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GAS CONTENT MEASUREMENT AND ITS RELEVANCE TO OUTBURSTING

Ian Gray

ABSTRACT: The use of core and alternatives to its use for gas content measurement of coal is examined. The measurement of gas content from cuttings is presented in two forms, one involving the recovery of cuttings with air drilling and the second involving the collection of all released gas from the hole during overbalanced drilling. The latter approach is suitable for not only coal but all gas bearing formations including siltstones and sandstones, provided they do not have major open pore space such as vugs. The paper also deals with the importance to outbursting of gas content, broken coal particle size and diffusion coefficient.

CORE DESORPTION

Core desorption is the standard process for determining the gas content of cores. This process is described by McCulloch and Diamond (1976), and more recently Standards Australia (1999). The process generally involves using wire line coring to cut a core so that the core may be retrieved quickly. Once the core is retrieved to surface the core is placed in a canister and the released gas is monitored with respect to time. This should be undertaken at reservoir temperature. An example of gas release versus time is shown in Figure 1.

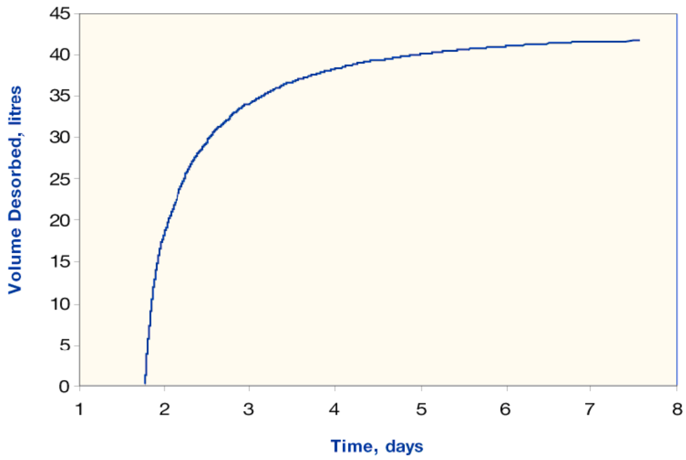

Figure 1 - Example of desorbed gas measurement (Q2). Note the time here refers to time of day

Once the core has been further desorbed the canister is opened and the core is logged and weighed with density determination. Weighed sub sections of the core are then crushed to enable the remaining gas to diffuse out more quickly than from the core.

This process is relatively straight forward but the determination of the gas lost before the core is placed in the canister is not. The usual process adopted is to assume a time when the core begins to release gas and to plot the gas release with respect to the square root of time. An example of such a plot is shown in Figure 2.

Figure 2 shows a very good straight line plot. Equation (1) for Fickian diffusion from a homogeneous cylinder is as published by Crank (1975).

$$\frac{M_t}{M_\infty} = 1 - \sum_{n=1}^{\infty} \frac{4}{JOR_i} e^{\left(-D\left(\frac{JOR_i}{a}\right)^2 t\right)} \tag{1}$$

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Where: $\frac{M_t}{M_\infty}$ is the ratio of desorbed gas over the total gas that may be released;
JOR_i are the roots of a Bessell function of the first kind for the equation;
D is the diffusion coefficient (length^2/time);
t is time;
a is the radius of the cylinder.

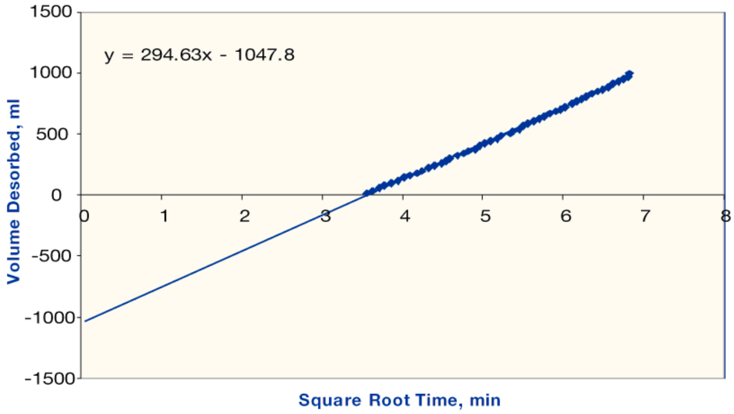

Figure 2 - Example of lost gas determination plot (Q1)

For small values of Dt/a^2 equation the general equation may be approximated to that of Equation 2 below, also taken from Crank (1975):

$$\frac{M_t}{M_\infty} = \frac{4}{\sqrt{\pi}}\left(\frac{Dt}{a^2}\right)^{\frac{1}{2}} - \frac{Dt}{a^2} - \frac{1}{3\sqrt{\pi}}\left(\frac{Dt}{a^2}\right)^{\frac{3}{2}} + \dots \qquad (2)$$

The straight line approximation with the square root of time comes from the first term of the above equation and shows a 10% error at a value of $Dt/a^2 = 0.05$. For values of Dt/a^2 greater than 0.05 the value from the first term approximation of equation 2 diverges rapidly from the theoretically correct solution.

Care must be exercised in the use of the straight line approximation for gas loss. A prime source of error is the incorrect determination of the time when initial gas loss occurs. Standards Australia (1999) arbitrarily sets this at the mean time between when the core starts being pulled and reaches the surface. In some cases determining the onset of gas release in the hole needs to be looked at more carefully. Another source of error occurs if the core is retrieved too slowly and substantial gas loss occurs. In this case the value of Dt/a^2 may mean that the linear approximation is quite simply incorrect. This can be checked quite readily from a calculation of the slope of the lost gas plot and the total gas content.

It must be remembered that the coal core is not a uniform cylinder. It is inhomogeneous and fractured and contains various macerals and ash. The more highly fractured components of the core and those with higher diffusion coefficient will release their gas more quickly than the less fractured ones with a slower diffusion coefficient. A basic method of checking the validity of the initial gas loss estimation is to examine the ratio of the lost gas (Q1) to total measured gas content (Q2+Q3). If this value is too high then a question will remain over the total gas content value.

It is possible to derive an estimate of the diffusion coefficient from the slope of the lost gas plot. This has particular relevance in assessing gas an energy release from coal particles in an outburst.

CUTTINGS DESORPTION FROM AIR DRILLING

It is possible to determine gas content by collecting cuttings using air drilling. This is possible because the high speed at which the coal is delivered to the hole collar minimizes the gas loss. The process for doing this in the underground mine context is shown in Figure 3. Here drilling is taking place using air flushing with the cuttings being collected by a cyclonic separator and bag filter arrangement. The cuttings collected are transferred to a canister and the gas release with time is measured, much as in the case of core desorption, except that the process happens more quickly (approximately 2 hrs) because the coal is in small pieces. As desorption slows the canister can be opened, the sample weighed and a sub sample taken for crushing to obtain a value of the residual gas content. Thus the measured gas release includes both the values from normal desorption (Q2) and from crushing (Q3).

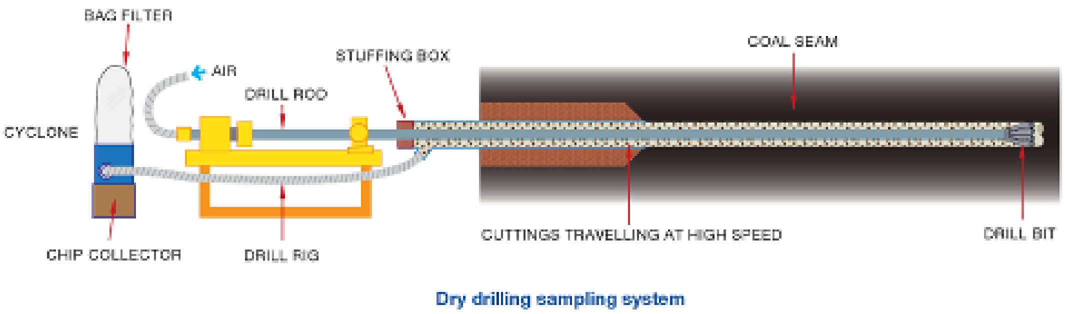

Figure 3 - Underground drilling setup to collect cuttings with air flush drilling

There is a need to then determine the lost gas volume (Q1). This is in some ways easier to do than for the case of core desorption because the time at which gas loss starts is known with precision (within 30 s) as the time at which drilling takes place. The key to determining the lost gas is to measure the particle size distribution of the remaining cuttings. Using this size distribution, and the gas release versus time information, combined with the residual gas content it is possible to use a model of diffusion to determine the lost gas using a best fit history match. Equation (3) from Crank (1975) has been found to be model the situation quite adequately. It describes Fickian diffusion from spherical particles.

$$\frac{M_t}{M_\infty} = 1 - \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}e^{\left(\frac{-Dn^2\pi^2 t}{a^2}\right)} \quad (3)$$

Here the symbols are the same as previously noted except that *a* refers to the sphere radius.

The total gas content is thus determined from the estimate of lost gas and the measured gas released, providing a very accurate estimate of the gas content of coal and a value of the diffusion coefficient of the coal particles. Figure 4 shows an example of a real gas content determination from this process. The example is from work by the author in the D6 seam at Lenina mine in the Karaganda Basin, Kazakhstan. This was a dry coal seam which made the operation easier.

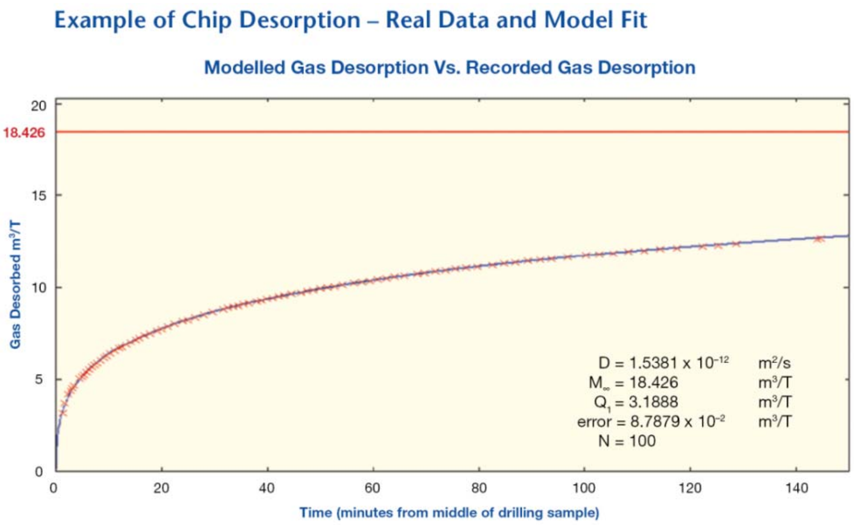

Figure 4 - An example of gas content measurement from air drilled cuttings desorption

The results taken from the case described in Figure 4:

- the diffusion coefficient is calculated at 1.54 x 10^{-12} m^2/s;
- the total gas content is calculated at 18.4 m^3/t;
- the lost gas estimate is 3.19 m^3/t; and

- the residual gas measured is identical to that predicted - 4.6 m^3/t.

GAS CONTENT MEASUREMENT WITHOUT CORING (GCWC) IN HOLES DRILLED WITH MUD

There are many cases where air drilling is impractical, more particularly from a well control and hole stability viewpoint. While in the past there have been many efforts made to determine the gas content of the material drilled from cuttings these have been subject to substantial inaccuracy due to an inability to determine the volume of gas lost from the cuttings in their passage up the well bore. This inaccuracy comes from the same source as that for core, namely an uncertainty as to when gas release commences and the rate at which it takes place.

The proposed solution which is being tested is to drill overbalanced so that no gas is released from the formation into the well bore. This is combined with the use of a rotary seal between the drill pipe and the casing to ensure that no gas escapes without measurement at surface. Thus all the material coming from the well including mud, cuttings and gas may be directed to a separation system. The separation system splits the gas from the mud and cuttings and permits the gas volume to be measured. The mud and cuttings are then further separated on a shaker and the cuttings may be desorbed further. Indeed the gas released while the cuttings are on the shaker may be determined by covering the shaker with a shroud ventilated at a known rate, and by measuring the rate of gas release in the air stream from the shroud.

The gas remaining in the cuttings may be determined by sampling these and measuring the gas release from them. This is followed by further grinding to measure the residual gas content of the cuttings.

The total gas volume measured must be related back to where the gas came from in the hole. This requires the position of the bit to be logged along with the mud flow rate, including periods of no flow while drill pipe is added. Care must be taken to ensure that air does not become entrained in the drill string when pipe is added to it. The use of a gas analyser to measure the composition of the gas delivered from the separator helps in detecting air that has become entrained in the system, either on the suction side of the mud pump or during the connection of drill pipe. It is also necessary to relate the volume of gas release back to the volume of the material which has been drilled. This can be approximated from the theoretical volume of the hole but is better checked by using a caliper log. The total estimation of gas content is calculated by incorporating of all of this information into a model.

Figure 5 is a schematic diagram of the system used to obtain gas content information from open hole drilling from surface using mud. This method has the potential to be more accurate than core desorption because there is no reliance on lost gas determination – all gas released is captured.

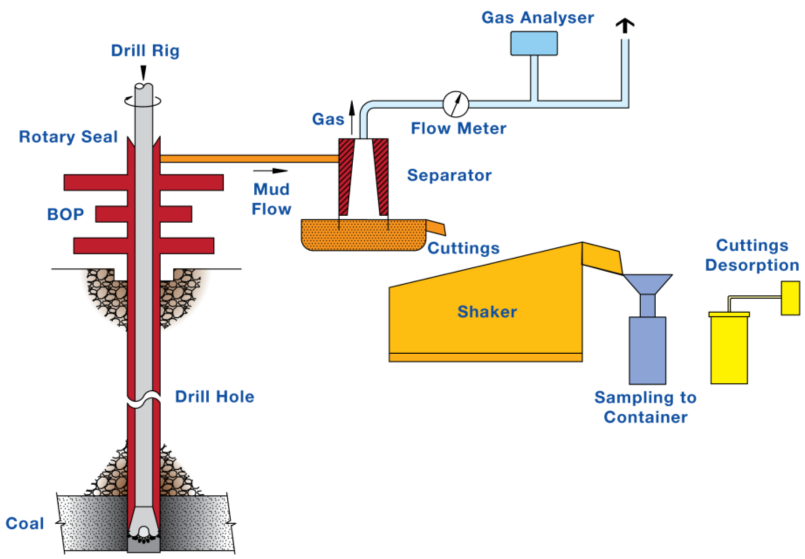

Figure 5 - Schematic diagram of gas content without coring process for surface drilling operations

It is possible to arrange an underground analogue of the system shown in Figure 6. In this case though the drilling fluid must be maintained at an artificially high pressure so that fluid flow into the borehole does not occur. Such a system is shown in Figure 6. This system was developed as part of an ACARP project

(Gray, 1998). Variants of it have been used successfully on surface for controlled pressure drilling but the system has never been used underground. If it were to be used the waste could be diverted to a separator system similar to that of Figure 5 to measure the gas released from the chips that are sampled.

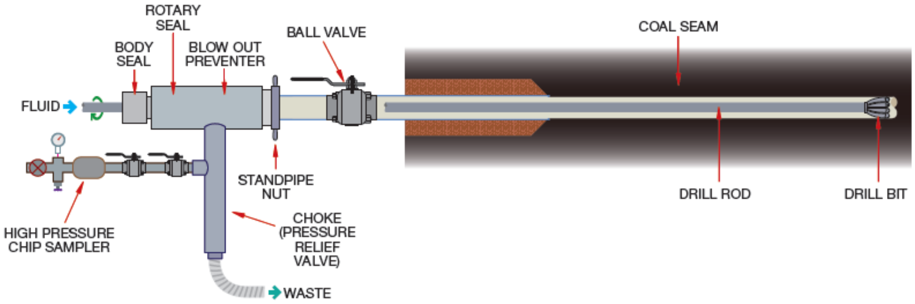

Figure 6 - Borehole pressurization system

IMPLICATIONS FOR OUTBURSTING

Outbursts are sudden expulsions of coal and gas from the working face. They may injure or cause fatalities through the action of mechanical force or through asphyxiation. In worst circumstances the sudden gas release may fuel and ignition which leads to a dust explosion.

The key to knowing danger presented by an outburst is substantially related to the energy release associated with it. Gray (1980,I and 2006) identified the energy sources as being strain energy of the failing material, the expanding gas contained in pore (cleat) space within the coal and from expanding gas which diffuses from the particles. The rate of gas diffusion from particles is related to their size, their gas content and diffusion coefficient. In the 2006 work the bulk of the energy release is identified as being related to expanding gas. Importantly the risk of outbursting is not simply related to gas content as is simplistically assumed by current Australian practice.

The system shown in Figure 3 has most of the components needed to determine outburst risk. The particle size distribution from drilling is determined by sieving the sample following desorption. It may conservatively (on the fine side) be assumed to resemble that produced in and outburst. In addition the diffusion coefficient and gas content can be calculated from the particle sizes, desorption rate and mass of the sample which is collected from the cyclonic separator. The volume of the cuttings held in the cyclone can be easily compared with the nominal volume of the borehole section drilled as another indicator of outburst proneness. If the air flow rate is known and the gas proportion in the return airstream is measured the total gas release from the hole may be measured to reveal abnormalities.

CONCLUSIONS

This paper reviews the process by which gas content of coals is determined by coring noting the main deficiency; namely the determination of the quantity of gas lost during core retrieval. Core gas content measurements can be made more reliable by calculating whether gas loss assumptions are handled properly. It presents a system for finding the gas content of coals by measuring the release of gas from cuttings obtained during air drilling. This has proven to be quite accurate because of the speed with which the cuttings are retrieved, and also the mathematical rigour used to calculate the gas lost from the cuttings between being cut and placed in a canister. This technique is derived from old technology from Europe and Japan (Gray, 1980, II) disregarded in Australian coal mining practice. Used with the correct analytical techniques, updated instrumentation and modern computer power it can be used to provide all the information to determine outburst risk. The exception being that it does not permit the calculation of strain energy.

Drilling with air does however simulate mining into the coal seam the results of which can be observed through measurement of the coal and gas volumes produced. Used with the correct analytical process these measurements can be used to produce energy release estimates on outbursting that incorporate such factors as toughness (through particle size), gas content and diffusion coefficient which are likely to be far more reliable than the blanket process of working off a gas content measurement derived from core.

The paper also presents a system by which the gas content of all strata, including coals may be determined. This is achieved by drilling using over balanced conditions and collecting all gas released during drilling of a hole. This system is intended to permit the measurement of all strata that might break up to form the goaf to be determined. This has important implications for gas release into the goaf and for greenhouse gas emissions.

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