original gas content 10.8 cm^3/g; 0.9% moisture; seam gas 99% CH_4.

(1-11 m^3/tonne), air quantity (2.4 - 9 m^3/s) and loading rate (4-8 tonne/min).

PERMEABILITY EFFECTS

In-seam boreholes have enabled much basic information about the relationship between coal and the contained seam gas to be obtained. This information is of great help in designing degasification layouts and other methane control techniques. Boreholes were used in-seam at West Cliff Colliery to determine background information on the nature of flows and pressures in the Bulli Seam (Hall, 1978) and to attempt to optimise borehole spacing for in-seam degasification (Lama, Griffiths and Marshall, 1980). Most information obtained from boreholes relates to the permeability or fluid conductivity (Mordecai and Morris, 1974) of the coal seam. Permeability refers to the ability of the coal to transmit gas when a pressure or concentration gradient exists across it.

One major characteristic of coal seam permeability is that the measured permeability to methane appears to increase with time. This was first reported by Kissell (1973), who found that solid ribs of older workings of a mine were more permeable than ribs of new workings. Zabetakis surveyed the rib emissions of a gassy Pittsburgh seam mine (1972) and found that sections of rib close to the working face and freshly exposed by mining were emitting gas at the same rate as comparable rib hundreds of metres outbye and exposed for many months. Preliminary work at West Cliff Colliery indicated a similar effect. If the rib permeability to methane was constant, this could not have occurred since older ribs would yield much less gas than freshly exposed ribs near the face. Several factors could account for this increase in permeability. One is the destressing or relaxation that results from strata movements that accompany mining (Stewart, 1971). Another is the coal shrinkage resulting from the loss of methane (Moffat and Weale, 1955). Kissell (1975) reasons that the most probable explanation is a relative permeability effect in which the flow of methane is partly controlled by the degree of water saturation in the coal seam: the permeability to methane increases as the water in the coal decreases and allows more pore space available to the gas phase. This assumption was based on the observation that as the waterflow from in-seam holes decreased, the gas flow increased to a peak, then slowly dropped off to a lower flow rate. Stewart (1971), discussing work done in the Bulli seam at Metropolitan Colliery found a similar increase in gas flow from a borehole in a freshly exposed conventional face and comments that the flow pattern is more consistent with an increased average diffusivity than with the opening up of shrinkage fissures. Increased diffusivity could have been the result of reducing the water saturation of the coal. Barron (1978), using an air-injection technique determined that the permeability of the central portion of a 40 m wide pillar increased remarkably between the time of formation and six months later. He subscribed the phenomenon to a reduction in the strength of the pillar caused by stress effects, but he admitted that no obvious physical deterioration had occurred in the structural integrity of the pillar. Perhaps a more plausible explanation of the reduction in permeability of the central portion of the pillar would be that it had in fact 'dried out' and the moisture loss had occasioned the increase in permeability.

The nature of the coal seam appears to have as equally important effect as overburden pressure or stress effects on permeability. Results obtained for permeabilities of U.S. and European coals have indicated that the U.S. seams are generally more permeable and therefore more amenable to in-seam degasification (Curl, 1978). The in-situ permeability of the Pittsburgh seam has been measured at about 10 millidarcies (md) (Kissell, McCullock and Elder, 1972), whereas the Bulli Seam permeability is considerably less than 1 md (Lama, 1980). Fisecki (1975), reworking some of Hargraves' data for the Bulli Seam (Stewart, 1971), calculated Bulli seam permeability as less than 10^{-3} md compared with values in excess of 2 md for Canadian coals studied. Free flow rates (i.e. unaided by vacuum) of gas flow from Pittsburgh in-seam holes averaged 20 m^3/day/m and Pocahontas No. 3 holes averaged 5 m^3/day/m, whereas Bulli Seam holes at West Cliff Colliery have averaged about 3 m^3/day/m, illustrating that gas flow rates are dependent upon many variables, including permeability. Permeability in a seam may also be directional, depending upon the position of major and minor cleats, permeability being greatest in the direction of the surface of the major cleat. Flows from holes drilled parallel to the major (face) cleat at West Cliff Colliery were found to be lower and sustained flow for a shorter time than holes drilled perpendicular to the major cleat (Hall, 1978).

CONCLUSION

From the foregoing, it is obvious that the nature of gas emission from the working seam into mine workings is a very complex one, resulting from the interaction of a variety of different factors, including gas content and composition, stress effects and permeability changes, as well as degree of breakage at the face. Further investigation of these factors and application of the knowledge obtained to such processes as gas drainage can only lead to a reduction in problems of gas accumulation and outbursts.

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