Development of a Portable Coal Seam Gas Analyser

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ABSTRACT: Gas content and composition are important parameters in predictive models for coal seam gas emission calculations, ventilation requirements and design of mine gas drainage systems. Accurate measurement of gas content is not easy. A number of different methods and approaches have been developed in Europe, the US and Australia. This paper examines various testing methods particularly a recently developed instrument, the Portable Gas Analyser (PGA). The PGA is a lightweight and low cost instrument used for direct measurements of seam gases such as CH_4, CO_2 and H_2S. It significantly changes the way seam gas quantities and concentrations can be estimated quickly. It allows quick estimations of these values to be made and reduces the need for full laboratory testing of exploration cores and mine samples to only those with very significant levels.

1 INTRODUCTION

The most significant coal seam gases are CH_4, and CO_2. Smaller quantities of N_2, H_2S and heavy hydrocarbon may also be found. The majority of seam gases are found adsorbed onto the coal microstructures. It is important to be able to both predict the gas content of a coal sample and to be able to forecast and model the gas generating capacity of a coal deposit.

There are many reasons why insitu gas quantity determinations are important to mining. Safety is a primary consideration, particularly in underground coal mining operations where gases released into mine workings may pose a hazard associated with gas toxicity or explosibility. Data on seam gas content allows appropriate operational measures to be undertaken prior to mining to maximise production and safety. These may include increased ventilation quantities and use of seam drainage to maintain gas concentrations within the mine openings below safe limits.

Accurate measurement of gas content is not easy. A number of different methods and approaches have been developed in Europe, the US and Australia. These can be described as direct and indirect methods.

Direct approaches are based upon extracting a coal sample, enclosing it in a sealed chamber and measuring the gas evolved. Indirect methods approach the issue in a number of ways. These include:

- Use of empirical data obtained from ventilation records.
- Gas release from sampled coal fractions from a hole ahead of mining can be undertaken and can be related to high-pressure sorption isotherms determined in the laboratory.
- Detailed chemical analyses can be used to determine material properties including those of gas present.
- Approaches which rely on crushing or pulverising samples and determining release over a short time period.

This paper gives some attention to some aspects of sampling and gas content methods particularly the recently developed approach making use of the Portable Gas Analyser (PGA).

2 SAMPLING TECHNIQUES

The prediction of insitu coal gas liberation levels which will be released in the mining sequence during cutting, breakage and transport can be achieved by testing exploration cores or exposed rib coal. Exploration core samples results can be compared to those of face samples collected during mining through high gas zones to determine the correlation between the two for future prediction of gas levels from exploration core samples.

Intersection of a gas during gateroad development gives an indication of the seriousness of the problems that may be experienced while mining the panel in the near future. In order to predict the levels of gas concentration, a number of different sampling and testing methods can be utilised. These include rib sampling and seam horizontal and vertical drill hole core sampling methods (Gillies et al. 1997 & 1998).

Obtaining representative samples from coal containing seam gases is complex. Some seam gases are highly reactive and difficult to contain.

Each sample collected for immediate testing must be as intact as possible and weigh approximately 1 kg. Samples must be put into plastic bags and sealed on site as soon as possible. The sample should be subdivided into two 0.5 kg pieces, one piece is used in the gas content test and the other is archived for future references. All samples should be named according to the location, sampling depth and time. For longer-term storage of samples Teflon containers or a plastic pipe capped at both ends (Figure 1) can be used. Samples must be tested as soon as possible and preferable within a few hours.

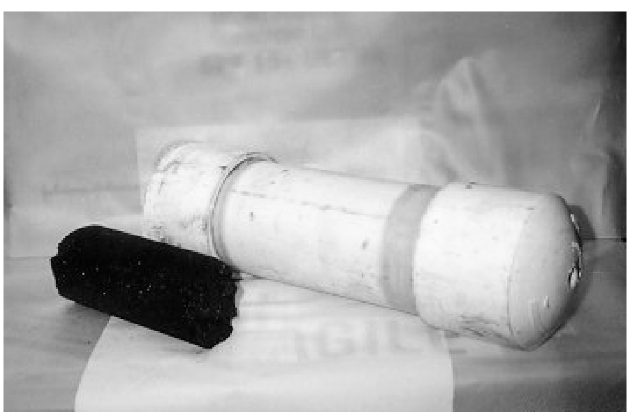

Figure 1. Core sample and plastic pipe container

2.1 *Rib Sampling Technique*

One of the methods of detecting seam gas content is to take channel samples from the rib sides of the gateroad headings when a gassy zone is intersected during development. A number of rib samples should be taken along the development maingate and tailgate headings as seen in Figure 2A. The rib samples can be taken from the middle of the rib sides (Figure 2B) using a handheld pneumatic chainsaw.

2.2 *Seam Horizontal Drilling Technique*

Rib sampling is a good method for predicting the location and the extent of gas zones along the panel if intersected during development. However, it does not provide any details of the size and shape of the zone and on the concentration levels of the gas within the panel. One way of obtaining this information is through seam horizontal drilling.

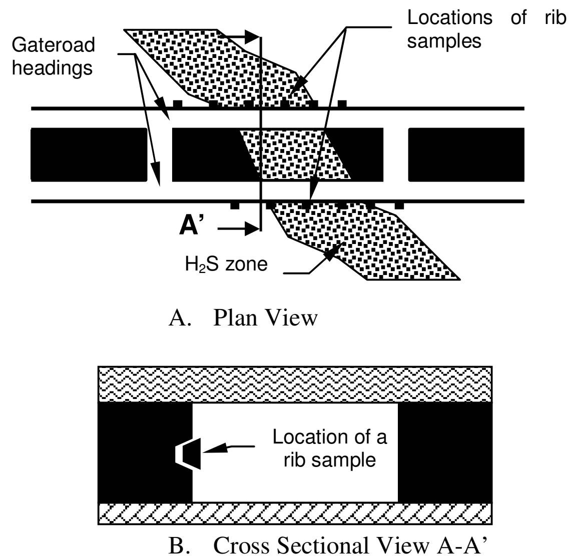

Figure 2. Rib sampling technique

After a gassy zone is located on one or both sides of a panel, a horizontal drilling program can be carried out to determine the extent of the zone within that panel. During this program, core samples should be taken and tested. The location of the horizontal holes and testing results can then be indicated on a plan map.

2.3 *Vertical Drilling Technique*

Another way of identifying the gas zones is the vertical drilling form the surface. Although it is easier to work on the surface and use heavier machinery it is more expensive to drill as a thick layer of rock must be penetrated before reaching the coal seam. In addition, more holes need to be drilled to precisely delineate the gas zone making the approach expensive and time-consuming option.

2.4 *Face Sampling Techniques*

The indicated gas released during mining can be determined from coal samples collected and tested from the panel face while mining through gassy zones. These results can then be compared to these predicted from horizontal and vertical drilling and rib sampling.

3 DIRECT GAS TESTING METHODS

The mechanisms in which coal seam gas is stored in coal assumes that the majority of the gas is contained in the coal as absorbed layer "sandwiched" between adjacent coal layers or as free gas in pores and fissures existing within the coal structure.

In some circumstances the coal matrix pores are so enclosed that gas cannot diffuse out of the sample. These gases remain adsorbed to the internal surfaces even in instances where coal cores samples are exposed to atmospheric pressure for long periods. The gases are known as residual gas and an understanding of them is critical and necessary for evaluating gas reserves and for mine safety considerations.

The most frequent means of determining residual gas, after desorption is no longer evident, is to crush the coal finely enough in an attempt to release the remaining gas. Currently, the most popular techniques used to determine residual seam gas concentrations are through use of chemicals such as silver nitrate, pulveriser, Drum tumbler, and portable gas analyser approaches. Each method has its own advantages and disadvantages, which are discussed below.

3.1 *Silver Nitrate Test*

The silver nitrate test can be used to measure H_2S content. The test procedure requires the sample to be ground to a finer particle size to increase surface area. The test attempts to quantify the amount of H_2S present by allowing reaction with excess silver nitrate to form silver sulphide (Ko Ko & Ward 1996). The unreacted silver nitrate is back titrated against sodium thiocyanate. This value is then adjusted by subtracting the quantity of silver sulphide formed from a blank purged duplicate sample. The amount of H_2S can then be calculated using the formula below.

$$H_2S = \frac{(0.0282 * V_1 - 0.0250 * 22.4 * 1000 * V_2)}{2 * W} \quad (1)$$

Where V_1 = Total volume of silver nitrate
V_2 = Titration volume
W = Weight of the sample

Final H_2S = H_2S in test sample – H_2S in blank sample.

If the blank sample has more H_2S content than the test sample, it is assumed that zero level of H_2S is present in that sample. The silver nitrate test has a number of disadvantages:

- It can give inconsistent results if H_2S reacts with the metal used for grounding the sample.
- The process of pulverising and treating the ground sample with silver nitrate solution is difficult.

3.2 *Pulveriser Test*

The pulveriser test has been developed at the University of Queensland to analyse the total quantity of gas within coal samples. A Seibtechnick standing type t-100 pulveriser has been modified for this purpose. A schematic diagram of the experiment set-up is illustrated below (Figure 3).

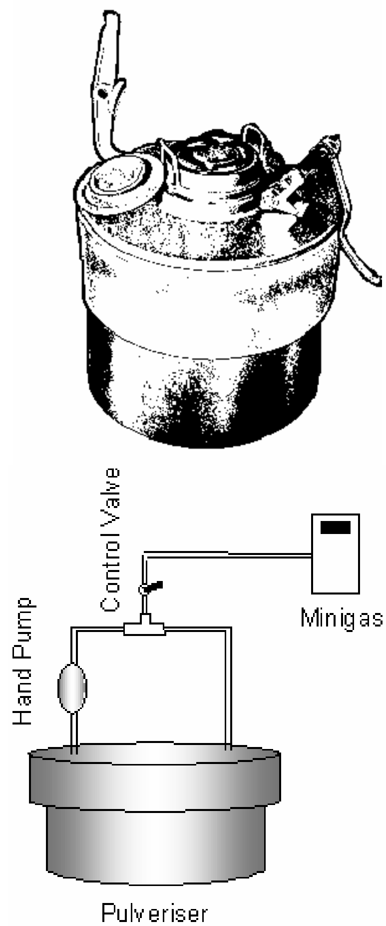

Figure 3. Siebtechnick standing type pulveriser

The steel container of the pulveriser was fitted with a cover with two holes in it, for intake and outlet. A combination of plastic and Teflon tubes were connected such that a loop can be produced. A manual regulator was inserted between the T-connector and the electronic gas detector to regulate the incoming gas directly to the detector as trial readings were taken. The other section of the connector drives the gas back to the steel container as grinding is taking place. The regulator switch is always off during the grinding process. The manual hand pump is used to circulate the emitted gas from the closed loop before trial readings are taken.

In order to determine the H_2S gas emissions as a function of time, a number of 5g coal samples of approximately were pulverised. Samples were placed inside the pulveriser steel container (volume = 431 cm^3) and trial runs undertaken for 5s, 10s and 20s. Gas readings were then taken with the Minigas gas detector and the ground samples were collected for size analysis. An example of gas release is given in Figure 4.

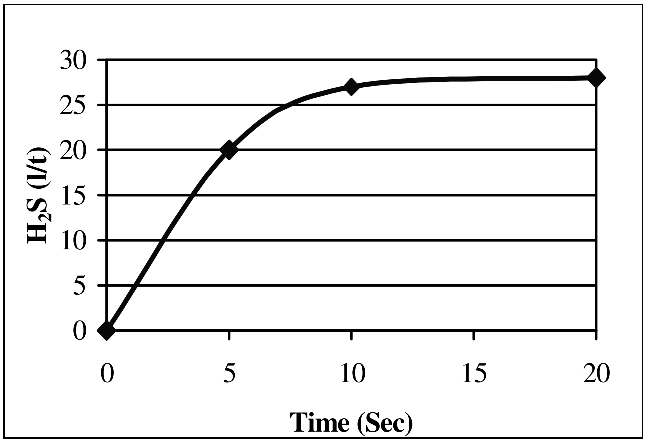

Figure 4. H_2S release rate vs pulverising time

The figure indicates that gas liberation increases as pulverising or grinding time increases. However, it can be noted that gas release decreases over time. This could mean that H_2S gas liberated at 5s time interval is not yet complete, since further grinding to 10s liberates more H_2S. The majority of gas is liberated within the first 10 s grinding time.

3.3 *Drum Tumbler Test*

The drum tumble test is used to measure the level of gas liberated during comminution of a coal sample (Ryan et al. 1988). This test was developed in the late 1980s while mining through an H_2S zone near the Southern Colliery mine portal entries in Central Queensland. The initial drum tumbler had a steel drum of 200 litres coated with tiling cement. A sample of 150 to 180 g was crushed by autogenous milling and then tested for H_2S with a gas analyser. Crushing was effected by rotating the mill at 20 rpm about its long axis for 225s.

A modified version of this machine was designed and built by O&B Scientific incorporating new approaches proposed from operational experiments. The general structure of this drum tumbler is shown in Figure 5. The test predicts the volume of H_2S released into the atmosphere during mining by comparing gas levels measured during mining with drum tumbler results from samples taken from the mining face (Gillies & Kizil 1997).

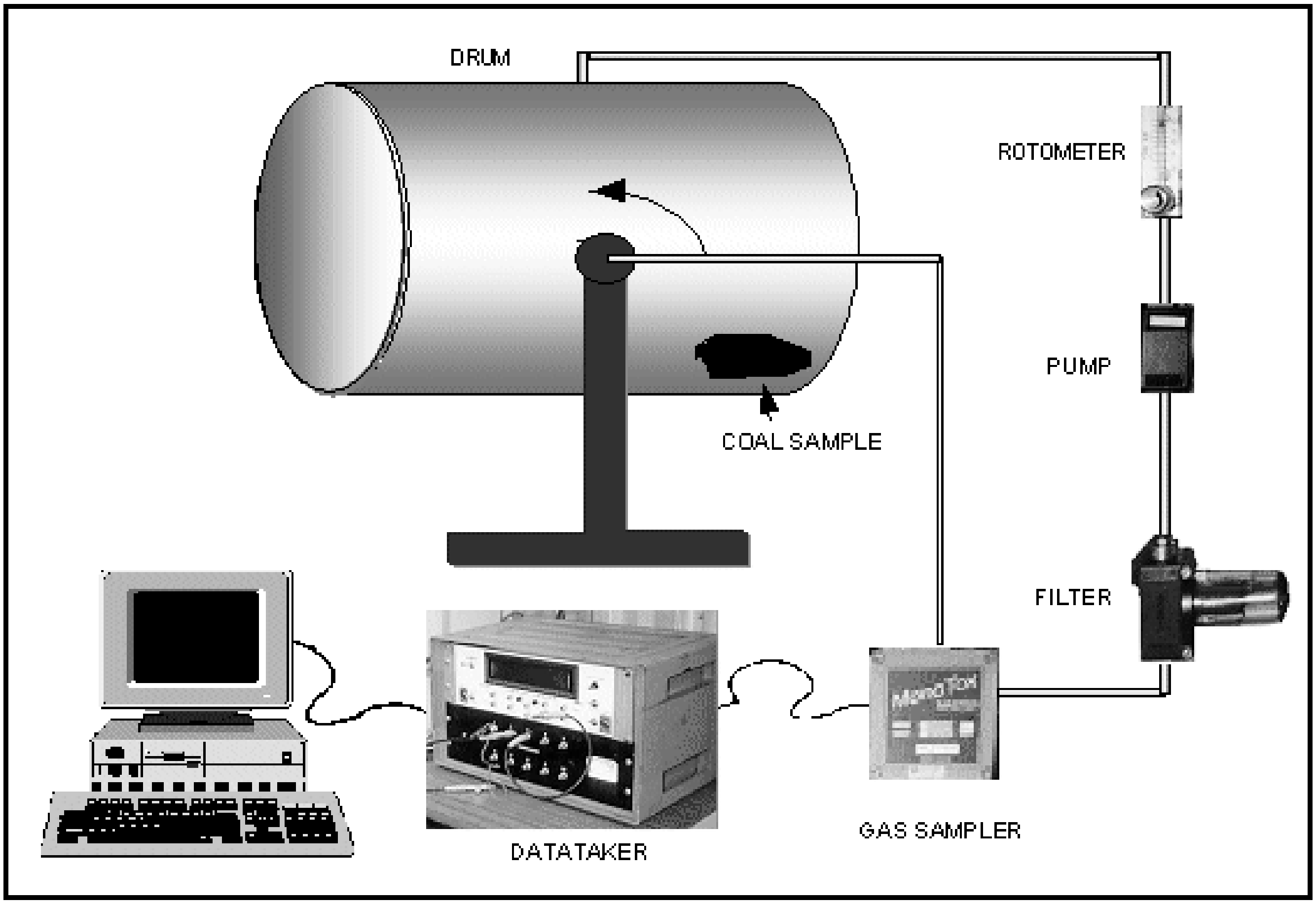

Figure 5. General structure of the drum tumbler (Gillies & Kizil 1997)

The Drum Tumbler is made up of a number of instruments and devices as described below:

Drum: a polyethylene 255 litres cylinder mounted on a steel axel providing 360° rotation.

Gas sampler: reads H_2S gas concentration levels upto 500 ppm within the drum atmosphere.

Datataker: a microprocessor based data logger which measures inputs from monotox device, thermocouple and Zener motor rotation drive and transfers to the computer for data handling and storage.

Computer: linked to the datataker for data read, handling and storage.

Rotometer: adjusts the airflow rate from the pump to gas sampler and keeps it constant.

Air pump: circulates the air in the drum between the drum and gas sampler.

Electrical motor: provides power to rotate the drum.

Electrical motor driver (Zener): controls the frequency (speed) of the electrical motor.

4 DEVELOPMENT OF A PORTABLE SEAM GAS ANALYSER

Coal samples collection from the mine face and transporting to the surface for testing for seam gases is a labour intensive and time consuming process. To simplify the process and save time, an instrument called Portable Gas Analyser has been developed. This instrument is taken directly to the mining face for insitu gas testing.

PGA is a portable coal crusher that is intrinsically safe allowing it to be taken directly to the mining face for insitu seam gas testing. After evaluating several designs for the PGA, the design shown in Figure 6 was selected. Stainless steel construction was chosen to avoid corrosion. The grinding mechanism of the PGA is shown in Figure 7.

4.1 *Testing Procedure*

The coal is placed in the crushing chamber and the crushing plate placed on top. The sample is crushed by the pressing and rotating action of the movable metal plate against the firm metal plate bottom. Screw action crushing pressure is exerted on the coal to be ground. A bottom plate is fitted to stop the bottom portion from rotating while crushing The crushed coal passes through the stainless steel screen to the containment chamber. The gas emitted by the crushed coal is then measured by fitting a rubber hose attached to a gas detector via the outlet valve.

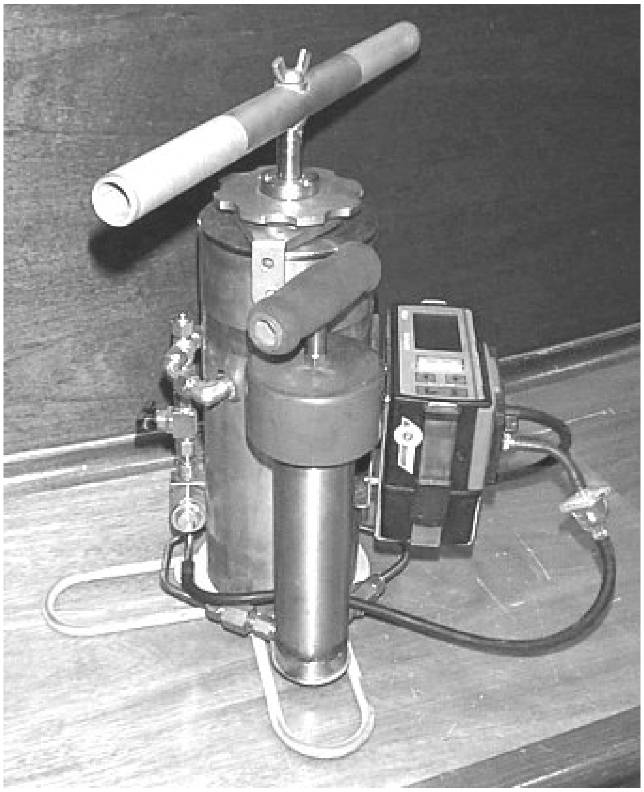

Figure 6. Photographic view of the PGA

Figure 7. Photographic view of the PGA's accessories

4.2 *Accessories*

Container: The stainless steel cylindrical container, has a capacity of 2.5. Approximate weight of the stainless steel grinder excluding the gas detector is 5.6 kilograms.

Air Pump: The air pump is similar to a bicycle pump. It is made in stainless steel and has a length of 180 mm and diameter of 50 mm. Instead of the usual rubber bushings, the pump was installed with Teflon bushings to eliminate recirculation of gases. Holes of approximately 6 mm in diameter were drilled on top of the pump to serve as air inlets. A cover, made up of nylon material was placed on top of the holes to prevent foreign materials from entering the air inlet. To ensure the one way recirculation of the air/gas mixture, relief valves were installed along the inlet and outlet tubing.

Gas Detector: Modern mine electronic portable gas detectors such as the Minigas or Drager Multiwarn II (Figure 8) brand can be used as attachment to the PGA for gas level measurements. This approach to gas measurement was chosen because of portability, versatility and intrinsically safe design.

Figure 8. Drager gas instrument

The Draeger Multiwarn II is a portable multiple gas monitor capable of monitoring and detecting a range of ambient gases such as O_2, CO, CO_2, H_2S and flammable gases. The instrument utilises an infrared sensor for measuring CH_4 and up to four individual electrochemical sensors to measure a range of other gases. It has a built in internal sampling pump for circulating gas to the sensors for measurements and is capable of logging data and providing TWA and STEL evaluation.

The Minigas (Figure 9) can detect H_2S, CH_4, O_2 and CO, simultaneously in one reading. It is a rugged, self-contained instrument with a diecast metal case. It has the option of either a dry cell or a rechargeable (NiCd) battery-pack, which can be changed in hazardous areas. Total weight of the gas detector is approximately 1.54 kilograms.

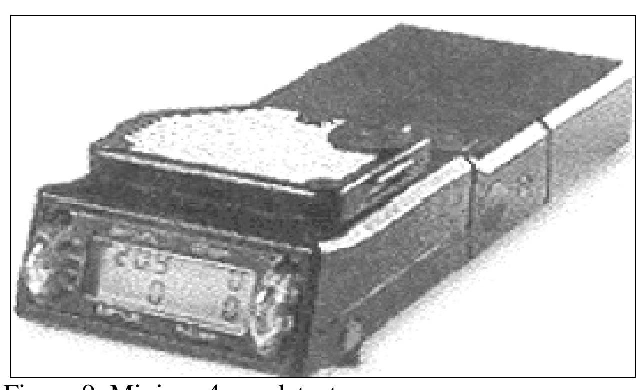

Figure 9. Minigas 4 gas detector

Dust Filter: A stainless steel dust filter is fitted in the gas stream to contain the fine coal dust produced in the crushing procedure and prevent it from damaging the gas detector. The removable filter element is made of stainless steel wire mesh of 40-micron size. The advantage of the inline filter is that it's easy to replace and clean.

4.3 *Testing*

The PGA has simplified the testing of coal samples for seam gases. A small coal sample of known weight is required to be finely crushed by the instrument. The coal gases will desorb quickly from the coal sample into the vessel chamber of the PGA, where the gases are trapped. As the gases liberates, governed by the desorption mechanics, the gas concentration inside the vessel continues to rise towards an equilibrium state. When the equilibrium state is achieved and all free gases have been liberated the gas measurement unit will indicate concentration. The time requires for the readings to reach equilibrium is dependent on the coal matrix pore size, diffusivity, the type of gas and other aspects. This can be seen by plotting gas concentration versus time.

4.4 *Case study*

A number of H_2S measurement tests have been done to check the reliability of the PGA. The table below shows the resulting mass and percentage distribution from coal after passage through the coal grinder using a sample mass of about 5g.

Table 1. PGA test results

Sample #	Mass (g)	H_2S (ppm)	H_2S (l/t)
1	5.01	30	15
2	5.02	37	19
3	5.04	47	23
4	5.06	45	22
5	5.02	26	13
6	5.01	45	22
7	5.06	39	19
8	5.04	44	21
Average			19

As seen from the table, consistent results can be achieved by the PGA with some exemptions. The slight variations in the results might be due to the following factors:

- Distribution of H_2S gas within the coal sample is not uniform,
- Properties of coal is different even for a small portion of the sample,
- Time delay of testing the samples.

After the PGA tests, the crushed coal samples were sized using a Microtrac device. The results of this classification are shown in Figure 10. It can be observed that the size distribution obtained from the coal grinder is identical to the earlier results gathered from the drum tumbler test. However, the PGA results are finer compared to drum tumbler, with 80-90% less than 1 mm size.

4.5 *Advantages*

PGA has a number of advantages over the other direct seam coal gas measurement methods:

- It is light, weight just over 5 kg, can be carried underground,

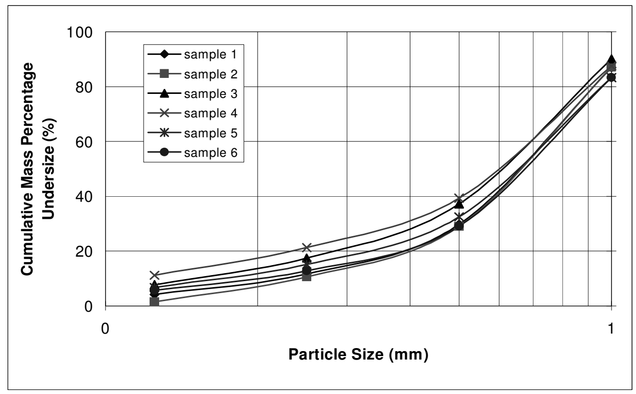

Figure 10. Trend of % weight undersize vs particle size

- It's more accurate as it uses fresh samples underground,
- It is less labour intensive, as coal samples don't need to be taken to the surface,
- It is quick, gas levels of a coal sample can be determined in less than 5 minutes and results conveyed to operations personnel at the face,
- It is one tenth of the Drum Tumbler cost to fabricate,
- It is equipped with a gas detector that reads multi gases (for instance O_2, CO, CH_4, H_2S).

4.6 *Areas of Usage*

PGA can be used for:

- Testing surface exploration core samples for seam gases such as: H_2S, CH_4 and CO_2,
- Testing face coal samples,
- Testing rib samples, and
- Testing horizontal drilling core or chip samples obtained underground.

5 CONCLUSIONS

Despite the recent developments in instrumentations and testing techniques, accurate measurement of seam coal gas content is not easy. Time remains as a critical factor in obtaining accurate estimation of gas concentration. The PGA has been tested to be effective in measuring gas emissions from coal samples. It greatly reduces the sampling and testing time with more accurate results as it can be taken underground for measurements.

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