TEST NOTE

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Hot hole telemetry at Kleinkopje Colliery

Summary

In surface coal mining the occurrence of "Hot Holes" is increasing and blasting these areas is considered a safety risk. In order to understand the conditions in a "hot blast hole", *Designs Unique* have developed a probe recording system that continuously monitor temperature and pressure when explosives are loaded into these holes.

The system was tested in two hot holes at Kleinkopje Colliery on the 11 November 2009. Good results were obtained with the temperature monitoring although limited in-hole pressure data was obtained due to the pressure transducers that were damaged by the extreme heat inside the holes. The maximum pressure generated in the middle of Hole 1 was 14.3Bbar despite temperatures of about 100°C. According to MBP theory the pressures must be greater than 70Bar before an event will occur.

Introduction

During a previous trial with the monitoring system at Kleinkopje Colliery, no test results were obtained due to an electronic phenomenon called 'ground-loop', resulting in all sensors 'tracking' each other, and producing false and confused readings, as explained in test note E-038-09 dated 1/9/2009. Subsequently, a second trial was conducted on the 11th November 2009.

Experimental set up

The telemetry equipment used to monitor the holes consisted of three temperature probes per hole as well as two pressure transducers per hole. The pressure transducers were placed in the bottom and centre of the holes whilst the temperature probes were placed in the bottom, middle and top of the holes. The wiring of the probes was pushed through a normal 20mm PVC pipe in order to protect it

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from abrasion and heat. The temperature probes and pressure transducers were taped onto the outside of the pipe.

Spacing of the temperature probes and pressure transducers were as follows:

Hole no	**Bottom probe**	**Middle probe**	**Top probe**
1	1m from bottom of hole	3.3m from bottom of hole	5m from bottom of hole
2	1m from bottom of hole	4m from bottom of hole	6m from bottom of hole

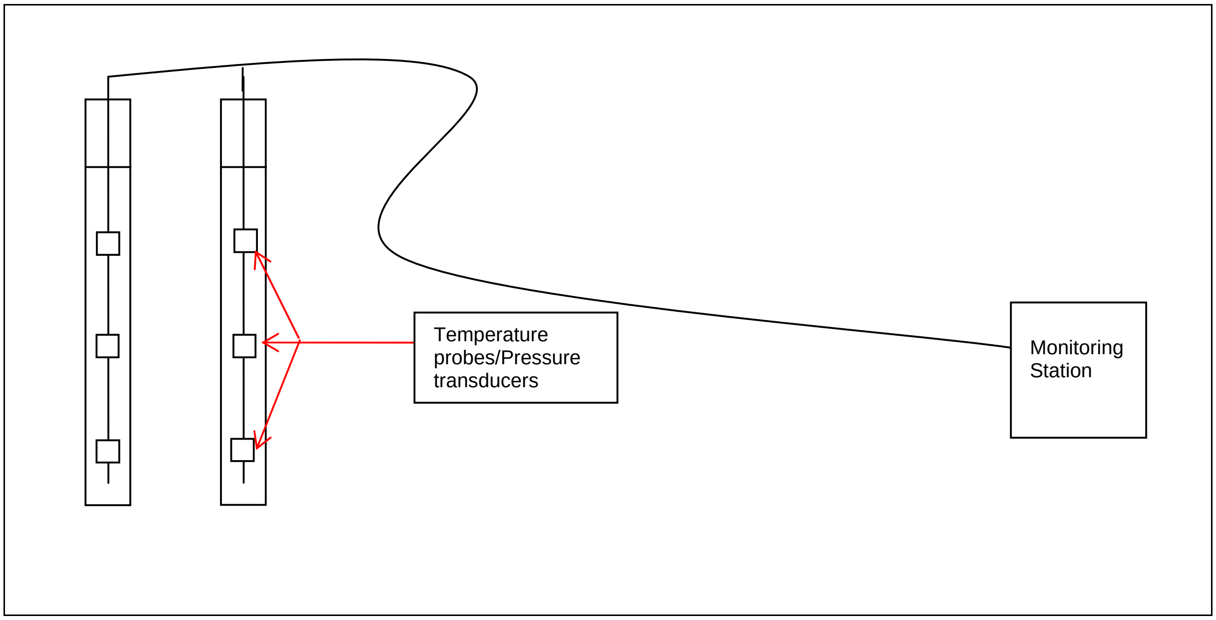


Diagram 1: Schematic layout of hot hole monitoring

Each hole was charged with 200kg of explosives prior to inserting the probes in the holes where after the probes were lowered and positioned inside the holes. The holes were then charged up to 1m from the crest of the hole.

Blast Parameters

Site	Kleinkopje Colliery
Date	11/11/2009
Bench Name	Ramp 13, Overburden
No of Holes	2
Hole diameter	311mm
Explosives	Synergy 435
Charge mass per hole (kg)	Hole 1: 735 Hole 2: 800
Hole depth (m)	Hole 1: 8 Hole 2: 9
Uncharged length (m) – no stemming	1

Two hot holes in the first row closest to the free face were identified by the mine to be used during the trial. The temperature of the holes were measured with the mine's temperature probe that only records temperatures up to 200°C. Both holes recorded temperatures in excess of 200°C because the instrument recorded up to this temperature before it stopped.


Image 1: Hot hole temperature


Image2: Burning coal in a hot hole

Data Recording

Monitoring and recording of the data of the holes were done at a station situated 300m from the holes. Data recording (sampling rate) of the instrumentation was every 5 seconds and the charged holes were monitored for a period of 2hours and 2minutes (from 11:47 till 13:49). During this period, 1462 data points were captured.

Hole monitoring was stopped after 2 hours, the holes were top primed with a 400g booster per hole and set off.

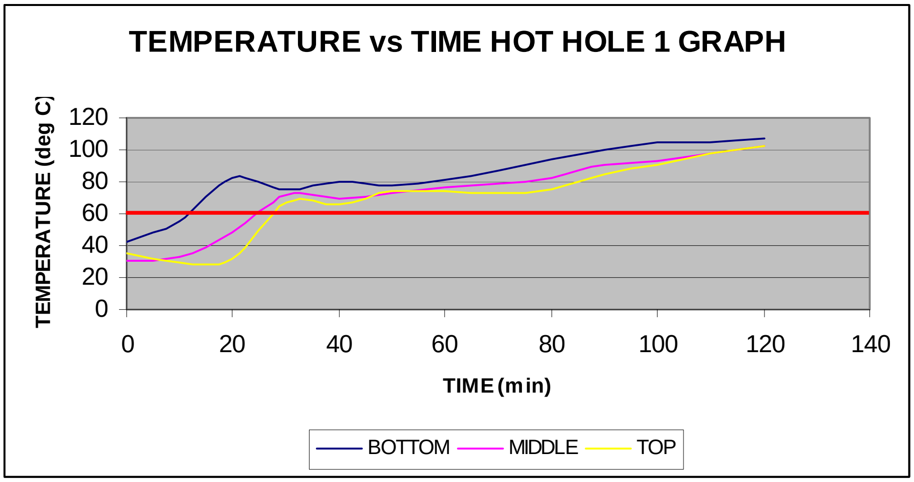
Trial Results

The aim of the trial was to obtain a "footprint" of a hot hole by means of virtual in-hole telemetry; By doing so, guidelines as far as the safe and best way of charging hot holes, can be supplied to mines having to face the difficulty of charging such holes on a bench.

Monitoring of the holes were conducted over a period of two hours, during which time temperature and pressure feedback inside the holes were continuously transmitted to the monitoring station.

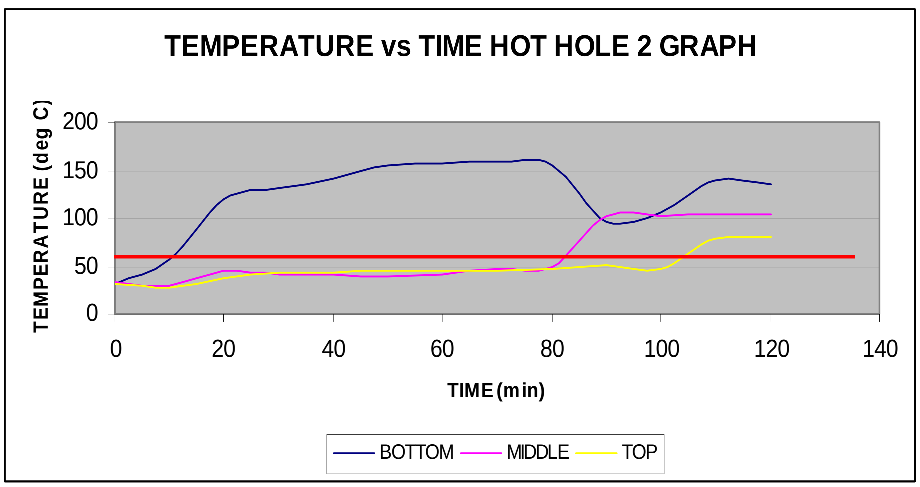
Temperature monitoring results

Graphs 1 -5 below give an indication of the temperature conditions inside the two holes as well as comparative results.



Graph 1: Temperature footprint of hole 1

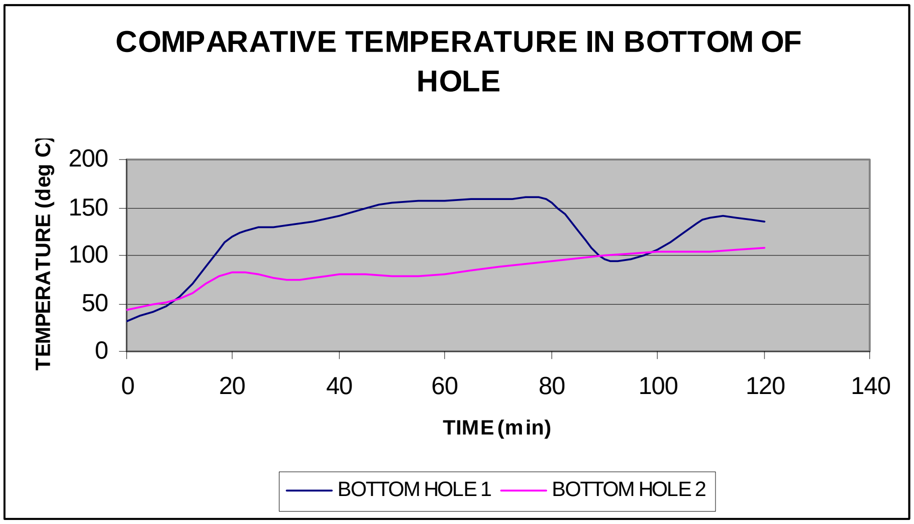
Hole number 1 was the shorter hole (8m) of the two hot holes that were monitored. The temperature increased quite quickly in all three sectors of the hole within the first 30 minutes. Thereafter the temperature increased gradually through the explosives column. An almost uniform temperature just over 100ºC was reached over the entire length of the hole after 2 hours. The two top zones remained within the 60ºC safety limit for 29minutes where after it raised above the safety limit.



Graph 2: Temperature footprint of hole 2

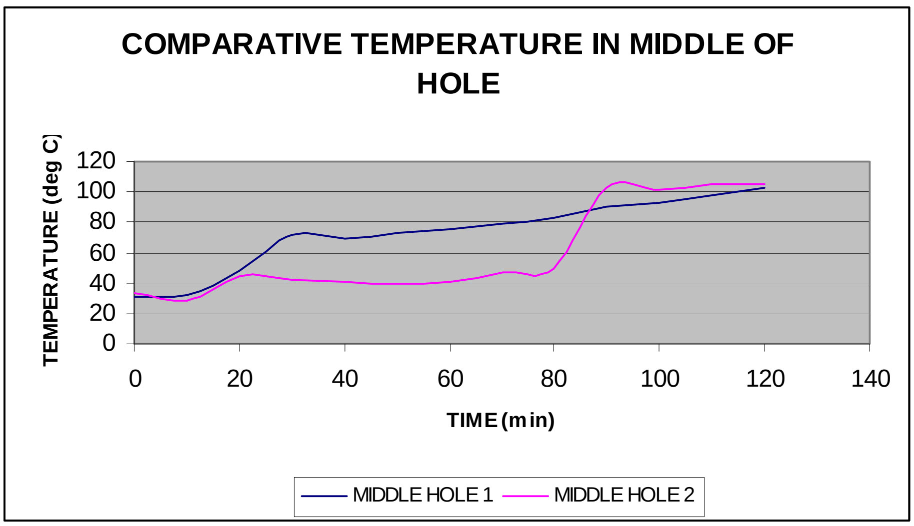
Hole number 2 was the deeper of the two holes (9m). The two top zones remained below 60ºC for 80 minutes where after the temperature of the middle section started to increase suddenly followed by the top section. The top part of this hole remained below the 60ºC safe margin for 100 minutes.

A sudden drop in the temperature of the bottom part was experienced after 80minutes but at the same time a sudden increase in the middle sector of the hole was experienced. The same phenomenon was observed some 20minutes later with the top column. It was noticed that at certain points a fair amount of orange yellow fumes were emitted from the top of the charged holes. It is surmised that this emission is the formation of NOx gases brought about by the decomposition of the emulsion directly exposed to the high temperature burning coal. On one occasion it was noted that this emission corresponded to the drop in the temperature around the thermocouple at the bottom of the hole. It appears therefore that product directly in contact with open flame or excessive temperature is decomposed. The void of gas is filled with cooler product sliding down from above as the lighter gasses escape through the column.

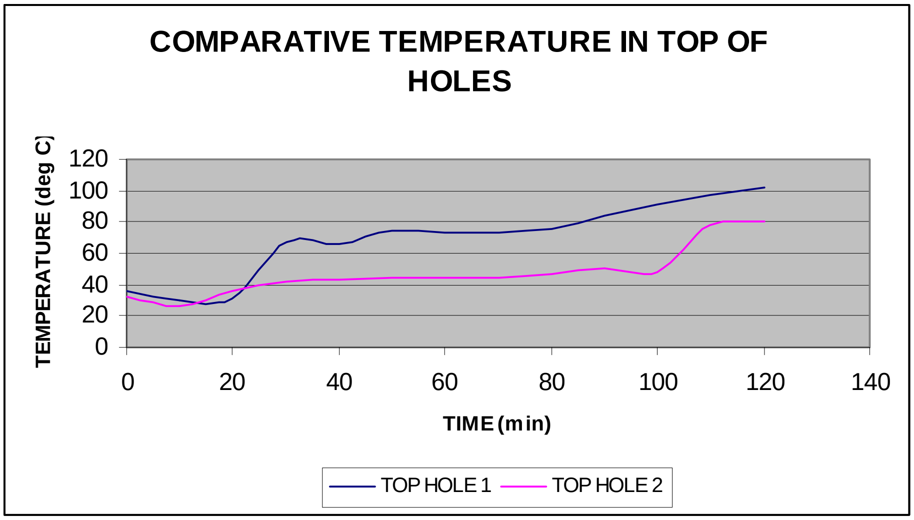


Graph 3: Comparison of bottom temperatures

The original bottom temperatures of both holes (graph 3) were higher than 200ºC. Unfortunately the exact temperatures are unknown due to the fact that the temperature probe only measured up to 200ºC. Both holes were charged with 200kg of explosives prior to lowering the bottom temperature probe. From graph 1 it appears as if hole number 1 was at a higher initial temperature than hole 2.



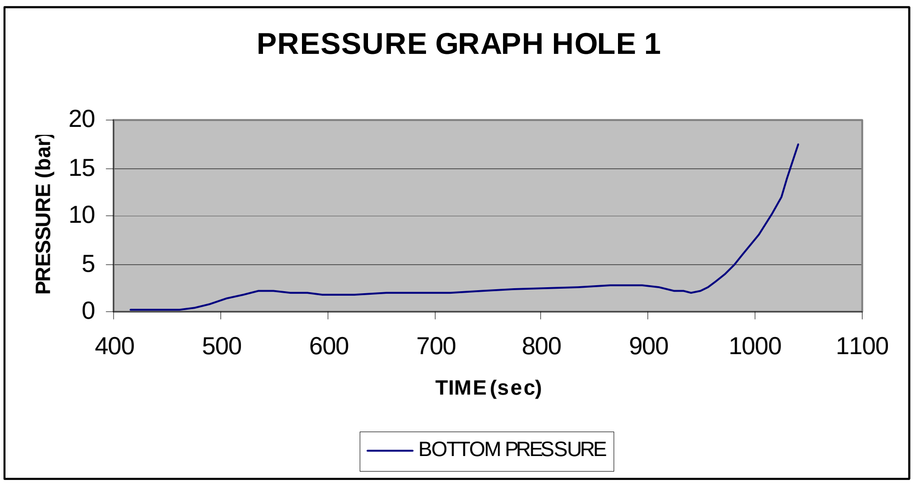
Graph 4: Comparison of middle temperatures



Graph 5: Comparison of top temperatures

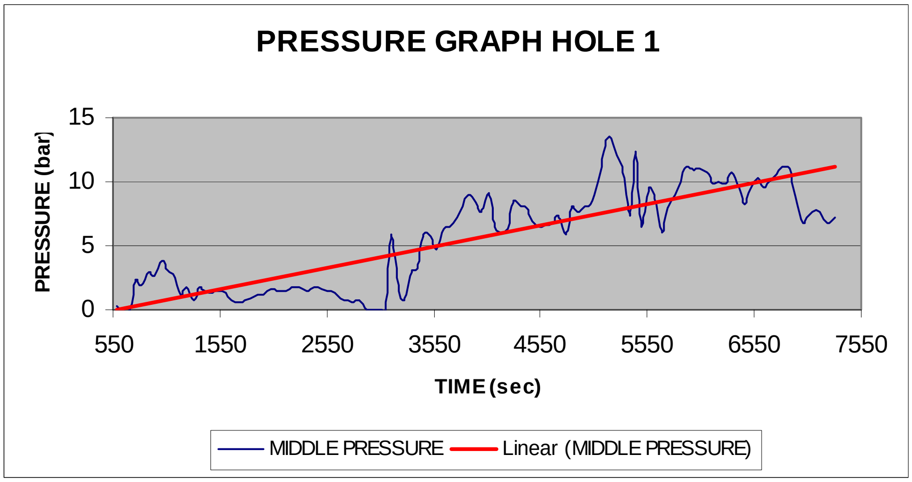
Pressure monitoring results

Graphs 6 -11 below give an indication of the pressure build up inside the holes. Unfortunately, only limited results were obtained due to the fact that the 3 of the pressure transducers were damaged by the intense heat.



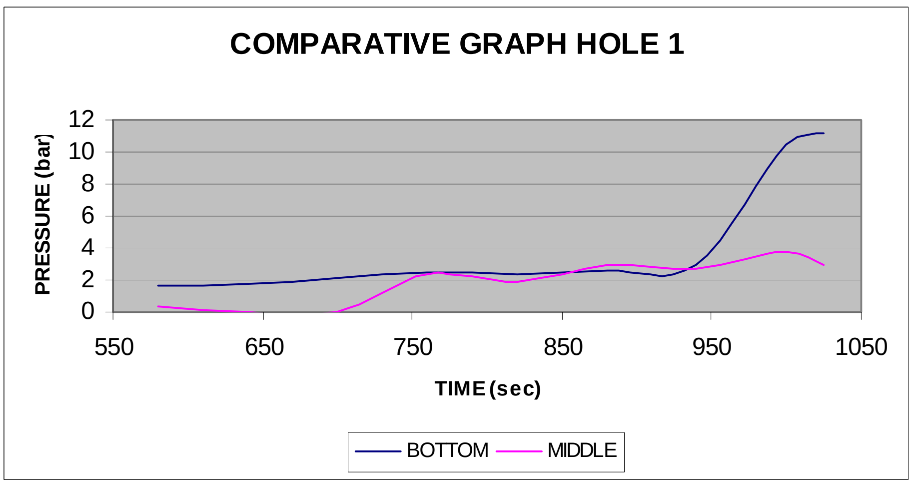
Graph 6: Hole 1 bottom pressure

Recordable pressure built up in the bottom of hole 1 started 6 minutes and 55 seconds after the hole was charged. A maximum pressure of 17.5bar was recorded after 17 minutes at which point the transducer also failed. According to the electronic experts this value corresponds to the signal emitted when the electronics circuitry has failed probably due to the excessive temperature.



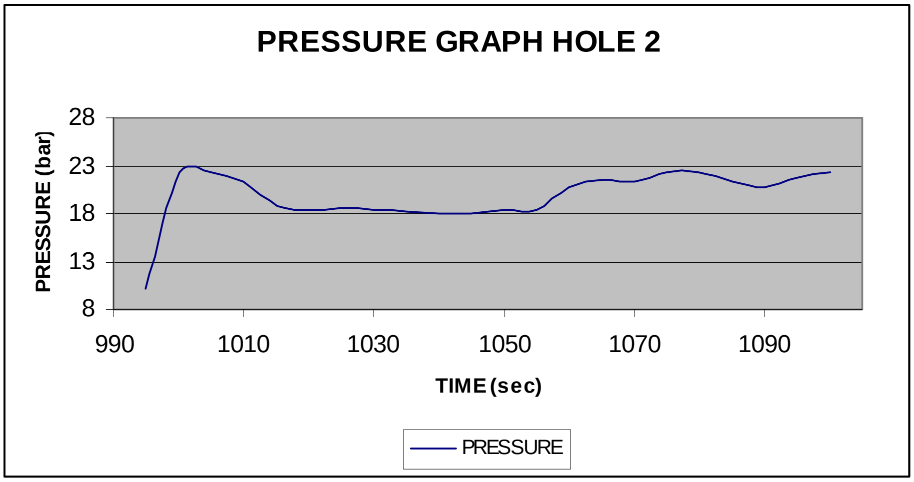
Graph 7: Hole 1 middle pressure

Recordable pressure built up in the middle of hole 1 started 9 and a half minute after the hole was charged. A maximum pressure of 14.6bar was recorded.

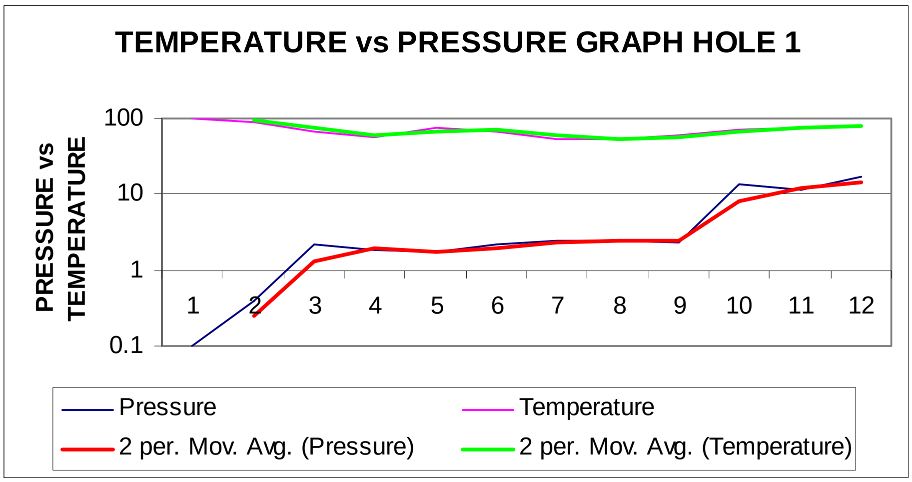


Graph 8: In-hole comparison of hole 1

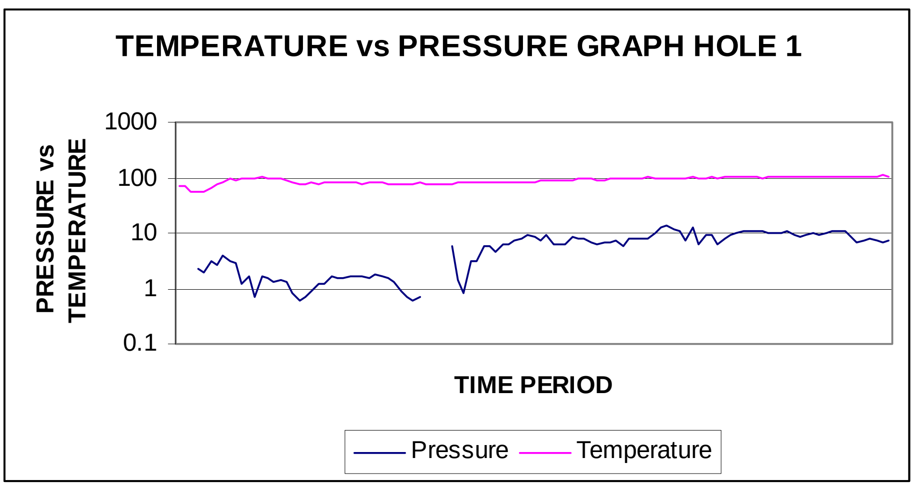
The comparison of the pressures in the two different positions in hole 1 indicated in graph 8, is an overlap for the 17minute period where both transducers transmitted data.



Graph 9: Hole 2 bottom pressure



Graph 10: Temperature/Pressure relation in bottom of hole 1



Graph 11: Temperature/Pressure relation in middle of hole 1

An important point from this graph is that despite temperatures of 100°C the pressure in the middle of the hole rose to a maximum of only 14 bar. This is seen as extremely positive. For an incident to occur the pressure has to build up to the Minimum Burning Pressure (MBP) of the product which is greater than 70 Bar.

Conclusions
Kleinkopje Colliery is currently revising their method of charging up hot holes. This entails that the holes are charged to a pre-determined height from the crest of the hole where after it is top primed with a booster and fired. From a safety point of view, this is a much safer way than bottom priming of hot holes. Hole number 1, that was the worst case scenario as far as the temperature in the top zone of the hole is concerned, had a safety margin of 29 minutes (the time that the hole temperature remains below 60ºC) whilst hole number 2 had a one hundred minute safety margin. Note too that these holes were not cooled prior to loading; If the cooling procedure is time for the temperature to exceed 60°C will be longer.

From the four pressure transducers, only three transducers functioned. Of these three, only one transducer (hole 1 middle) functioned for almost the entire period of the trial (1hour 55minutes). Data received from the remaining two bottom transducers were limited (17 minutes and 2 minutes respectively).

The temperature in the top and middle of the hole is not necessarily dependent on the temperature in the bottom of the hole. This can be seen in hole 2 where the top and middle stayed cool below 60 °C for 80 mins before increasing whereas in hole 1 the temperature in all three regions rose above 60 in a matter of 25 minutes and kept on rising. Although the temperature remained almost constant over the 17 minute period (graph 10) the pressure increased in steps until the transducer failed. However, in the middle of hole 1, the pressure increase was more gradually whilst the temperature almost remained constant.

The pressure in the middle of the hole did not exceed 14 bar.

Recommendations
The data obtained can be used as a guideline in the planning of future hot hole blasting. This data, combined with the hot hole detector, will aid towards the safe charging of hot holes.

A follow-up trial must be conducted with more robust pressure transducers (possibly externally placed) in order to obtain in-hole pressure data over a longer period of time and in the bottom or very hot areas. It is anticipated that the pressure build up will be higher in the bottom of the hole and it is important that we know how high the pressure rises.

Deeper hot holes should also be monitored although short holes as monitored in this trial are considered to be a worst case scenario.

The remote data collection system must be employed and situated at a very safe distance at least 1km from the charged holes.