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ENHANCED GAS RECOVERY FIELD TRIAL: UTILISING A COAL MINE GAS DRAINAGE SYSTEM TO MINIMIZE FUGITIVE EMISSIONS

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ABSTRACT

As part of a PhD research program into the feasibility of enhanced gas recovery for coal mine gas drainage, conducted by UNSW in collaboration with CSIRO under an ACARP project (C17055), the possibilities of achieving very low residual gas contents in coal reserves have been demonstrated (Packham, *et al.,* 2009). Australian coal mines face the prospect of fugitive emission taxation and one method of controlling the emission is by enhanced recovery of the seam gas such that subsequent emissions upon mining are significantly reduced or eliminated. This paper presents the preliminary results of an enhanced gas recovery field trial incorporating nitrogen as an injectant, and utilizing medium radius gas drainage boreholes, in a partially depleted, coal mine gas reservoir.

The trial is being conducted at a coal mine in central Queensland, Australia. The mine pre-drains seam gas prior to mining at depths of 160-230m using medium radius holes referred to as surface to inseam (SIS) boreholes. Typically 3 years of pre-drainage is conducted to reduce residual gas content to 2-3 m^3/t. To satisfy the mine's outburst management plan the efficacy of the drainage is demonstrated by gas content testing using core samples after drainage has been conducted.

The trial involves injecting nitrogen, sourced from a membrane filter, at a maximum flow rate of 500 l/s (STP) and a maximum pressure of 900 kPa (gauge) into existing gas drainage installation. The installation comprises parallel SIS holes typically 2.2km long and 100m apart. The central hole is used as an injector and flanking holes used as producers. Existing facilities enable the monitoring of: injection well pressure and gas flow; production well bottomhole pressure (BHP), gas flow, and water production. In addition gas composition is provided by an onsite gas chromatograph.

INTRODUCTION

The possibility of a tax on carbon emissions from coal mines has prompted an investigation into the feasibility of enhanced gas recovery techniques to remove all methane from coal seam during a pre-drainage operation.

Modelling of enhanced gas recovery from a coal seam using nitrogen as an injectant gas has been shown to be capable of reducing residual gas concentrations to near zero levels (Packham *et al*, 2009). Production data from 4 SIS boreholes at a mine site was history matched to establish reservoir characteristics.

The SIS boreholes vary between 2.2 and 2.4 km inseam length. All SIS boreholes intersect two vertical wells. The well from which water and gas is collected is referred to as the vertical production well (VPW). The vertical production wells are established at the deepest point of the lateral to facilitate water drainage (Fig.1). The second well is a service well (VSW) used for checking lateral pressure and for lateral flushing if necessary.

The history matched model was extrapolated in both normal drawdown drainage and enhanced drainage. One of the SIS boreholes, SIS29, was used as an injection well. The two flanking boreholes SIS28 and SIS30, were used as production wells in the model and subsequent trial (Fig.2).

Results of the modelling indicate that methane would be removed from around the injection well as the nitrogen traversed the reservoir towards the production wells (Fig.3). The model indicates that nitrogen breakthrough of 1% at the VPW28 occurs after 51 days and that an increase in flow rate of approximately 50% at the production wells occurs after 85 days.

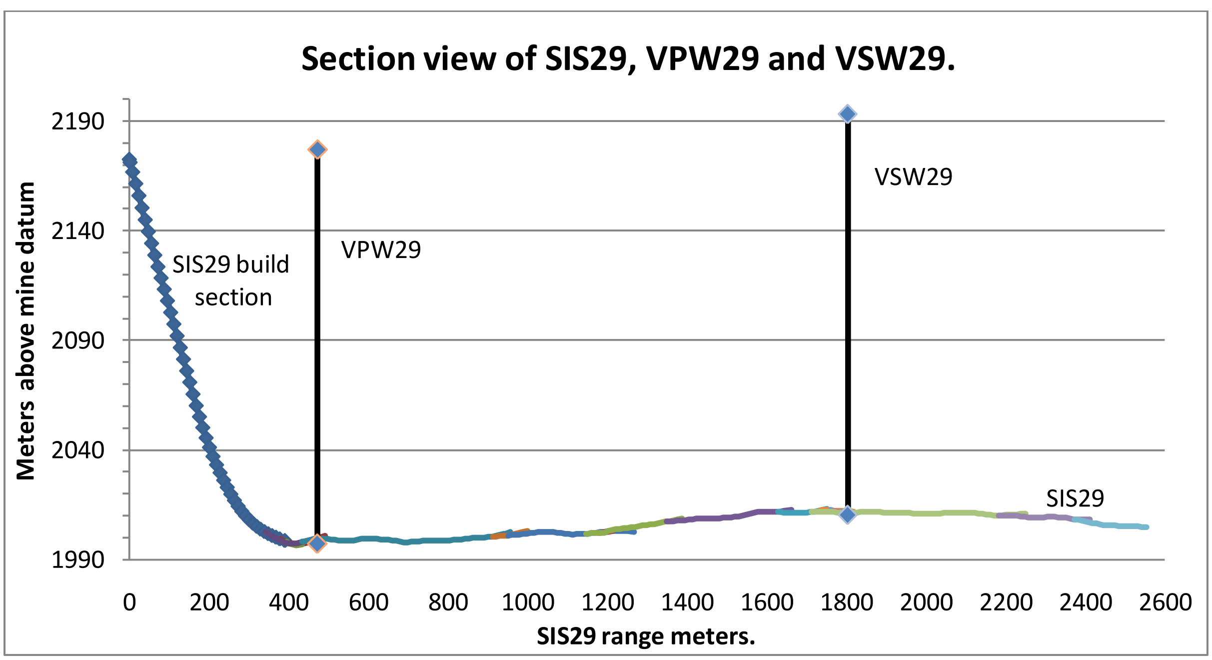

Figure 1. Section view of SIS29 with VPW29 & VSW29.

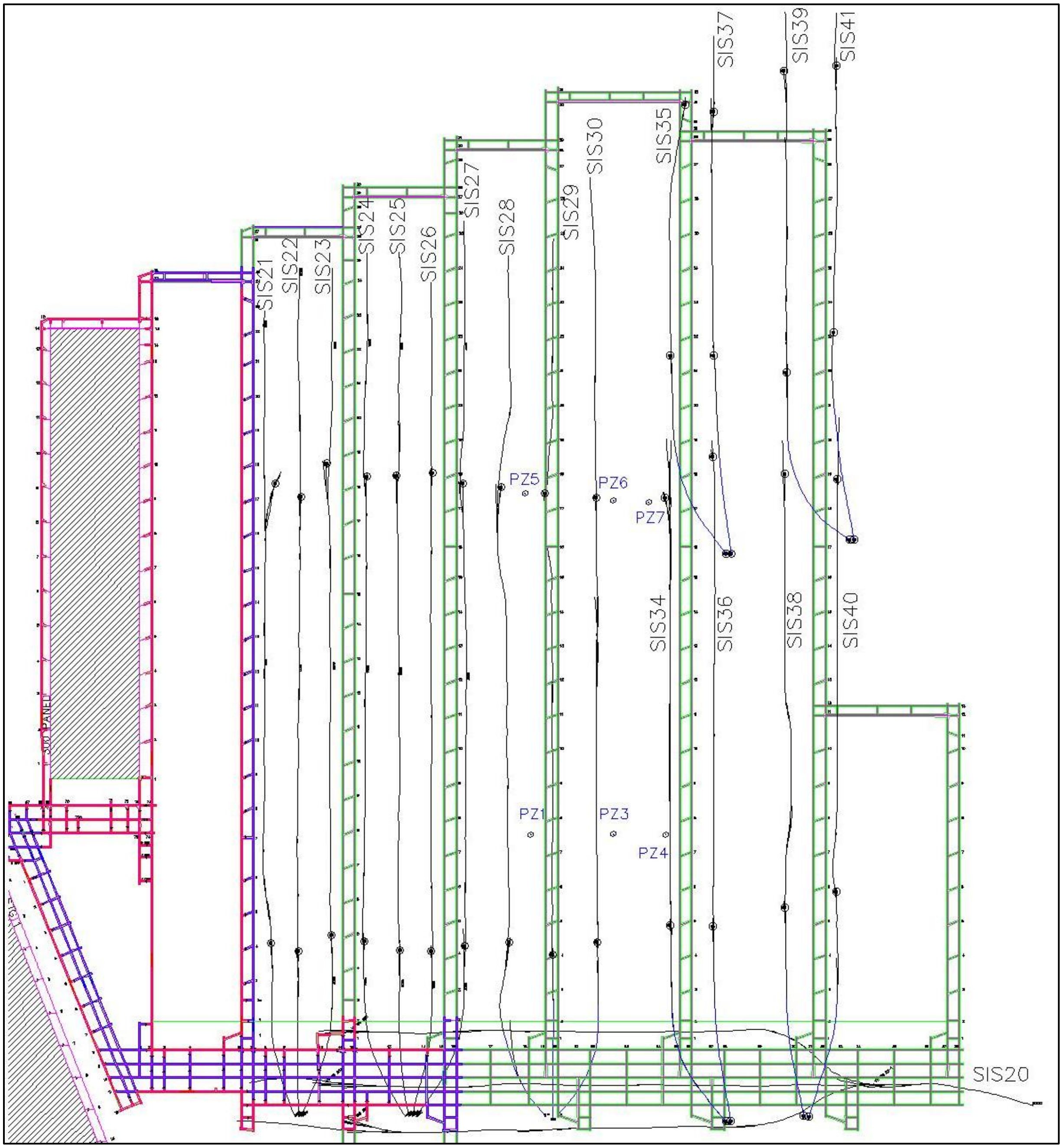

Figure 2. Mine Layout showing SIS28, 29 & 30 and Piezometers PZ1 & PZ5.

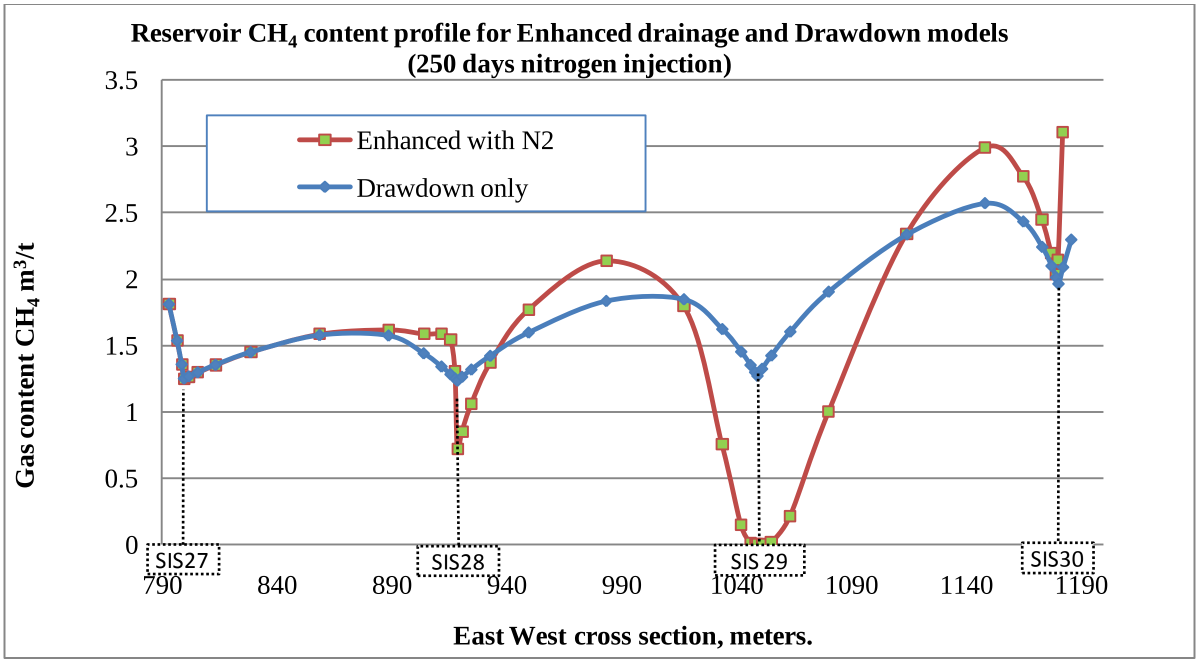

Figure 3. Reservoir methane content with and without enhanced drainage.

TRIAL SUMMARY

Initial commissioning injection began on the13th January 2010. System commissioning was conducted for 6 hours during which period 7,954 m^3 of nitrogen was injected. Further injection was delayed until the 27th January when 138,364 m^3 of nitrogen was injected over 199 hours. The trial was suspended on the 4th February when the nitrogen membrane system filtration developed a problem resulting in reduced system gas production and indications of nitrogen leakage became apparent at the surface around the injection well.

During the trial, the gas flow and gas composition from flanking production wells was monitored, as was pore pressure from two piezometer boreholes (PZ1 and PZ5). The bottomhole pressure and surface casing pressure were recorded at both the injection well and production wells.

No increase in gas production from the flanking production wells was observed and no significant change in gas composition at the production wells was evident. Piezometers “PZ1” and “PZ5” registered changes in seam pore pressure coincident to the time of the gas injection on the 27th January.

The cause of nitrogen leakage to the surface is speculated as either leakage through the casing or leakage from the seam horizon to the surface (177m depth). It is proposed to re-attempt nitrogen injection through an EUE tube from the surface to the seam horizon, isolated from the casing by an inflatable packer installed immediately above the seam horizon.

MONITORED PARAMETERS

Bottomhole pressure

The bottomhole pressure at the VPW29 is characterised by oscillation (Fig. 4). This oscillation represents a change in the water level above the downhole sensor brought about by the water pumping cycle. It is assumed that the inflow of water into VPW29 will stop when the injection pressure is higher than the peripheral pore pressure around the horizontal SIS29.

Daily examination of the service well pressure was conducted when weather conditions permitted. An examination of the records showed that the service well VSW29 pressure during the trial was compatible with that at the injection well. This suggests that the horizontal well was not blocked.

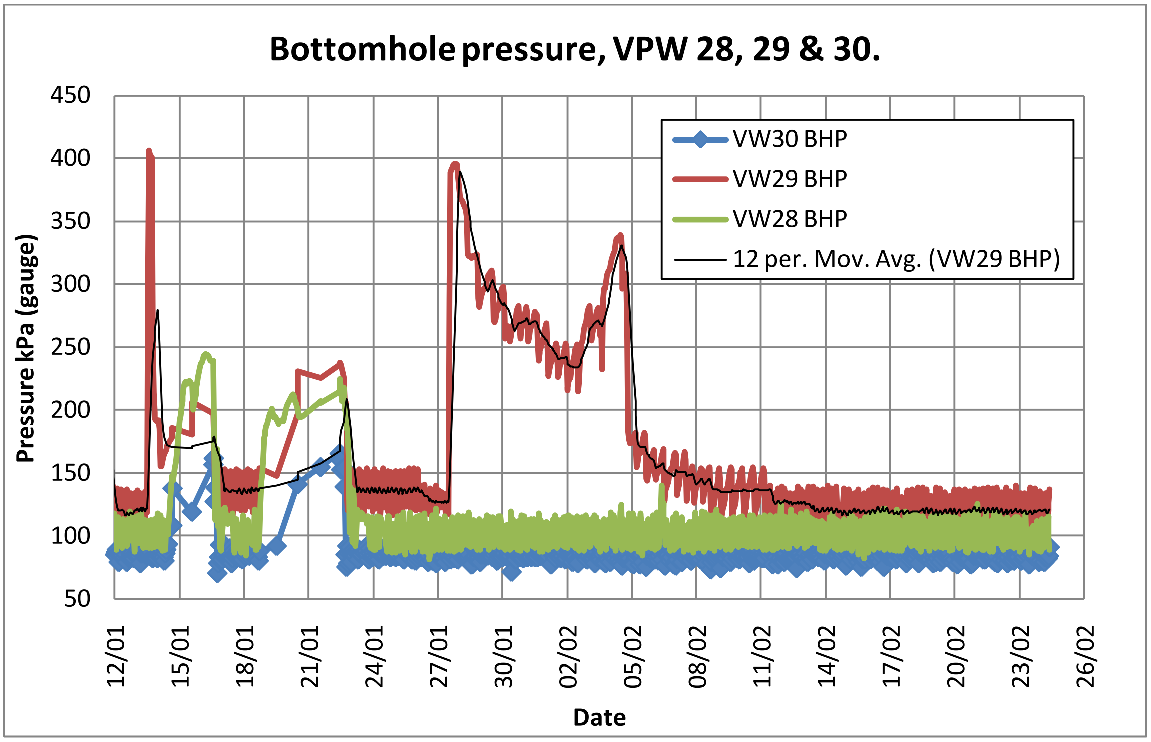

Figure 4. Bottomhole pressure at injection and production wells.

Gas flow rates

Nitrogen flow was measured at both the injection well and membrane filter. The gas flow at the production wells was simultaneously monitored. It can be seen (Fig.5) that the injected gas flow peaked initially at ~1750 m^3/hr (490 l/s) before quickly falling off. No flow rate change was evident at the production well locations.

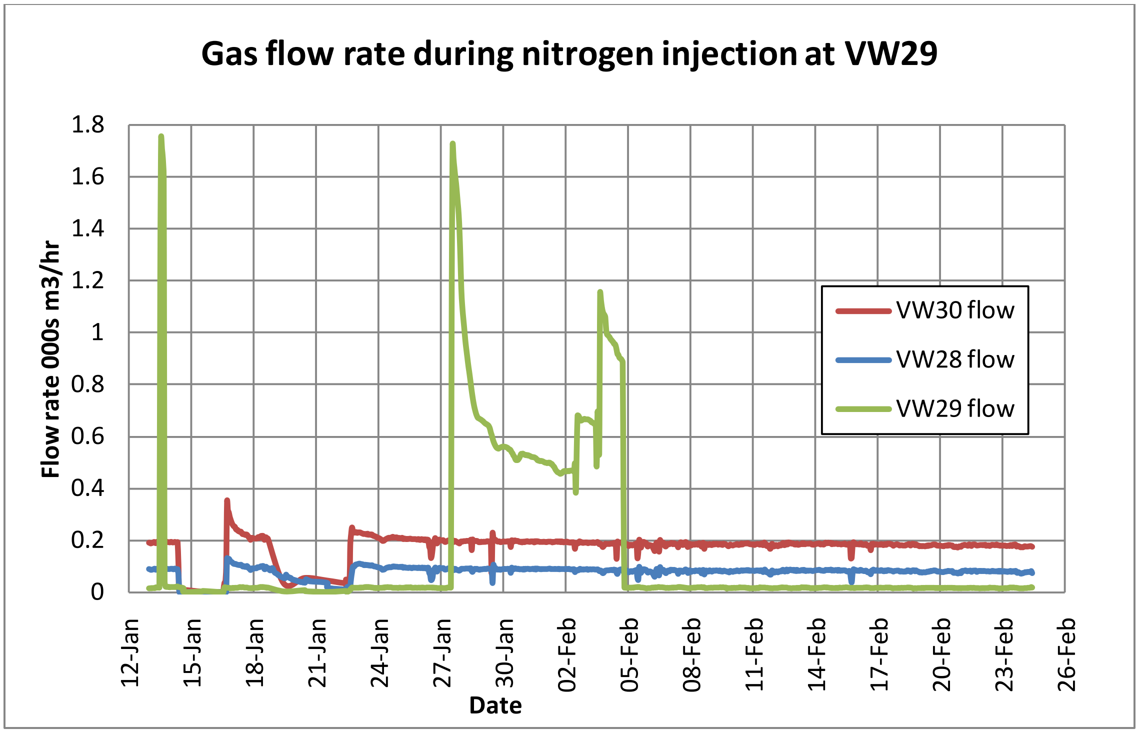

Figure 5. Gas flow measured at VPWs 28, 29 & 30 during N_2 injection trial.

The gas production rate at the membrane filter was measured separately (Fig.6). The nitrogen production rate at the membrane filter matches the nitrogen injection rate recorded at VPW29, indicating that the injection rate was controlled by the membrane filter performance rather than a characteristic of the reservoir. Initial nitrogen purity at the membrane filter was set to 2% oxygen, 98% nitrogen. In an attempt to improve nitrogen production rates the purity was adjusted to 3% nitrogen 97% nitrogen on the 4th of February. This did not however resolve the lack of flow rate and the filter was shutdown pending repairs.

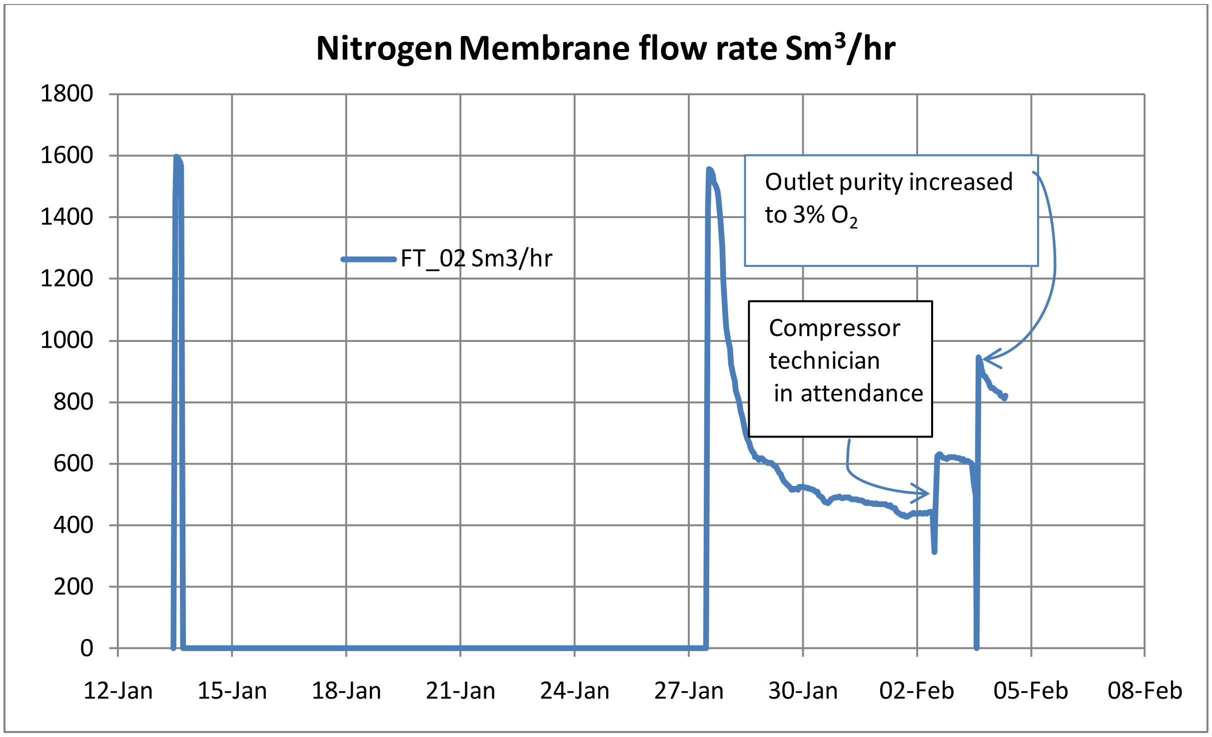

Figure 6. Nitrogen flow rate measured at the membrane plant during N_2 injection trial.

Piezometer results

Both piezometers PZ1 and PZ5 registered changes in pore pressure at the time of the injection starting 27th January. No response was observed during the commissioning trial on the 13th January. PZ1 response was highly variable (Fig. 7); this may be due to the injection pressure falling below the local pore pressure at PZ1 (due to problems at the nitrogen membrane plant) or possibly intermittent leakage to the surface. It is unclear why peak pressure occurred after nitrogen injection was stopped (5th February).

PZ5 (Fig.8) shows a clear increase in pore pressure during the second injection period and a steady decrease in pore pressure when nitrogen injection was suspended on the 4th February. Both piezometers showed a maximum pore pressure increase of around 5kPa. Both piezometers were located approximately 60 m from the horizontal injection well.

PZ1 and PZ5 are approximately 13m difference in elevation, this may account for the lower pore pressure at PZ5. It is noted that any increase in pore pressure at a piezometer location represents 're-charge' of the local reservoir. The increase in pore-pressure observed on 27th January may be reasonably considered as the response to nitrogen injection into the seam.

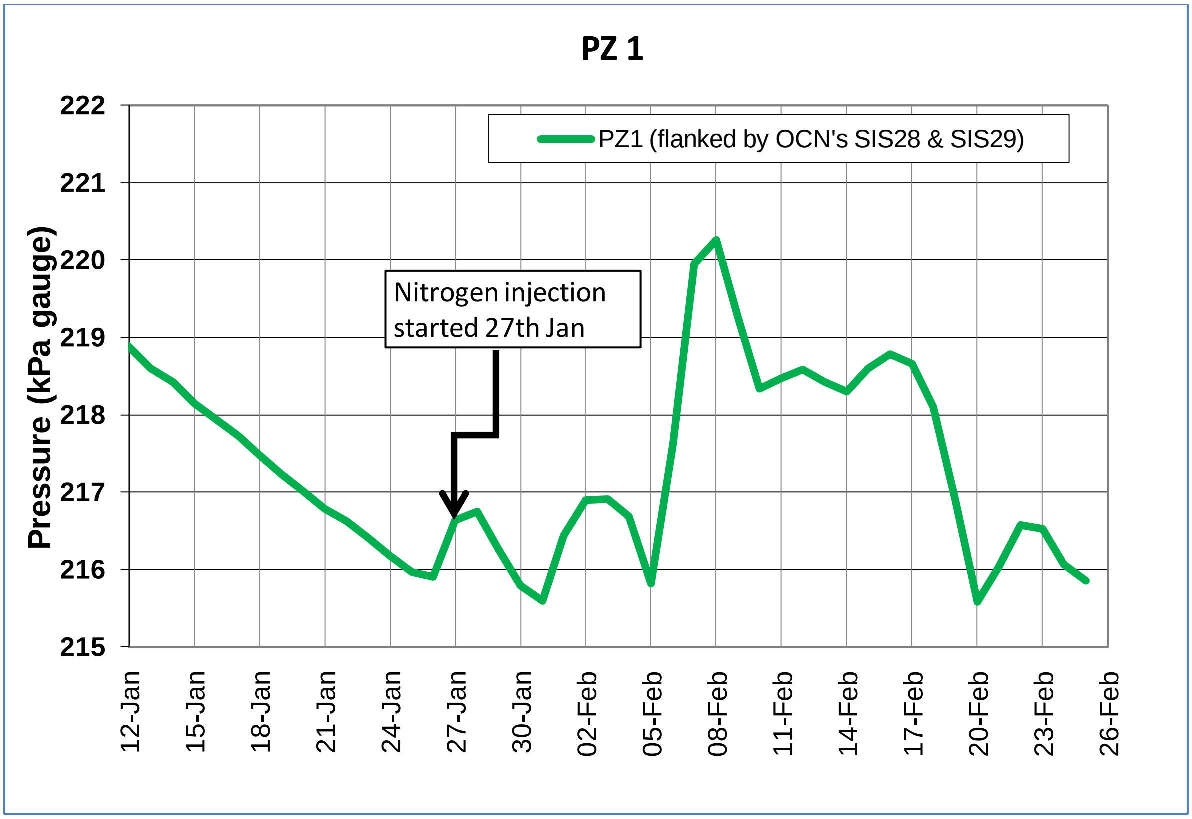

Figure 7. Piezometer PZ1 pressure response during nitrogen injection.

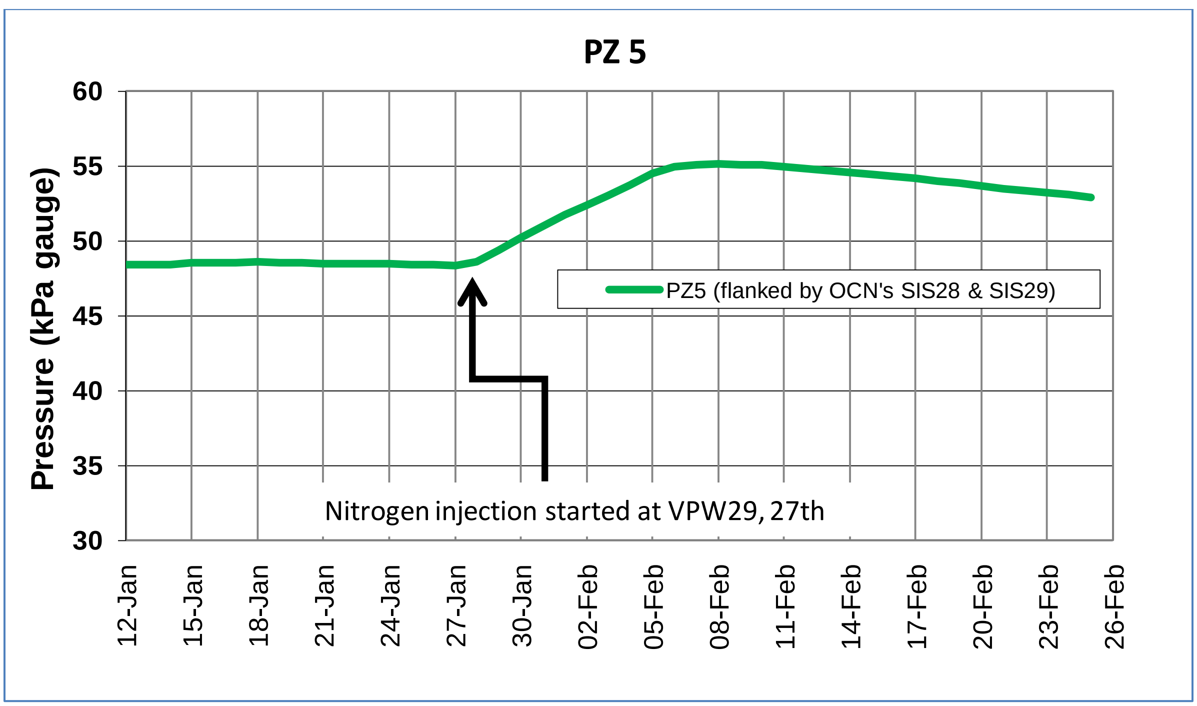

Figure 8. Piezometer PZ5 pressure response during nitrogen injection.

Gas Composition

Gas composition was determined by sampling production well gas from VPW28 and VPW30 on a daily basis during the injection trial. The gas samples were analysed at the mine site using a gas chromatograph. Normalised analysis results represent the sum of component gasses have been corrected to 100%. Leakage of air into the sample bag during sampling is not unusual and can be identified from the oxygen concentration in the sample. The 2% oxygen content of the injected gas, is assumed to have been chemically absorbed in the coal while migrating to the production wells. Correction of the results for an air free condition has been conducted to help determine nitrogen breakthrough (Table.1).

Table 1 Gas Chromatograph analysis results.

		Normalised analysis %							Air free analysis %		
Well	DATE / TIME	H2	O2	N2	CH4	CO2	Ethane C2H6	Ar	N2	CH4	CO2
VPW28	14/01/10 09:27	0.0002	2.61	6.90	89.49	0.92	0.0050	0.08	-3.29		
VPW28	28/01/10 11:36	0.0002	0.56	2.90	95.50	1.01	0.0060	0.03	0.84	98.15	1.01
VPW28	29/01/10 11:20	0.0002	2.56	10.51	86.24	0.93	0.0050	0.12	1.10	97.93	1.02
VPW28	30/01/10 08:13	0.0001	1.23	5.22	92.46	1.02	0.0060	0.06	0.68	98.27	1.05
VPW28	02/02/10 09:48	0.0001	1.83	5.55	91.52	1.03	0.0050	0.06	-1.42		
VPW28	04/02/10 10:38	0.0002	0.56	3.10	95.21	1.09	0.0060	0.04	1.05	97.85	1.09
VPW28	05/02/10 14:03	0.0001	0.68	2.32	95.92	1.06	0.0060	0.03	-0.23		
VPW28	06/02/10 11:20	0.0001	10.62	38.19	50.15	0.59	0.0030	0.44	-2.99		
VPW30	14/01/10 09:18	0.0000	0.77	5.26	92.54	1.36	0.0060	0.06	2.51	96.11	1.38
VPW30	28/01/10 11:32	0.0000	1.29	6.69	90.86	1.09	0.0050	0.08	2.02	96.84	1.13
VPW30	29/01/10 10:01	0.0000	0.71	5.33	92.98	0.91	0.0050	0.06	2.81	96.28	0.91
VPW30	02/02/10 09:44	0.0000	0.90	5.76	92.29	0.98	0.0050	0.07	2.54	96.46	0.99
VPW30	04/02/10 10:35	0.0001	0.98	6.30	91.65	0.99	0.0050	0.07	2.80	96.18	1.01
VPW30	05/02/10 13:57	0.0000	0.22	3.59	95.19	0.96	0.0050	0.04	2.83	96.22	0.94
VPW30	06/02/10 11:18	0.0001	0.43	4.42	94.17	0.93	0.0050	0.05	2.91	96.17	0.92

It is interesting to see that the VPW30 analysis shows noticeably higher nitrogen levels than the VPW28 results. Furthermore, the air free results for VPW28 indicate negative nitrogen results suggesting low nitrogen levels in the gas sample and errors in the analysis accuracy. Whilst there is a slight increase in the nitrogen levels from samples at VPW30 there are insufficient results to confirm breakthrough of nitrogen from SIS29.

SURFACE LEAKAGE

During the trial an unanticipated event – namely gas leakage to the surface - was encountered. Nitrogen leaking to the surface was identified as bubbles of gas at the end of nitrogen pipeline trench, approximately 4m from the VPW29 well head. Unseasonal rain had filled the trench allowing bubbles to be visible (Fig.9). On closer inspection the surface around the vertical well showed small 'pin hole' leakage points up to 15m from the well. An interesting feature of the leakage was the presence of small, dispersed leakage points rather than a localised fracture.

It is important to note that leakage has not been observed at any other well on the site. Well casing typically involves 6m of 9 5/8” diameter conductor and 6 5/8” casing to within 2m of the seam roof. The casing is cement grouted using a displacement technique.

The leakage of gas is considered to present two significant problems to the ongoing trial, viz: preventing mass balance calculations of nitrogen injected into the seam being determined and restricting the injection pressures at which the trial could be conducted. In addition, the loss of nitrogen to the atmosphere had obvious unattractive cost implications.

Figure 9. Gas bubbles evident in the nitrogen pipeline trench at VPW29.

Leakage of the nitrogen at the surface and the need to repair the membrane filter resulted in the suspension of the nitrogen injection trial.

REMEDIAL ACTIONS

The cause of the nitrogen leakage was assumed as either casing corrosion or cement shrinkage around the casing. It is plausible that coal seam matrix shrinkage could have occurred however it is considered unlikely that the shrinkage could result in leakage paths to the surface.

A proposed remedy for leakage through or around the casing is to inject nitrogen directly to the seam isolating the casing. This may be achieved by removing the existing EUE tubing, (currently fitted with a progressive cavity pump) and re-establishing it with an inflatable packer at the bottom of the casing but above the coal seam. The tubing would subsequently be used to inject nitrogen directly to the top of the coal seam. A problem with this proposal is the loss of pumping facility for the well. It can be seen (Fig. 2) that the oscillating bottomhole pressure continued whilst the nitrogen injection was active, implying that water inflow into the pump continued during injection. Close inspection of the bottomhole pressure suggests that the oscillations are not present at bottomhole pressure in excess of 300 kPa (gauge). This suggests that the water inflow may be prevented if injection pressure is maintained above 300 kPa.

At the time of writing this paper the inflatable packer had not been established however repair to the membrane filter had been completed. When injection is re-established an examination of the surface at the injection well, the service well and build section collar will be conducted.

Nitrogen leakage at the injection site represents a significant impediment to adoption of enhanced gas recovery as a standard technique. An alternative approach may be to inject nitrogen whilst drawdown is being conducted rather than injecting into a reservoir which has already been largely drained. This may avoid the possibility of well casing deteriorating due to age and minimise the likelihood of disturbance of the well by subsidence induced ground movement.

It is intended to run the history matched model using the actual nitrogen injection rates in an attempt to estimate how much nitrogen leakage is necessary to result in the effects observed at the piezometer wells.

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