

FINAL REPORT

**Real Time Return Gas Monitoring
for Outburst and Gas Drainage
Assessment**

**C3076
July 1997**

A C A R P

ACARP

Australian Coal Association Research Program

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REPORT ON:

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MONITORING FOR
OUTBURST AND GAS
DRAINAGE ASSESSMENT

REFERENCE:

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1. Abstract

This project involved the design and construction of a return gas monitoring system and its trial at Tahmoor Colliery and Dartbrook Mine. The system comprises hardware components (mainly, high accuracy CH₄ and CO₂ gas analysers, air velocity meter, belt weigher, PLC, MODEMS and computer), data logging software (CITECT) and data processing software.

The prime aim was to create a turn key, prototype, stand alone, real time, gas monitoring system capable of providing quantitative assessments of gassiness levels on at least a shift by shift basis and enabling unusual gas emission patterns to be readily flagged.

The gas monitoring system (hardware and CITECT software), is a fully functional monitoring system in its own right. It has a number of features not found in other systems currently operating in Australian underground coal mines.

The GeoGAS Return Gas Monitoring System (RGMS) data processing software was written from the ground up to undertake the necessary calculations and establish a process for operators to follow, to arrive at meaningful results. The RGMS software is a fully functional PASCAL language (Borland Delphi 2.0), 32 bit WINDOWS program.

Quantification of the face area gas emission on a shift by shift basis has been achieved with low maintenance and high system up time. Reports are generated quantifying the gas make of CO₂ and CH₄ (in m³/t), and the gas quantity in m³. A significant part of the process is validation of the data. That process is well defined in the RGMS data processing software. A hard copy report is finally generated that includes the computers characterisation of the gas emission in terms of abnormally high, normal above average, normal below average, and abnormally low emission.

Via the documented process, the user is provided with a wide range of data and data checks, so that his final hard copy report contains his verdict on the gas emission in a form that should be readily useable in mine gas management plans.

While there is ample scope for further refinement, and research into devising an intra shift gas emission assessment, the system as it stands has considerable application within the coal industry. Particular areas of application are:

- Characterisation of gassiness in areas of difficult drilling. The minor outburst at South Bulli Colliery provided a good example of the application of this system. Return gas monitoring was the only real option in assessing gassiness during mining.
- Return gas monitoring is an additional barrier that could make the Inspectorate feel agreeable to raising the gas content threshold for coals with inherently low gas desorption rates.

- New mines, especially those in Queensland where depth and gas content are progressively increasing with depth, need to know that mining is being carried out in an environment of zero “gas dynamic incidents”. Conditions will change with depth. In addition to measures (such as the GeoGAS Desorption Rate Index) aimed at defining when to take action to alleviate outburst potential, return gas monitoring should prove to be an important additional barrier.
- Existing mines with well developed outburst management strategies can still benefit from this application. Apart from introducing an additional safety barrier, there is the potential to rationalise drilling operations through fine tuning of gas drainage design. In time, there may be scope to increase gas content threshold levels without compromising safety, by placing greater reliance on the return gas monitoring system.
- In the event of an incident occurring, the return gas monitoring system enables the best possible back analysis, quantification and diagnosis of the event. The “borehole blowout event” at Tahmoor Colliery is one such example.
- Miner drivers from time to time report increased (or decreased) gassiness. Ready access to return gas monitoring data can help to understand the environment, alleviate peoples concerns and take action as appropriate.

2. Summary

2.1. Project Objectives

The prime objective was to create a turn key, prototype, stand alone, real time, gas monitoring system capable of providing quantitative assessments of gassiness levels on at least a shift by shift basis and enabling unusual gas emission patterns to be readily flagged.

Sub objectives were:

- To define and document the process of using this data to back analyse gas drainage effectiveness.
- To assess the potential for using the technique to quantitatively define seam gassiness on a sub shift period basis.
- To define indices relating the gas emission response (rate of emission, peak emission rate, quantity, composition) to outburst proneness in terms significant to outbursting.

The project scope covers design and fabrication of the gas monitoring system, trial of the system at Tahmoor Colliery and Dartbrook Mine and development of reporting procedures and associated software to facilitate its real world application.

2.2. Main Findings and Conclusions

The prime aim has been essentially achieved.

The “turn key” aspect of the project has been an overriding consideration. By “turn key”, we mean a system that has been thought through, is well documented in its application and is robust.

The gas monitoring system (hardware and CITECT software), is a fully functional monitoring system in its own right. It has a number of features not found in other systems currently operating in Australian underground coal mines:

- High gas analyser accuracy coupled with short response time.
- High sampling frequency (down to 2 seconds).
- High level of flexibility in setting sample rates and moving averages, with the user able to change settings in the PLC via the CITECT software interface.
- Complete automatic calibration of the gas analysers.

- A high level of PLC controlled condition monitoring to ensure that the system is working.

The decision to use CITECT software was made to create a fully functional, WINDOWS based, operator interface, complete with trending, alarms and user access rights. CITECT is an Australian made and supported product, that is becoming widespread throughout the industry.

CITECT is good for data logging and trending (real time functions), but less amenable to intensive data processing. The GeoGAS Return Gas Monitoring System (RGMS) software was written from the ground up to undertake the necessary calculations and establish a process for operators to follow, to arrive at meaningful results. The RGMS software is a fully functional PASCAL language (Borland Delphi 2.0), 32 bit WINDOWS program.

Because it is a separate program to CITECT, it has the ability to process data derived from any SCADA package - not just CITECT.

The system achieved shift by shift assessment of gas emission. It was built with the capability to undertake intra shift analysis, by inclusion of the belt weigher output. The belt weigher worked long enough at Tahmoor Colliery to establish that this aspect works. The system hardware and the CITECT software take full account of the belt weigher output. Additional programming of the RGMS data processing software is required to include belt weigher output. Other algorithms will need to be developed in this software to use belt weigher output for intra shift assessments.

The aim of “defining and documenting the process of using this data to back analyse gas drainage effectiveness” has been achieved, but without physically undertaking an actual analysis.

The subsidiary aim to “assess the potential for using the technique to quantitatively define seam gassiness on a sub shift period basis” was not addressed due to inability to obtain belt weigher data.

The aim of “defining indices relating the gas emission response (rate of emission, peak emission rate, quantity, composition) to outburst proneness in terms significant to outbursting” has been reasonably achieved. The detailed reporting process as defined in the RGMS data processing software, guides the user toward arriving at a decision concerning the level of gassiness of the coal being mined and implications from a gas emission and outburst view point.

The system is put forward as an additional barrier to outburst prevention. Until more use is made of the technique, it is not seen as a replacement for existing barriers.

A small outburst at South Bulli Colliery triggered a real life need for this type of monitoring. Day by day updates on the levels of gassiness during mining were forwarded to the mine. Data files were accessed via MODEM, processed, and a report faxed back to the

mine. This showed that that concept had application, even though the data processing at time, was quite cumbersome.

A significant benefit beyond the scope of the project is the ability to use this data to more accurately model gas emission on development for design of ventilation and as necessary, gas drainage and gas capture control measures.

2.3. Work Program Description

The GeoGAS Return Gas Monitoring System (RGMS) is comprised of underground and surface located hardware, SCADA (SCALable Data Acquisition) software and data processing software.

Logged data from the SCADA software (CITECT) provides values and trends for:

- CO₂ flow rate (l/s)
- CH₄ flow rate (l/s)
- CO₂ concentration (%)
- CH₄ concentration (%)
- Air velocity (m/s) and air quantity (m³/s)
- Production rate

The data processing software differentiates background emission levels and on a shift by shift basis, calculates the following face area emission:

- Peak CO₂ emission rate (l/s)
- Peak CH₄ emission rate (l/s)
- CO₂ quantity (m³)
- CH₄ quantity (m³)
- CO₂ gas make (m³/t)
- CH₄ gas make (m³/t)

The system is comprised of the following main items of equipment:

UNDERGROUND

- 2 x UNOR 610 Gas Analysers (CO₂ and CH₄)
- 1 x Allen Bradley SLC 500 PLC
- 1 x Control Systems Technology IPM-10 Belt Weigher Monitor
- 1 x Mikan Short Haul Modem
- 2 x Calibration gas bottles (“DS” size Alpha standard span gas and “D” size HP N₂)
- 1 x Trolex TX1322 Vortex Shedding air flow sensor

ABOVE GROUND

- 1 x IBM Compatible PC running CITECT for WINDOWS SCADA package and the GeoGAS Return Gas Monitoring System data processing software.

- 1 x Mikan Short Haul Modem

The system PLC maintains autonomous control of the underground system accepting input data from the gas analysers, belt weigher controller and air velocity sensor every 2 seconds. It is normally in continuous interactive communication with the surface CITECT monitoring PC, buffering then forwarding data.

Some of the more notable system features are:

- Scaling of analog inputs under Auto Ranging Control.
- Calculation of moving averages of analog inputs to allow damping of signal levels, in particular, fluctuations in the air velocity signal .
- Totalising of coal production as recorded by the belt weigher. This is done on a per shift, day and year basis.
- Control of the auto-calibration procedure for the gas analysers. The PLC is programmed to calibrate the gas analysers at an automated interval (weekly), or under command from the surface PC. Pressure sensors in the Zero and Span gas lines allow the PLC to indicate fault alarms when the calibration gases are spent.
- Alarm monitoring of CH₄ % and CO₂ % concentration levels.
- Decoding of gas analyser control signals to enable text display in CITECT of the current status of the gas analysers and calibration gas bottles.

The system cabinet contains a mix of electrical and mechanical components, some intrinsically safe but most “non-IS”. The system must at all times be operated within non-hazardous conditions. If the system PLC detects CH₄ levels at or above 1.25% for 10 seconds it will send an alarm flag to the surface PC and then immediately shutdown the system, isolating power to the interlocked door switch.

The operators “window “ to the RGMS is provided by the “CITECT for WINDOWS ver 3.4” SCADA package. This software communicates with the PLC “reading from” and “writing to” the PLC registers in “real-time”.

The CITECT software enables user interaction for trending, user access privilege control for PLC settings, trending pages and alarm setting and acknowledging.

The GeoGAS Return Gas Monitoring System data processing software accesses ASCII or dBase files generated by a SCADA package (such as CITECT) and provides a means for calculating, checking and reporting the gas emission data. Its prime function is to aid the determination of gas conditions at the face, providing an additional safety barrier to measures currently being adopted.

This software is limited to evaluating the gas conditions at the completion of mining for the shift in question.

The software defines a process for calculating the gas emission indices and assessing the validity of the data. In addition to quantifying the gas emission, the software compares the results to historical readings and provides a rating of the emission (abnormally high, normal higher than average, normal lower than average, abnormally low).

Site trials were carried out at Tahmoor Colliery (13/2/95 to 13/10/95) and at Dartbrook Mine (9/1/96 to 15/11/96).

The Tahmoor Colliery trials succeeded in quantifying and characterising the gassiness on a shift by shift basis for coal that had been predrained to below the threshold limit for outburst alleviation. A major incident was recorded, involving mining into a pressured, in-seam borehole. The belt weightometer, which was originally configured for West Cliff Colliery proved unsuitable for the belt structure at Tahmoor Colliery.

Improved system up time was achieved at Dartbrook Mine. Background emission comprised the majority of gas emission (80%). This is a very different gas emission response compared to Tahmoor Colliery, where background emission comprised 46% of the total emission. The contrast is even greater given that Tahmoor Colliery have predrained the seam and Dartbrook Mine have not. Such high background emission is due to the large gas reservoir at Dartbrook Mine.

Compared to Tahmoor Colliery, gas quantities generated in the face area are around 5 times higher. This appears to be the normal pattern for gas emission of undrained coal at Dartbrook Mine. No "abnormal" emissions (for Dartbrook) were recognised. Gas makes and peak emissions above background are similarly high compared to Tahmoor Colliery.

Real life application of return gas monitoring occurred at South Bulli Colliery, in response to a small outburst in a cinder zone. At one stage, preparations were under way to transfer the RGMS equipment from Dartbrook Mine, but it was decided to adapt the mines gas monitoring system to this application. With a MODEM link to daily generated data files, daily reports were provided to the mine on the level of gassiness encountered. As a guide, a draft threshold established for Tahmoor Colliery was utilised. Emission levels were all low.

The South Bulli Colliery system was compared with the GeoGAS system.

2.4. Potential for Industrial Applications

The minor outburst at South Bulli Colliery provided a good example of the application of this system. The South Bulli Colliery cinder zone was so fragmented, that gas content cores could not be taken and in-seam drilling for gas drainage was very difficult. Return gas monitoring was the only real option in assessing gassiness during mining. As embryonic as the system was, it did provide data that the colliery could use and in a timely manner.

GeoGAS has been involved in making cases for raising the gas content thresholds in some mines (on the basis of an inherently low gas desorption rate as measured by the GeoGAS Desorption Rate Index). Return gas monitoring is an additional barrier that could make the Inspectorate feel agreeable to raising the gas content threshold.

New mines, especially those in Queensland where depth and gas content are progressively increasing with depth, need to know that mining is being carried out in an environment of zero “gas dynamic incidents”. Conditions will change with depth. In addition to measures (such as the GeoGAS Desorption Rate Index) aimed at defining when to take action to alleviate outburst potential, return gas monitoring should prove to be an important additional barrier.

Existing mines with well developed outburst management strategies can still benefit from this application. Apart from introducing an additional safety barrier, there is the potential to rationalise drilling operations. In time, when enough is known about the characteristics of gas emission, there may be scope to increase gas content threshold levels without compromising safety, by placing greater reliance on the return gas monitoring system.

In the event of an incident occurring, the return gas monitoring system enables the best possible back analysis, quantification and diagnosis of the event. The “borehole blowout event” is one such example.

Miner drivers from time to time report increased (or decreased) gassiness. Ready access to return gas monitoring data can help to understand the environment, alleviate peoples concerns and take action as appropriate.

In short, return gas monitoring creates a level of “vision” that may be hard to justify being without.

3. Recommendations

Results from this project should be discussed with potential end users with a view to implementing and further developing the approach.

The principles and procedures developed need to be put into practice and further refined. The gas emission response is different at each site, and there is no doubt that new relationships will emerge with further application.

The next major area of research will be in intra shift assessments of gas emission using belt weightometers and integrated data processing that can provide feed back to mining crews during the shift. A significant part of this work will be the software development required to ensure that anomalous/poor data are recognised and are not falsely reported.

Improvements in air quantity measurement accuracy would accompany any further research.

4. Introduction

In January 1994, GeoGAS Pty. Ltd. was awarded an ACARP grant (Project 3076) to research the development of a real time, return gas monitoring system over a three year period.

The prime objective was to create a turn key, prototype, stand alone, real time, gas monitoring system capable of providing quantitative assessments of gassiness levels on at least a shift by shift basis and enabling unusual gas emission patterns to be readily flagged.

Sub objectives were:

- To define and document the process of using this data to back analyse gas drainage effectiveness.
- To assess the potential for using the technique to quantitatively define seam gassiness on a sub shift period basis.
- To define indices relating the gas emission response (rate of emission, peak emission rate, quantity, composition) to outburst proneness in terms significant to outbursting.

The project scope covers design and fabrication of the gas monitoring system, trial of the system at Tahmoor Colliery and Dartbrook Mine and development of reporting procedures and associated software to facilitate its real world application.

Unless otherwise stated, all reference to gas content means Total Desorbable Gas Content (Q1+Q2+Q3) at 20°C and 1013 hPa.

5. The System

5.1. Overview

The GeoGAS Return Gas Monitoring System (RGMS) is comprised of underground and surface located hardware, SCADA (SCAlable Data Acquisition) software and data processing software.

Logged data from the SCADA software (CITECT) provides values and trends for:

- CO₂ flow rate (l/s)
- CH₄ flow rate (l/s)
- CO₂ concentration (%)
- CH₄ concentration (%)
- Air velocity (m/s) and air quantity (m³/s)
- Production rate

The data processing software differentiates background emission levels and on a shift by shift basis, calculates the following face area emission:

- Peak CO₂ emission rate (l/s)
- Peak CH₄ emission rate (l/s)
- CO₂ quantity (m³)
- CH₄ quantity (m³)
- CO₂ gas make (m³/t)
- CH₄ gas make (m³/t)

The system is comprised of the following main items of equipment (figure 5.1.1):

UNDERGROUND (Non Hazardous Zone)

- 2 x UNOR 610 Gas Analysers (CO₂ and CH₄)
- 1 x Allen Bradley SLC 500 PLC
- 1 x Control Systems Technology IPM-10 Belt Weigher Monitor
- 1 x Mikan Short Haul Modem
- 2 x Calibration gas bottles (“DS” size Alpha standard span gas and “D” size HP N₂)

UNDERGROUND (Hazardous Zone)

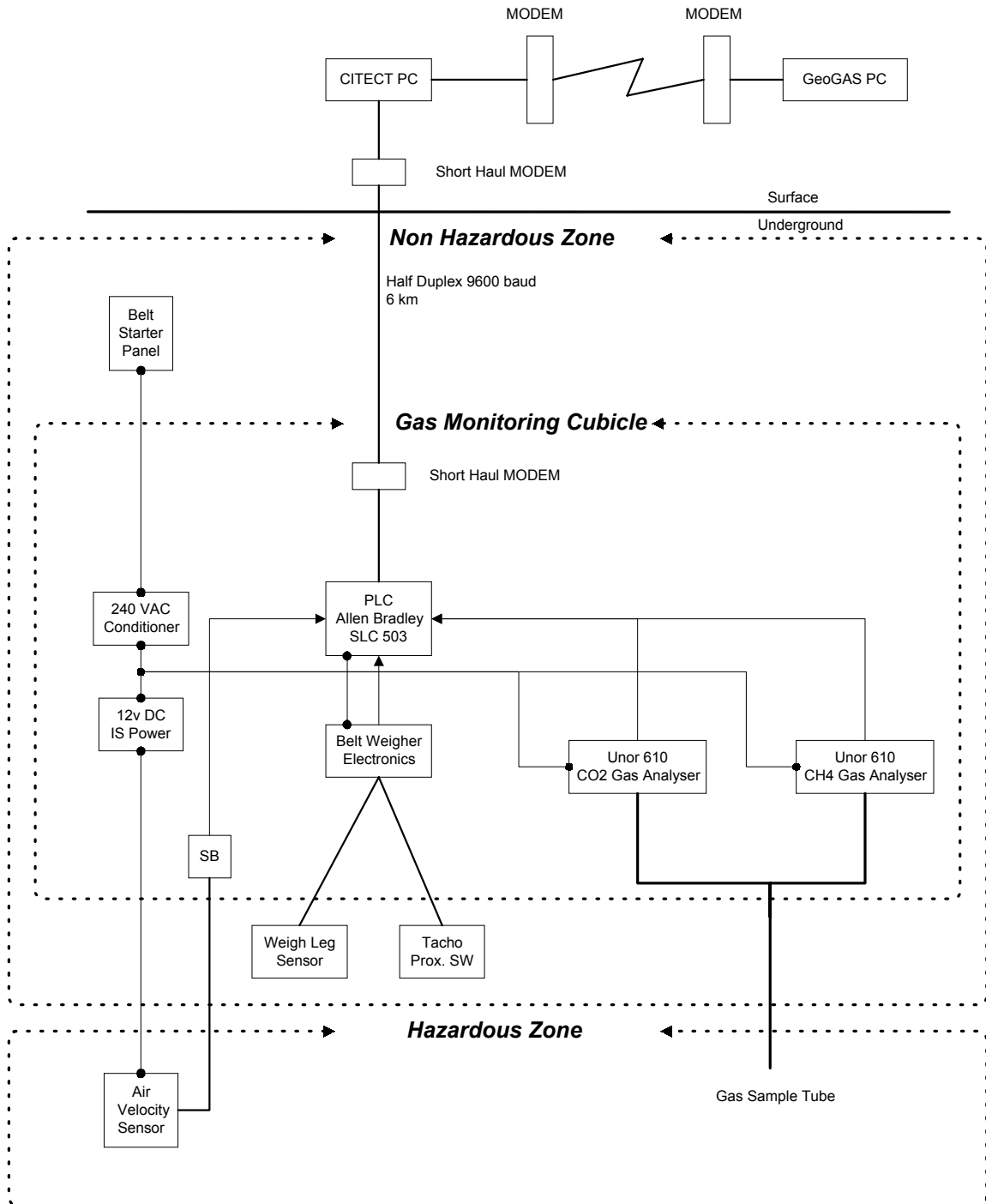
- 1 x Trolex TX1322 Vortex Shedding air flow sensor

ABOVE GROUND

- 1 x IBM Compatible PC running CITECT for WINDOWS SCADA package and the GeoGAS Return Gas Monitoring System data processing software.

- 1 x Mikan Short Haul Modem

Fig. 5.1.1 Real Time Return Gas Monitoring - System Layout



5.2. System Hardware

The system PLC maintains autonomous control of the underground system accepting input data from the gas analysers, belt weigher controller and air velocity sensor every 2 seconds. It is normally in continuous interactive communication with the surface CITECT monitoring PC, buffering then forwarding data. The system operates in the following manner :

- *Upon power-up* , the Gas Analysers take between 5 and 45 minutes to warm up depending upon ambient temperature and cool down period since last operation.
- *After warming up* the “ Sample “ solenoid valve is energised and air is drawn from the Return airway via the sample tubing. The resultant values of CO₂ and CH₄ concentration are displayed on the LCD screen of the relevant analyser and are correspondingly fed to the PLC via a 4 - 20 mA analog output. The Gas Analysers have been configured with an Auto Ranging facility , ranges set at :
 1. 0 - 1 %
 2. 0 - 2 %
 3. 0 - 3 %
 4. 0 - 5 %
- If an analyser measures a gas sample which is out of the current range it automatically changes range , re-scales the analog output and indicates to the PLC the new range. The PLC then scales the analog input accordingly, with all resultant values in the range of 0 - 5 %. Both gas analysers are routinely accurate to 0.01% but will resolve to 0.001%.
- *Other Analog inputs* fed to the PLC are :
 1. Return air velocity - in the range of 0.5 - 5 m/s
 2. Tonnage rate of coal passing over the belt weigher - in the range of 0 - 1000 t/hr. The PLC totals the coal produced and maintains cumulative totals of this shift, today and year, and reference totals for last shift and previous day.
- *Moving window* averaging is applied to the real time data with a selectable sampling interval and sampling weight. The default window for the gas concentrations is 20 seconds (or 10 samples) and 200 seconds (100 samples) for the air velocity.
- *All analog values are scaled* appropriately then moved to an area of memory which is set aside for access by CITECT. The entire process underground is monitored by and interactive with CITECT. For more information on the structure of the operator interface see the section on “CITECT Software”.

5.3. PLC

5.3.1. Program Features

The PLC program, contains the following features :

1. Scaling of analog inputs under Auto Ranging Control.
2. Calculation of moving averages of analog inputs to allow damping of signal levels, in particular, fluctuations in the air velocity signal .
3. Totalising of coal production as recorded by the belt weigher. This is done on a per shift, day and year basis.
4. Determination of the number of production shifts per day and start times of each production shift.
5. Control of the auto-calibration procedure for the gas analysers. The PLC is programmed to calibrate the gas analysers at an automated interval (weekly), or under command from the surface PC. The analysers have built-in gas sampling pumps and the PLC controls 3 solenoids to affect sampling of the Zero, Span and Return Air gases in turn. Pressure sensors in the Zero and Span gas lines allow the PLC to indicate fault alarms when the calibration gases are spent.
6. Transfer of critical data to CITECT to be stored in ASCII format. Should CITECT fail to respond to the relevant handshaking signals, the data may be buffered in the PLC memory (where non-IS PLC batteries are permitted) with up to 128 records possible.
7. During normal data transfer operations, the data sampling rate (selectable from CITECT) will be in the range of 2 to 300 seconds. If buffering is initialised, an over-ride sample rate is used (also selectable from CITECT) in the range of 10 - 600 secs. This gives a buffering time of between 21 min 20 secs and 21 hrs 20 min depending on over-ride sample time.
8. Alarm monitoring of CH₄ % and CO₂ % concentration levels (see sections on “Safe Operation” and “Alarms List”).
9. Decoding of gas analyser control signals to enable text display in CITECT of the current status of the gas analysers and calibration gas bottles.

5.3.2. Safe Operation

The system cabinet contains a mix of electrical and mechanical components, some intrinsically safe but most “non-IS”. The system **must at all times be operated within non-hazardous conditions**. If the system PLC detects CH₄ levels at or above 1.25% for 10 seconds it will send an alarm flag to the surface PC and then immediately shutdown the system, isolating power to the interlocked door switch.

The system power is “latched-off” on all power interruptions. Personal intervention by appointed colliery personnel is required to restore power to the system. Power-up procedures are posted on the door of the RGMS system cabinet.

5.3.3. Operator Alarms

The PLC can generate three software alarm flags. These trigger the CITECT “Alarm Page” on the surface PC CITECT application for operator intervention (see “CITECT Software”).

1. **CH₄ > 1.0 %** Methane level has risen above 1 %.

The “Alarm Page” will be displayed (see “CITECT Software”) and a message will appear describing the shutdown procedure of the gas monitoring system should the CH₄ level rise above 1.25 % for 10 secs.

2. **CH₄ > 1.25 %** CH₄ level has risen to 1.25 % for 10 secs.

The “Alarm Page” will be displayed with the preceding message plus the following:

The Gas Monitoring System will trip. Power must be restored by the following procedure :

I. Test CH₄ gas levels in

- a) the return*
- b) immediately outside the Gas Monitoring System enclosure*
- c) inside the enclosure (gain access by turning door switch to OFF position)*

II. If all three are OK, shut enclosure door, switch Main Switch ON and press and hold the RESET push button for 3 to 4 seconds until the “Trip Relay” latches in.

WARNING: If the CH₄ level is above 1.25 % at any of the three locations described , power must **NOT** be restored to the RGMS.

NOTE: The RGMS will not permit another trip until 60 seconds after the gas analysers have warmed up and started the gas pumps. This allows the sample suction lines time to purge before monitoring resumes.

3. **BELT WEIGHER FAULT** The “Belt Weigher” has output a fault signal (yet to be configured)

5.4. CITECT Software

5.4.1. Overview

The operators “window “ to the RGMS is provided by the “CITECT for WINDOWS ver 3.0” SCADA package. This software communicates with the PLC “reading from” and “writing to” the PLC registers in “real-time”.

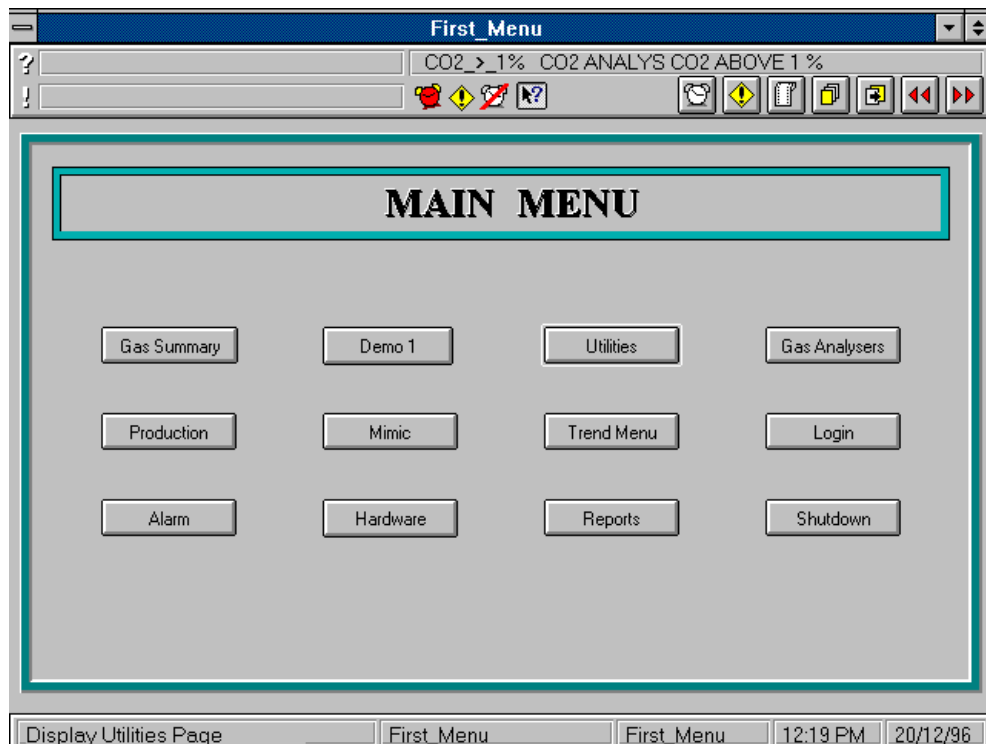
Depending upon the sampling settings, data are sent to the surface PC every 10 seconds and this updates the PC's trend history files and ASCII logged data files. The ASCII files log each set of CH₄, CO₂, air velocity, belt flow weight, time and date every 10 seconds. Additionally, the surface PC stamps each data point set with a shift number (determined from shift start times set in the PLC) to facilitate later data analysis.

Each day, starting at 23:00 hours with night shift, a new day's ASCII log file is initiated. The system is currently set to log 120 days of continuous production, but in practice would only be limited by the PC hard-disk capacity. A one Gigabyte hard-disk would afford continuous coverage of up to 1.5 years of operation.

Additional software written in Borland Delphi 2.0 has been developed to analyse and report the data (see “Data Processing Software”).

The PC is configured to run the CITECT application immediately from power-up or re-boot. After the CITECT application is loaded the title screen is displayed for 3 seconds followed by the Main menu screen (figure 5.4.1).

Fig. 5.4.1 CITECT Main Menu



The Main menu screen is a collection of 12 button which take the user to each of the systems input and display screens. (The system graphical Mimic Page has not been implemented).

Common to all screens are :-

- the status message areas (along the bottom),
- alarm status message area (top centre right),
- alarm indicators, alarm inhibitor and help toggle (centre top), and
- page scroll buttons (top right)

There are buttons on every screen to return the user to the Main menu screen. Similarly most screens have page scrolling buttons to return to previously accessed screens or advance to related screens in a sequence.

5.4.2. Login, User Access and Privileges

Access is provided through levels of password control, to the PLC controlling parameters (for the system supervisor) and trending display pages, software and hardware alarm pages (for the colliery-staff operators).

Four levels of privilege (Levels 0 - 3) have been incorporated into the system as follows :-

Level 0 (DEFAULT) - the lowest level is the default upon starting the CITECT application. All “read-only” display functions are accessible, alarms may be acknowledged, but no PLC parameters may be set and the application may not be manually shutdown.

Level 1 (SYSTEM OPERATOR) - adds to Level 0 permission for manual shutdown of the system. This may be necessary if extended file maintenance is required on slower PC systems.

Level 2 (SYSTEM SUPERVISOR) - adds to Level 1 permission to manipulate the specified PLC control parameters (detailed later in UTILITY PAGES).

Level 3 (SYSTEM ENGINEER) - adds to Level 2 permission to modify the CITECT application and grant user accounts and privileges.

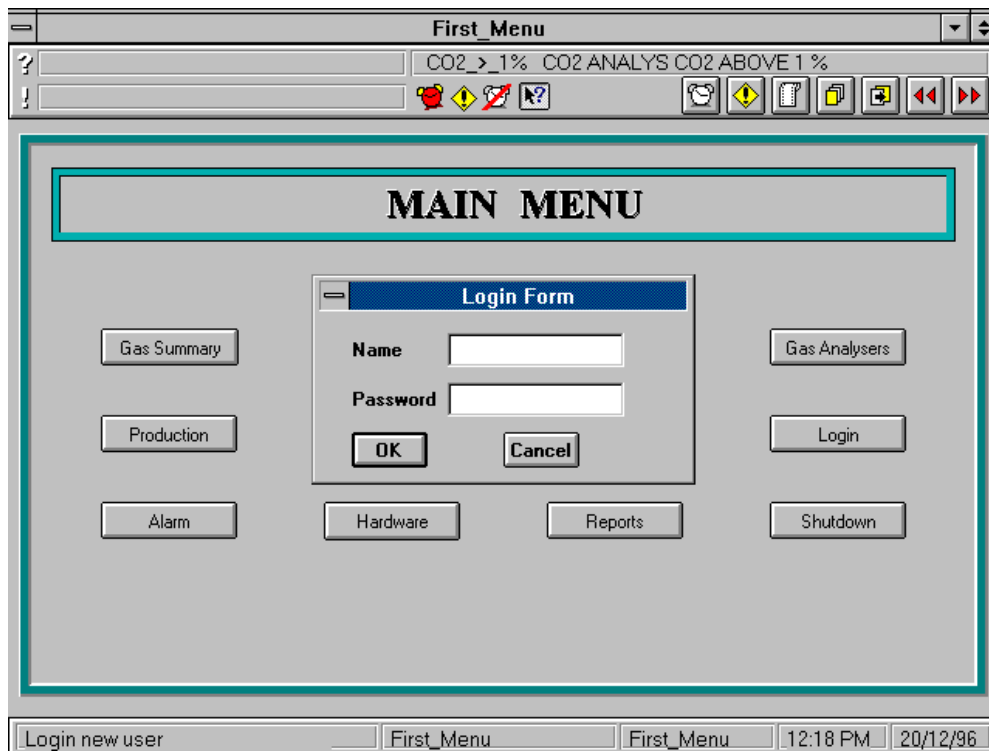
While this document presents a walk-through of all CITECT operations and system controls, access is provided by user names and passwords compiled within the application by the SYSTEM ENGINEER. Access to the read-only displays such as the trend pages, reports and summaries along with permission to shutdown can be obtained by the login :-

NAME: **OPERATOR**

PASSWORD: **OP**

in response to the Login dialogue box (figure 5.4.2).

Fig. 5.4.2 Login Form



5.4.3. Shut Down

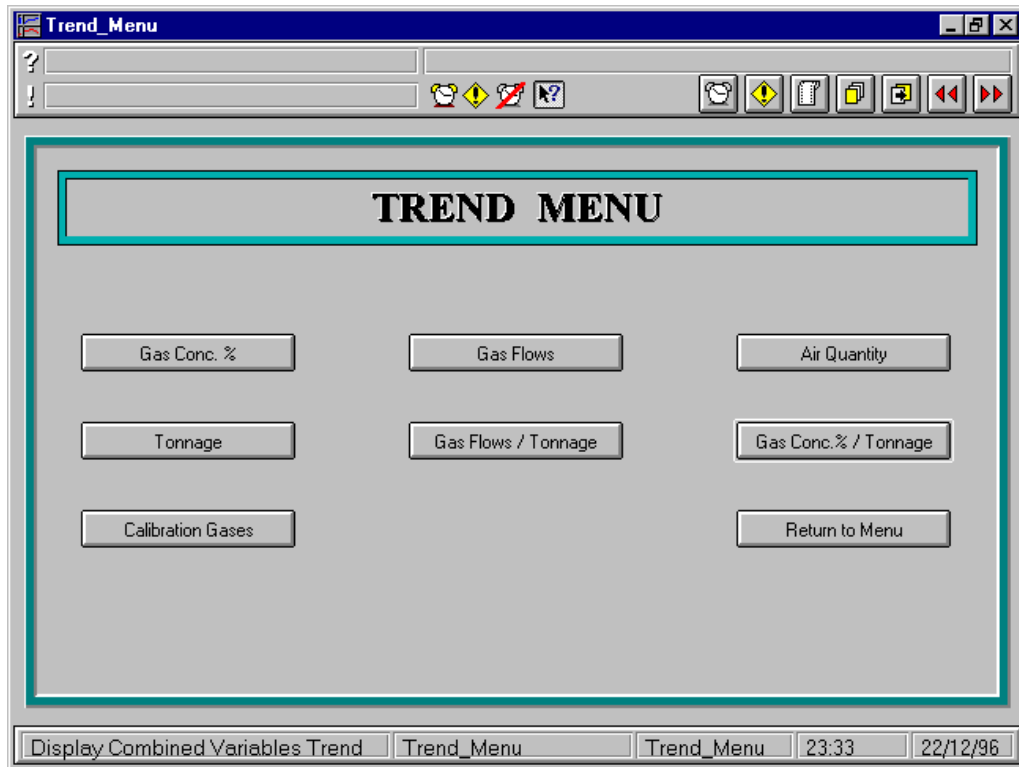
If a user with inadequate privileges attempts an unpermitted action they will receive a message warning they have insufficient privileges (as the Level 0 user has), upon attempting manual shutdown of the system.

If a user with adequate privileges requests a shutdown, a dialogue box asks for confirmation of the request.

5.4.4. Trend Menu and Trend Pages

The Trend menu (figure 5.4.3) can be called from the Main menu. It gives access to all of the trend history data maintained by CITECT in a graphical form. If the right most extent is set to NOW new data will scroll in from the right at a rate set by the trend base control.

Fig. 5.4.3 Trend Menu



The seven trend pages available present gas concentration levels, airflow, production and gas flow traces separately and in combination. A digital trace history of the calibration gas levels (ie. OK or LOW) is also available.

All of the trend pages have a common tool-set of controls which manipulate the span, scale and focus of the trended data (figures 5.4.4 and 5.4.5).

Fig. 5.4.4 CITECT Trend Page 2

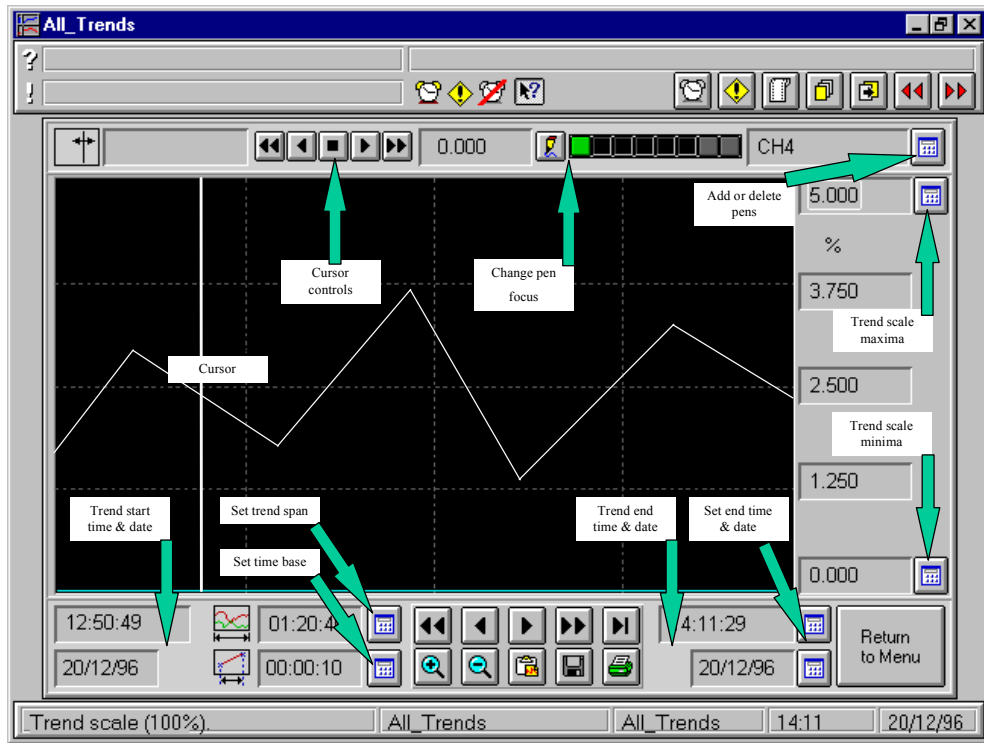
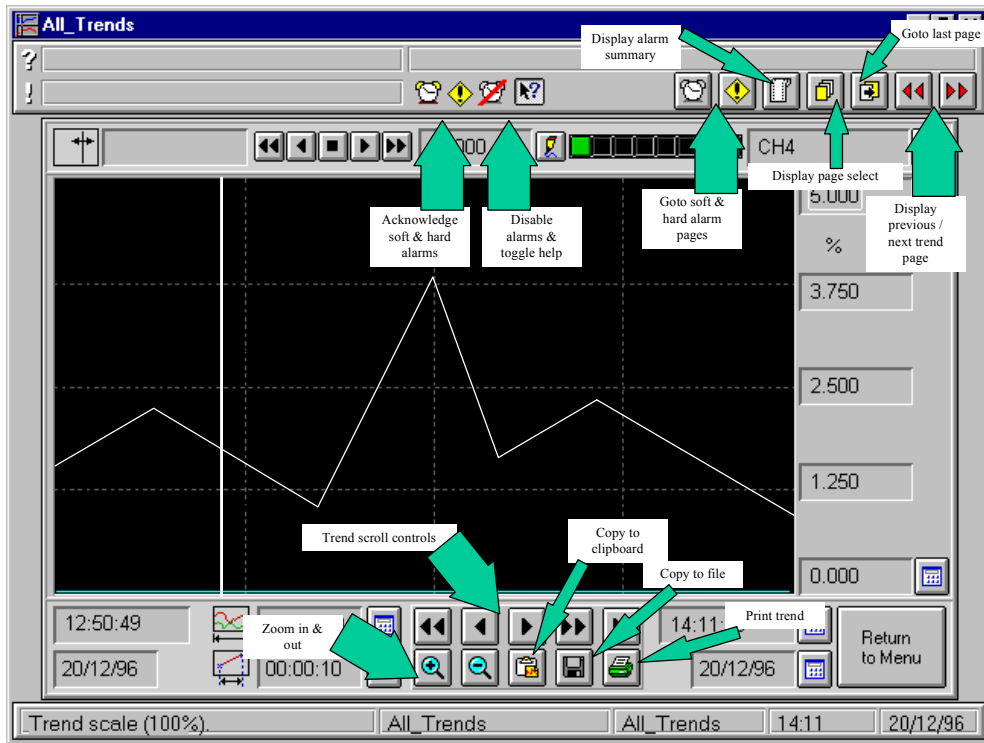


Fig. 5.4.5 CITECT Trend Page 3



The **trend span controls** do the following:

- The trend span status field and set button are located on the lower centre left of the screen (figure 5.4.4). This control sets the duration of the graphed data. Pressing the set button opens a dialogue box and allows control of the trend duration in hours, minutes and seconds.
- The trend base status and set button are immediately below, and alter the minimum time step which is displayed, and hence also the rate at which new data will scroll from the right.
- The extent of the current trend page data is displayed in the trend start and end status fields in the lower left and right corners respectively (figure 5.4.4).
- Next to the trend end fields are the set buttons for end time and date. Control of the trended data span is effected by combinations of the end time and date controls and the trend span and base controls. The right-most extent of the trend can be set to the current time by selecting NOW from the trend end dialogue box (accessed by the trend end set button).
- Additionally, the trend scrolling button (lower centre) may be used to scroll the trends fast / slow, left / right and to right extent.

Five **trend scale fields** are located to the right of the trend data (figure 5.4.4). The minima and maxima scale bounds are set by the pressing the buttons adjacent to the scale minima and maxima fields. The levels are set in a dialogue box, but the user is then prompted to specify if the new bounds apply to the current pen (trace in focus), all pens or none.

The pen focus and cursor controls do the following:

- Pen traces may be added or deleted from the trend traces using the pen editor button in the upper right (figure 5.4.4). Any CITECT variable tag may be added but some care should be taken to match the data.
- Cursor bar focus may be given to any of the available pens present in the pen focus selection rack (upper centre right, figure 5.4.4) or directly selected using the adjacent pen focus selection button and dialogue box.
- Once the required pen trace has the cursor focus any value for that pen within the displayed trend span may be obtained by “dragging” the cursor bar or by using the fine and coarse cursor scroll controls (upper centre left).

5.4.5. Gas Summary Page

The “Gas Summary” button in the “Main Menu” page will call up the display page (figure 5.4.6). If the underground system is powered, *live* data, updated every 10 seconds, will be displayed within the value fields. The measured and corrected air velocities, air quantity, CO₂ and CH₄ concentrations and calculated gas flow rates are displayed.

Clicking on the “Report Page” or “Trend Menu” buttons will take the operator to these pages. Clicking on either “Return to Menu”, “Last Page” or “Page Scroll” buttons will return the display to the Main Menu.

Fig. 5.4.6 CITECT Gas Summary Page

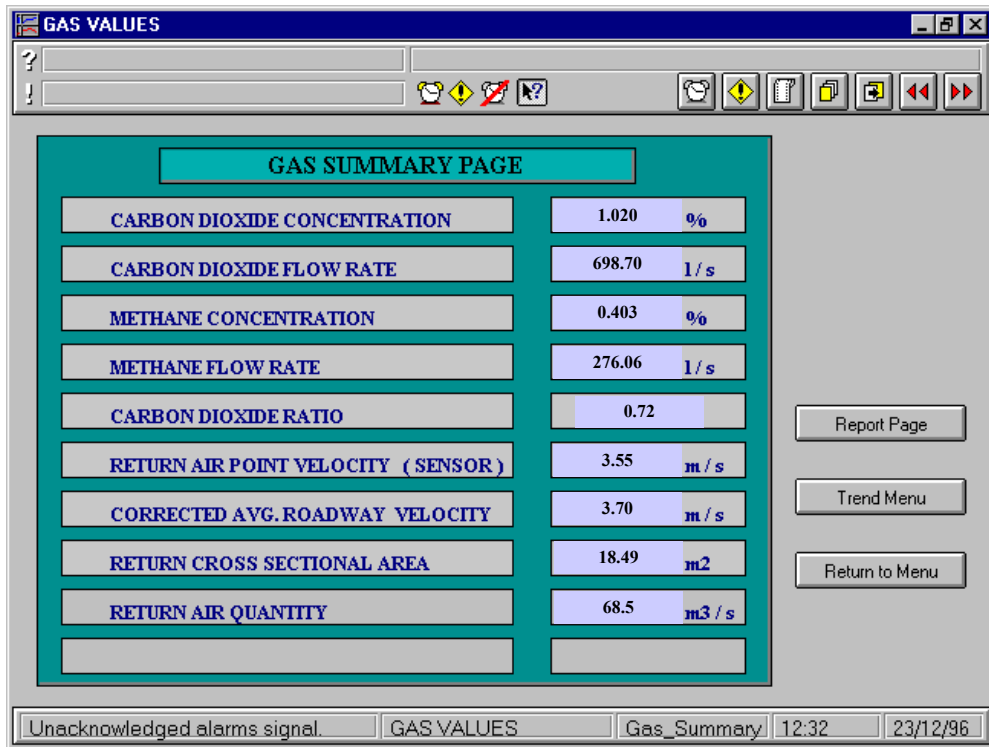
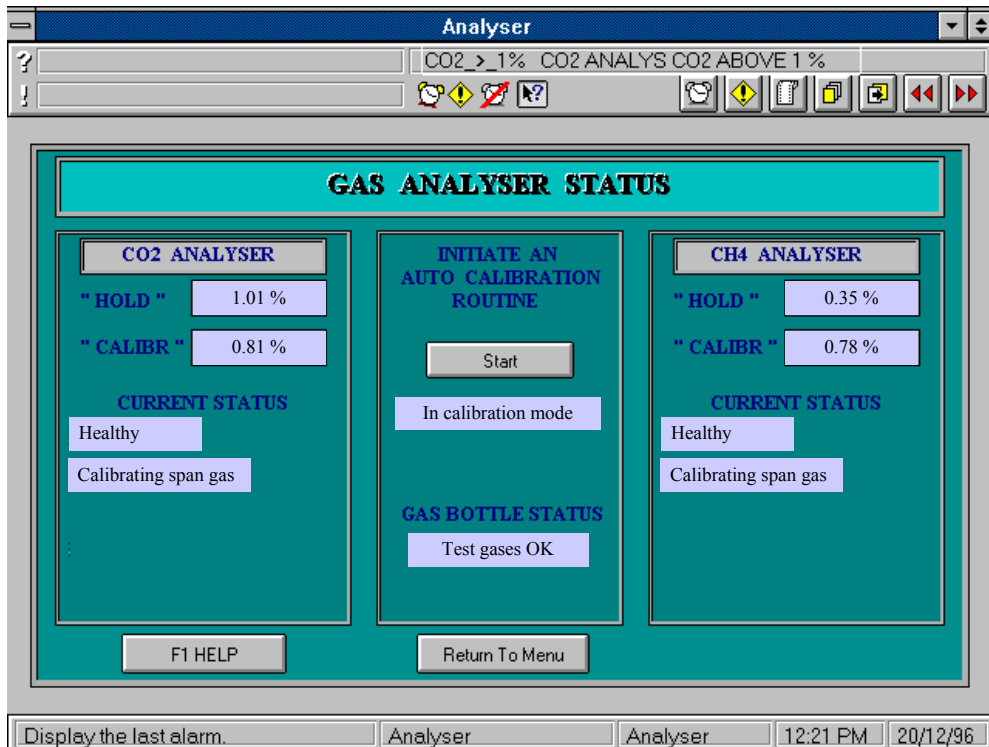


Fig. 5.4.7 CITECT Gas Analyser Page



5.4.6. Gas Analyser Pages

The "Gas Analysers" button in the "Main Menu" page will call up the display page (figure 5.4.7). This page displays the status of the CO₂ and CH₄ analysers, the zero and span gas bottle status, and permits initiation of the auto-calibration routine on both analysers.

The PLC is programmed to automatically instigate calibration of the analysers by introduction of span and zero gases at 12 noon each Wednesday. If analyser drift is suspected then a calibration run may be initiated by clicking on the *Start* button. Each "HOLD" display register will show the analyser readings immediately prior to calibration. Each "CALIBR" register will show the current analyser reading.

Each analyser will display its current status. The possible status displays are :-

- "WARMED UP" - the analysers are fully functional,
- "HEALTHY" - no fault flags are set,
- "CALIBRATION - ZERO GAS" - calibration is in progress with Zero gas (N₂),
- "CALIBRATION - SPAN GAS" - calibration is in progress with Span gas (0.9% CH₄ and CO₂),
- "MINOR FAULT - TEMPERATURE" - the analyser is warming up.

Both gas bottle lines are fitted with pressure sensors. The gas bottle status will indicate either "TEST GASES OK", "SPAN GAS EMPTY", "ZERO GAS EMPTY" or "BOTH GASES EMPTY".

The operator may click on the F1 HELP button for a further help screen (figure 5.4.8) or return to the menu by clicking Return to Menu, Last Page or Page Scroll buttons.

Fig. 5.4.8 CITECT Gas Analyser Help Page

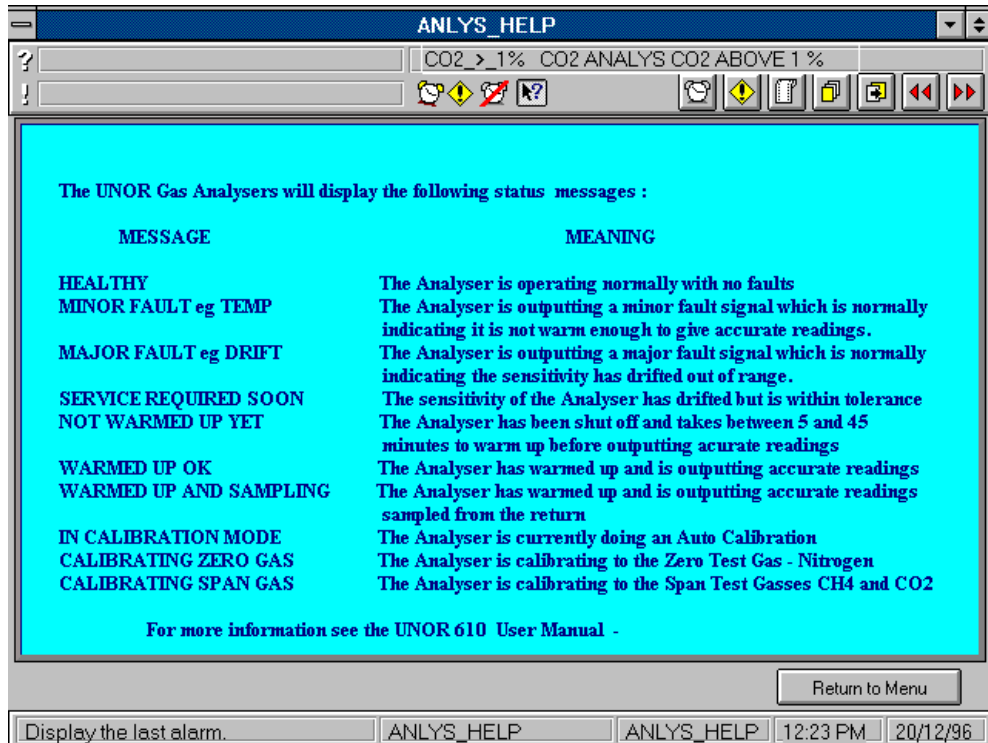
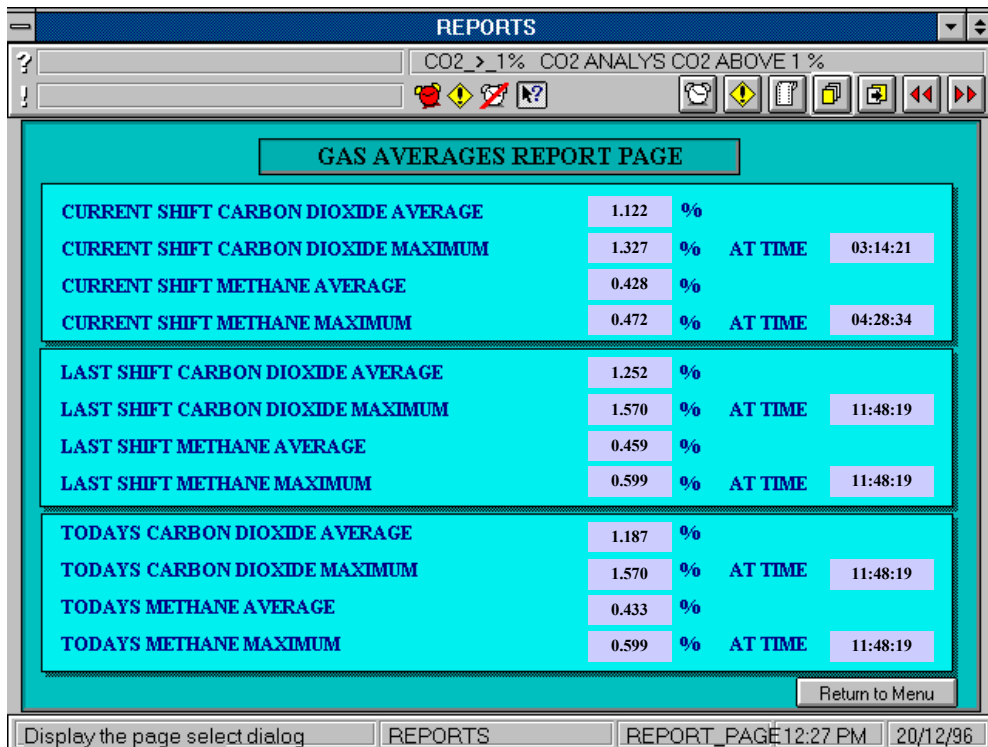


Fig. 5.4.9 CITECT Reports Page



5.4.7. Reports Page

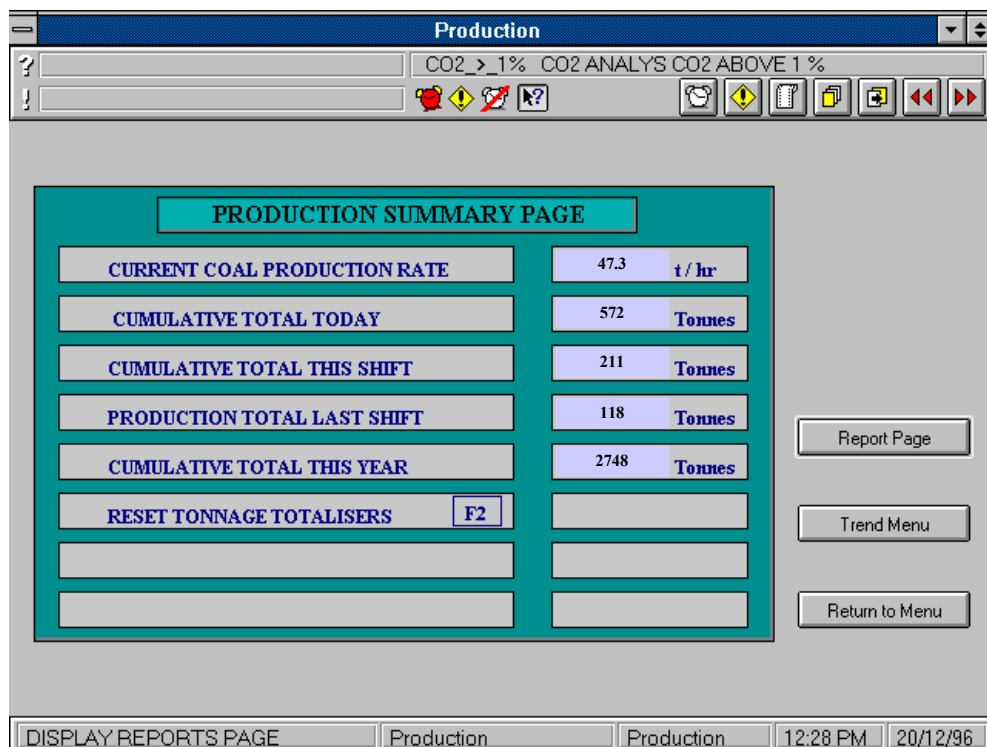
The “Reports” button in the “Main Menu” page will call up the “Reports” page (figure 5.4.9). This page presents a summary of the gas concentration averages and maxima for CO₂ and CH₄ in the current shift, last shift and current day.

To exit this page, the operator may return to the Main menu by clicking “Return to Menu”, the “Last Page” or “Page Scroll” buttons.

5.4.8. Production Page

The “Production” button in the “Main Menu” page will call up the display page (figure 5.4.10). This page presents *live* data for the current production rate measured on the belt plus cumulative totals for today, this shift, this year and production total for the last shift.

Fig. 5.4.10 CITECT Production Page



Users with Level 2 and 3 privilege can reset the tonnage totalisers by pressing the F2 function key.

Clicking on the “Report Page” or “Trend Menu” buttons will take the operator to these pages. Clicking on either “Return to Menu”, “Last Page” or “Page Scroll” buttons will return the display to the “Main Menu”.

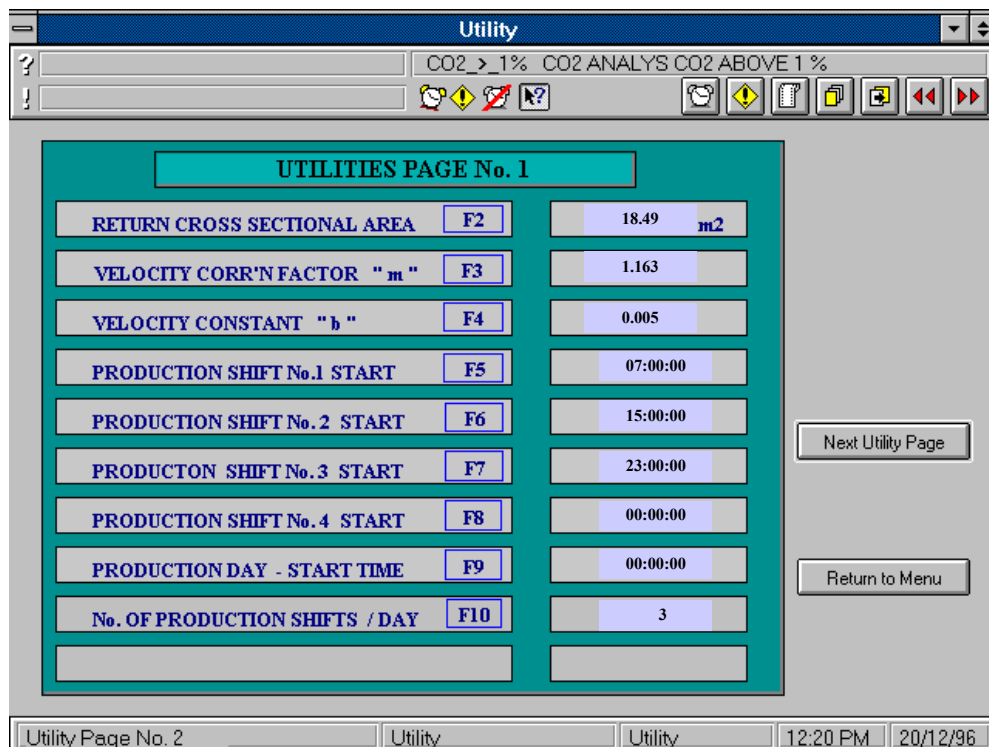
5.4.9. Utility Pages

The Utility pages can be called from the “Main Menu”. There are three Utility pages (figures 5.4.11, 5.4.12, 5.4.13) which allow the operator to change (within limits) certain operating parameters of the PLC and monitoring system. Level 2 or 3 access is required to alter any Utility page setting.

5.4.9.1. Page 1

This page (figure 5.4.11) sets PLC registers which hold parameters necessary to calculate the airflow quantity at the underground site and shift details necessary to collate the shift data.

Fig. 5.4.11 CITECT Utility Page 1



Calibration of the system’s point air velocity readings to average roadway air velocity is effected by linear function ($y = mx + b$).

By pressing the required function key, entering the appropriate value, and pressing the “Enter” key, the operator can change the following :-

- F2 Return Cross Sectional Area m²
- F3 Air Velocity constant “m” - ($mx + b$)
- F4 Air Velocity constant “b” - ($mx + b$)
- F5 Production Shift No. 1 Start Time
- F6 Production Shift No. 2 Start Time

- F7 Production Shift No. 3 Start Time
- F8 Production Shift No. 4 Start Time
- F9 Production Day Start Time
- F10 No. of Production Shifts per day

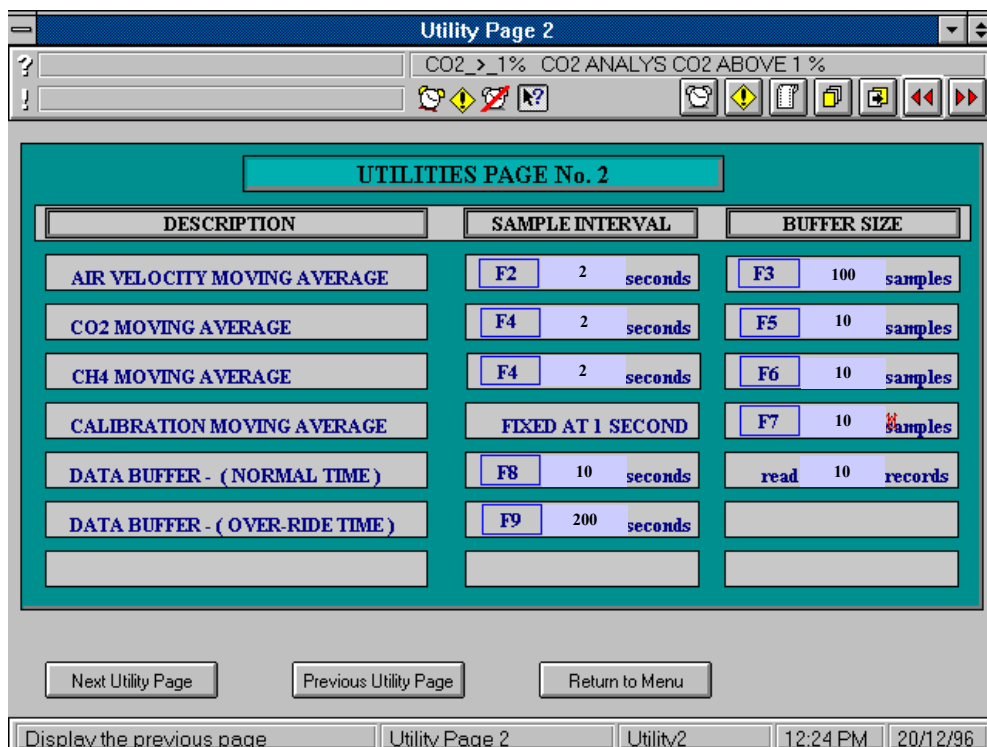
From this page the operator can press the dedicated buttons to return to the “Main Menu”, jump to the “Next Utility Page” or use the “Page Scroll” and “Last Page” controls.

5.4.9.2. Page 2

This page (figure 5.4.12) sets PLC registers which hold parameters to control buffering and sampling rates within the PLC. The PLC buffers input data for two reasons :

- To allow *moving window* averaged smoothing of analog input data (particularly air velocity) for damping of signal levels.
- To retain and store up to 128 data records during communication interruptions for download upon reconnection.

Fig. 5.4.12 CITECT Utility Page 2



This second function is dependent on the PLC being fitted with a memory back-up battery. Some mine electrical conformance guidelines prohibit a non IS battery.

During normal data transfer operations , the data sampling rate (selectable from CITECT) will be in the range of 10 to 300 sec. If disconnection buffering is initialised an over-ride

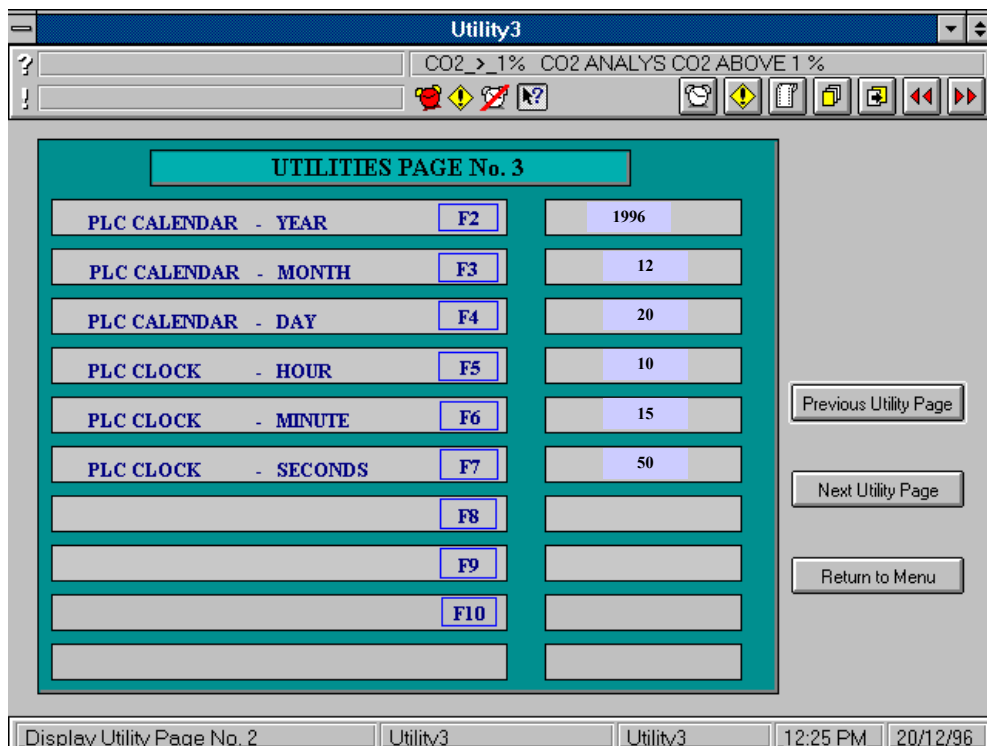
sample rate is used (also selectable from CITECT) in the range of 10 - 600 sec. This gives a buffering time of between 21 min 20 secs and 21 hours 20 min., depending on over-ride sample time.

By pressing the required function key, entering the appropriate value, and pressing the “Enter” key , the operator can change the following :-

F2	Air Velocity Averaging Sample Interval	2 - 20 sec
F3	Air Velocity Averaging Buffer Size	1 - 100
F4	Gas Analyser Averaging Sample Interval	2 - 20 sec
F5	CO ₂ Analyser Averaging Buffer Size	1 - 40
F6	CH ₄ Analyser Averaging Buffer size	1 - 40
F7	Gas Analyser Averaging Calibration Buffer Size	Set at 1
F8	Data Buffer Update Sample Time	10 - 300 sec
F9	Data Buffer Over-ride Sample Time	10 - 600 sec

From this page the operator can press the dedicated buttons to return to the “Main Menu”, jump to the “Next Utility Page”, return to the “Previous Utility Page” or use the “Page Scroll” and “Last Page” controls.

Fig. 5.4.13 CITECT Utility Page 3



5.4.9.3. Page 3

This page (figure 5.4.13) sets PLC registers which hold the day and date settings within the PLC.

By pressing the required function key , entering the appropriate value, and pressing the “Enter” key , the operator can change the following :-

F2	PLC Calendar - Year value
F3	PLC Calendar - Month value
F4	PLC Calendar - Day value
F5	PLC Clock - Hour value
F6	PLC Clock - Minute value
F7	PLC Clock - Seconds value

From this page the operator can press the dedicated buttons to return to the “Main Menu”, jump to the “Next Utility Page”, return to the “Previous Utility Page” or use the “Page Scroll” and “Last Page” controls.

5.4.10.Alarm Pages

The two alarm pages can be called manually from the “Main Menu” or from the “Hardware” and “Operator Alarm” buttons in each page (top centre right). When hardware or operator alarm conditions are triggered within the system :

- The corresponding alarm page is automatically displayed.
- The animated alarm clock icon simulates a ringing clock.
- The offending alarm is displayed in flashing text in the top right status field.
- The alarm message is added to the log of alarms in highlighted text (bright yellow).

If the user chooses to ignore the alarm, and return to the previously displayed page (via the “Last Page” button) the flashing status field message and “ringing” alarm will persist. Alternately, the user may acknowledge the alarm by either clicking on the offending text (which becomes an un-highlighted light grey) or by pressing the “Acknowledge” button on the centre left margin.

5.4.10.1.Hardware Alarm

This page (figure 5.4.14) lists current alarms generated by hardware failures within the system. In each session the application is active, the alarm messages are continuously logged with date/time stamped, plain English messages. Scroll button controls allow access to all messages.

5.4.10.2.Operator Alarm

This page (figure 5.4.15) lists any of three operator alarms.

- 1. CH₄ > 1.0 %** Methane level has risen above 1 %

Fig. 5.4.14 CITECT Hardware Alarm

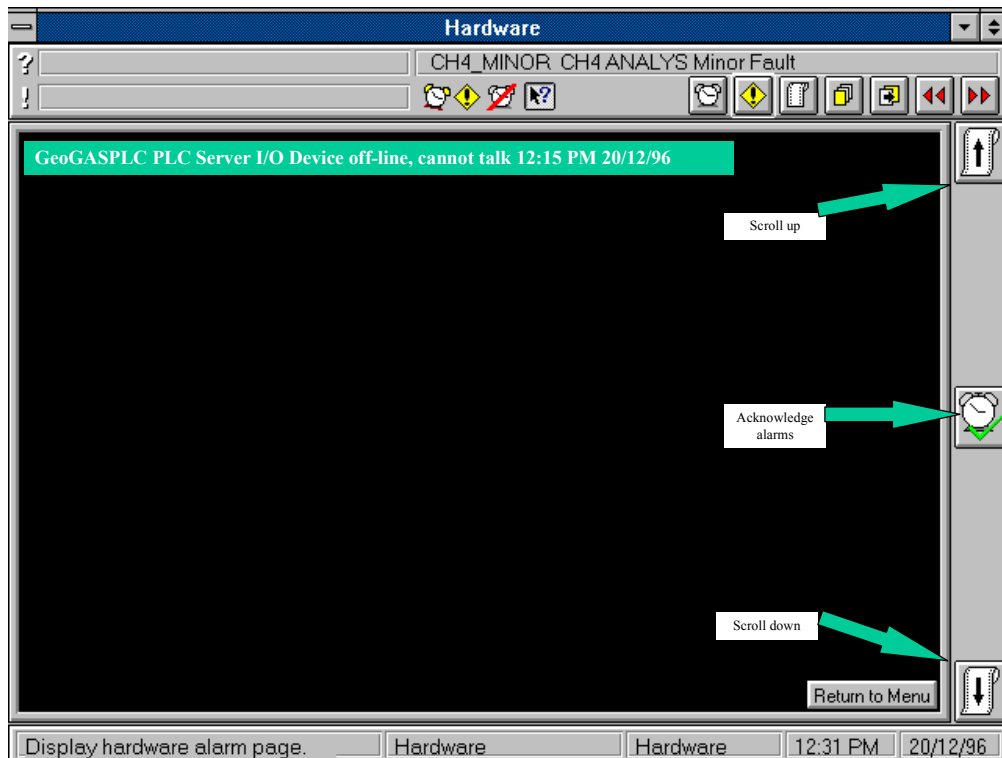
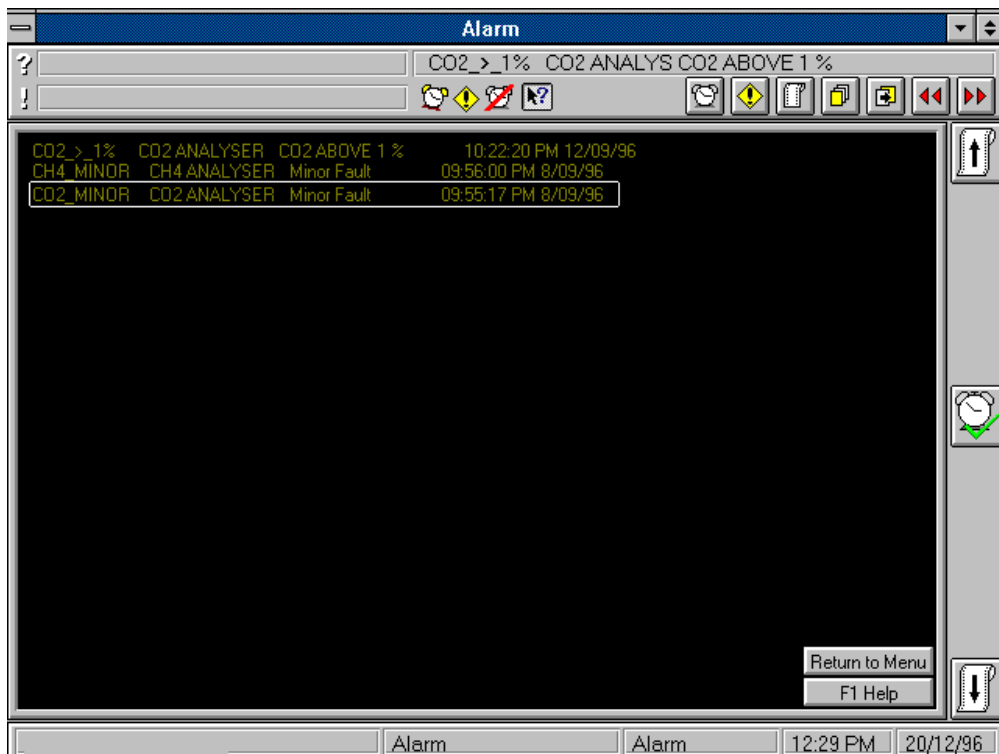


Fig. 5.4.15 CITECT Operator Alarm



The “Alarm Page” will be displayed and a message will appear describing the shutdown procedure of the gas monitoring system should the CH₄ concentration rise above 1.25 % for 10 secs.

2. CH₄ > 1.25 % CH₄ concentration has risen to 1.25 % for 10 secs.

The “Alarm Page” will be displayed with the preceding message. Pressing the F1 function key, or the dedicated “F1 Help” button will display the following operator information :-

The Gas Monitoring System will trip. Power must be restored by the following procedure :

I. Test CH₄ gas levels in

- a) the return*
- b) immediately outside the Gas Monitoring System enclosure*
- c) inside the enclosure (gain access by turning door switch to OFF position)*

II. If all three are OK, shut enclosure door, switch Main Switch ON and press and hold the RESET push button for 3 to 4 seconds until the “Trip Relay” latches in.

WARNING: If the CH₄ level is above 1.25 % at any of the three locations described , power must **NOT** be restored to the RGMS.

NOTE: The RGMS will not permit another trip until 60 seconds after the gas analysers have warmed up and started the gas pumps. This allows the sample suction lines time to purge before monitoring resumes.

3. BELT WEIGHER FAULT The Belt Weigher has output a fault signal (yet to be configured)

5.4.11.Demo Page

The “Demo” button in the “Main Menu” page will call up the display page (figure 5.4.16). This page allows the user to set various alarm flags within the PLC to test system performance. Level 2 or 3 access is required to alter any “Demo” page setting.

1. START / STOP GAS SAMPLING SYSTEM

Starting and stopping the gas sampling system may be simulated by pressing the buttons, which generates the corresponding hardware alarms.

2. BELT WEIGHER ALARM

The belt weigher alarm flag can be toggled by pressing the buttons, and a belt weigher hardware alarm generated.

3. GAS ALARMS

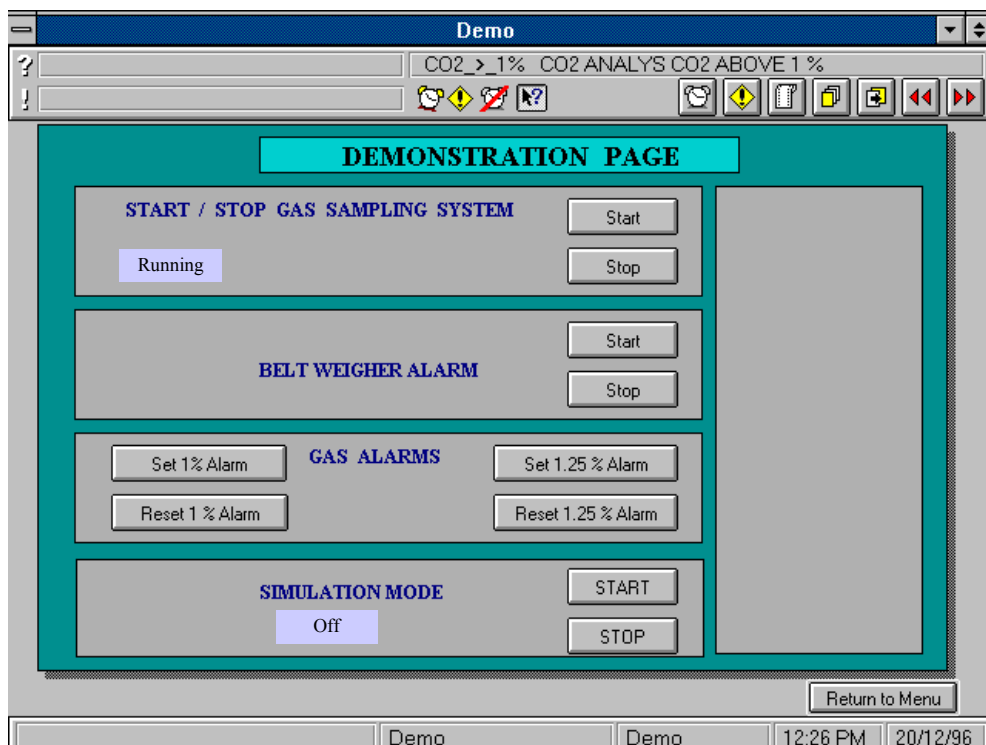
The 1% and 1.25% alarm flags can be set and reset, by pressing the corresponding buttons.

Note: the PLC will immediately shutdown the underground system when the 1.25% alarm flag is set, and underground intervention will then be required to re-power the system.

4. SIMULATION MODE

When the PLC is directly connected to the computer by serial cabling, and the PLC memory back-up battery is operating, the PLC can be instructed to generate dummy gas and production level signals to test the trend menu displays.

Fig.5.4.16 CITECT Demo Page



5.5. System Maintenance and Calibration

In both site trials once installed and commissioned the system functioned continuously with little maintenance and intervention.

5.5.1. Gas Analysers

In acceptance testing, prior to installation underground, the gas analysers exhibited almost no drift. The CO₂ analyser span drift (at ≈1%) was less than 0.05% (v/v) per month and no

zero drift was detected. The CH₄ analyser span drift (at ≈1%) was less than 0.01% (v/v) per month and again no zero drift was detected.

During the underground trials the analysers were calibrated under system control once a week (noon each Wednesday) and are deemed to have stayed entirely stable for the period of each trial. The “DS size” Alpha span bottle and “D” size zero gas (N₂) bottles were capable of calibrating the analysers at this rate for 4 months.

The Alpha grade span gas requires 6 weeks to mix and deliver, bottle pressure should be monitored weekly and ordered early.

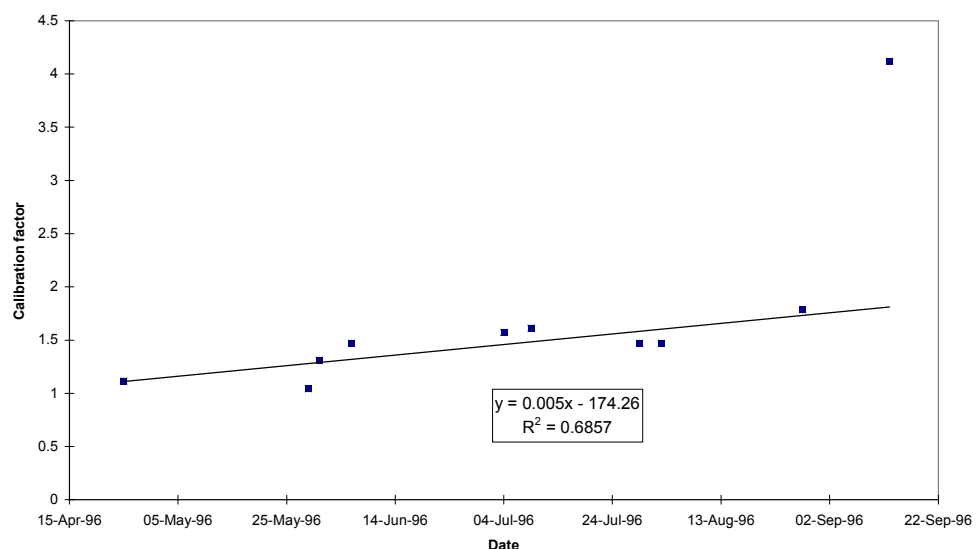
The analysers draw gas through a sintered metal sampling head, micron filter and water trap (with drain and dump chamber). In addition, each analyser has a final paper filter before the measuring cell, accessible through a screwed transparent plug in the analyser face. These filters must be changed when they are visibly tainted (between 6 weeks and 2 months).

5.5.2. Air Velocity Sensor

The air velocity head measures a point air velocity within the return air roadway. The point velocity is calibrated by linear function ($y = mx + b$) to estimate the average roadway velocity. The airway station’s dimensions are carefully measured to obtain the station cross-section and enable airflow quantity determination.

Significant drift was noted in the velocity head calibration factor “m” at about 0.005 / day. The head response (and indicated velocity) degraded in a linear manner over a period of 4½ months before sudden failure (figure 5.5.1).

Figure 5.5.1 - Drift in Velocity Head Calibration Factor



Cumulated coal dust and stone dust loading of the head slowly filled the sampling section until measurements failed “in-principle”.

During the trials, the calibration factor was adjusted to account for the drift. It is recommended that, in normal operation, the sampling section be cleaned with a bottle brush on a weekly basis.

5.5.3. System Enclosure

A small electric fan positively ventilates the system enclosure. Air is drawn through an inlet on the lower left side of the cabinet, across the analysers and exhausted on the upper right side. Air conditioner filter gauze rated to 2.5 micron is used in nacelles on the system cabinet exterior, and in a pad within the system unit to reduce the dust loading on the internal equipment.

In practice the filter pads required changing every 6 weeks to 2 months.

5.6. Data Processing Software

5.6.1. Introduction

The GeoGAS Return Gas Monitoring System data processing software accesses ASCII or dBase files generated by a SCADA package (such as CITECT) and provides a means for calculating, checking and reporting the gas emission data. Its prime function is to aid the determination of gas conditions at the face, providing an additional safety barrier to measures currently being adopted. At this stage, it is not intended as a replacement for any existing barriers.

This software is limited to evaluating the gas conditions at the completion of mining for the shift in question.

It has been developed to give the user considerable flexibility and control over how the data are evaluated. Visual and numerical checks are provided, in association with guidelines that should enable the user to competently evaluate the data. The quality of the results depend upon how well the user manages the software.

While using the software is reasonably intuitive, it is not intended for use by untrained persons.

Pressing a “Help” button, choosing {Help} from a menu or pressing F1 will provide access to context sensitive help.

This topic on data processing software covers:

- Maintenance of utility files (shift production, air velocity factors).

- Processing data.
- The Background algorithm.
- Generating graphs and reports.

5.6.2. Conventions

Text referencing to menu items is in curly braces eg {File|Exit}.

Reference to objects on the desk top is in bold, single quotation marks eg '**Background Settings**' describes an object containing two other objects - '**No. Records Averaged**' and '**Moving Average Interval**'.

5.6.3. The Software

Delphi 2.0 is a Windows based, object oriented, PASCAL, 32 bit compiler. Programs created under Delphi 2.0 will work under Windows 95 and Windows NT, but not the older 16 bit Windows 3.11.

Considerable use is made of the integrated Borland database engine (BDE). Data tables are normally created in Paradox format, with final data and report tables being in dBase format. This latter format can be read by almost any spreadsheet program, for further data analysis. Tables are queried and sorted using the database standard language SQL.

Graphing utilises the third party OCX program ChartFX Version 2.0. The main report for viewing and printing uses Borland's ReportSmith Version 3.0.

The screen is required to be in at least 600 x 800 pixel mode.

The program should be regarded as a "Beta" (ie trial) version. It is set up to accept data from the CITECT system at Dartbrook Mine. The following features to enable more universal application are not yet enabled:

- CH₄ only applications. This would require some down sizing of the application.
- Data file configurations other than the ACSII format for Dartbrook Mine. It is a relatively simple task to set up the program to accept other data file formats. This can only be done on a case by case basis, when the particular formats are known.
- Specification of shift start and end times different to Dartbrook mine.

5.6.4. Installing and Running the Program

Minimum requirements are Windows 95 or NT running on a 486-66PC with at least 16 MB RAM.

Insert Disk 1 in drive A. From “Windows Explorer”, log on to drive A and double click on Setup.exe. The Install wizard will guide the user through the installation process.

5.6.5. Setting Up Air Velocity and Production Data

Fig. 5.6.1 Selecting “Air Factors”

Load the ‘Air Factors’ form
{Edit/Air Factors}(figure 5.6.1).

Use the database navigation buttons to perform operations on the records of the “Air Sensor Factors” form (figure 5.6.2).

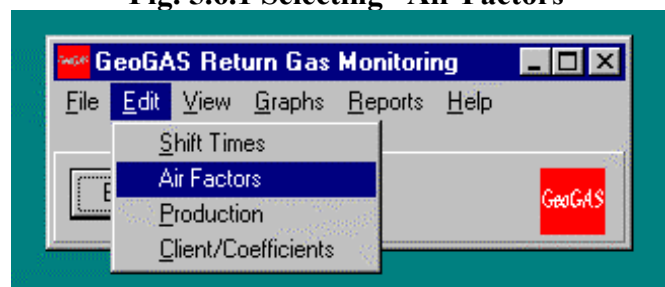


Fig. 5.6.2 Air Sensor Factors Form

Use the database navigation buttons to scroll through, insert, edit, delete and post data. (Holding the mouse over these buttons for a second or two will cause a note to appear explaining the purpose of the button). Eg To insert a new record, click the “Insert” (“+”) button. Enter the values for date, air velocity multiplier and roadway cross sectional area. To post (save) the record, either click on another record, or click the “Post” button (“tick” button).

Note: All operations on tables use the same database navigator buttons.

Date	Air Velocity Multiplier	Area (m2)
25/04/96	1.128	18.49
26/04/96	1.133	18.49
27/04/96	1.137	18.49
28/04/96	1.142	18.49
29/04/96	1.146	18.49
30/04/96	1.151	18.49
1/05/96	1.155	18.49
2/05/96	1.160	18.49
3/05/96	1.164	18.49
4/05/96	1.169	18.49
5/05/96	1.173	18.49
6/05/96	1.178	18.49

Fig. 5.6.3 Production Form

To add new or edit shift production data, load the "Production" form {Edit|Production}, and add to or change the data records (figure 5.6.3). {Same process as for the air sensor factors}.

Date	N/S Metres	D/S Metres	A/S Metres	N/S Tonnes	D/S Tonnes	A/S Tonnes
12/05/96	0			0	0	0
13/05/96	0	7.6	0	0	212.8	0
14/05/96	12.2	12.1	0	341.6	338.8	0
15/05/96	5.5	14.5	0	154	406	0
16/05/96	14	1	0	392	28	0
17/05/96	9	11	0	252	308	0
18/05/96						
19/05/96						
20/05/96	12	0	0	336	0	0
21/05/96	15.6	5.1	0	436.8	142.8	0
22/05/96	19	15.4	0	532	431.2	0
23/05/96	0	9.8	3	0	274.4	84
24/05/96	8	0	0	224	0	0

5.6.6. Client Details

From the main form, select {Edit|Client/Coefficients}. The form showing client and service provider details is displayed (figure 5.6.4). {Only part of the form is shown in figure 5.6.4. The remainder of the form covers historical coefficients, and is covered under "Rating the Gas Emission Results"}.

Figure 5.6.4 Client Provider Details

This record must have "Yes" to signify correct factors Yes

Client: Report To:

Panel: Title:

Service Provider: Report From:

Title:

Either edit or create a new record containing the client name and location and the service provider details. This information is printed on the final report. Each time the program is run, it looks for the record with "Yes" (top right figure 5.6.4), indicating that this records data matches the panel on which calculations are being performed.

5.6.7. Processing New Data

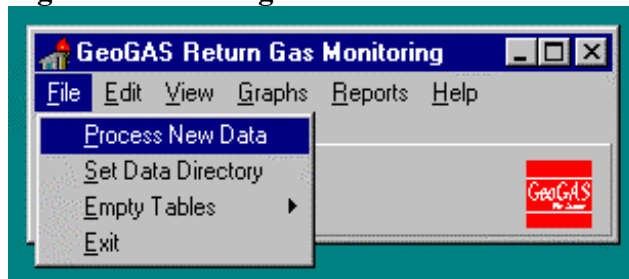
Before proceeding to process new data, make sure the “Air Factors” table and the “Production” table have entries corresponding to the day and shift in question. The data files will have been copied to a directory that can be accessed during this part of the operation.

Tip: It is convenient when processing a number of days of data to have the ‘**Production**’ table already on the desk top.

Procedure:

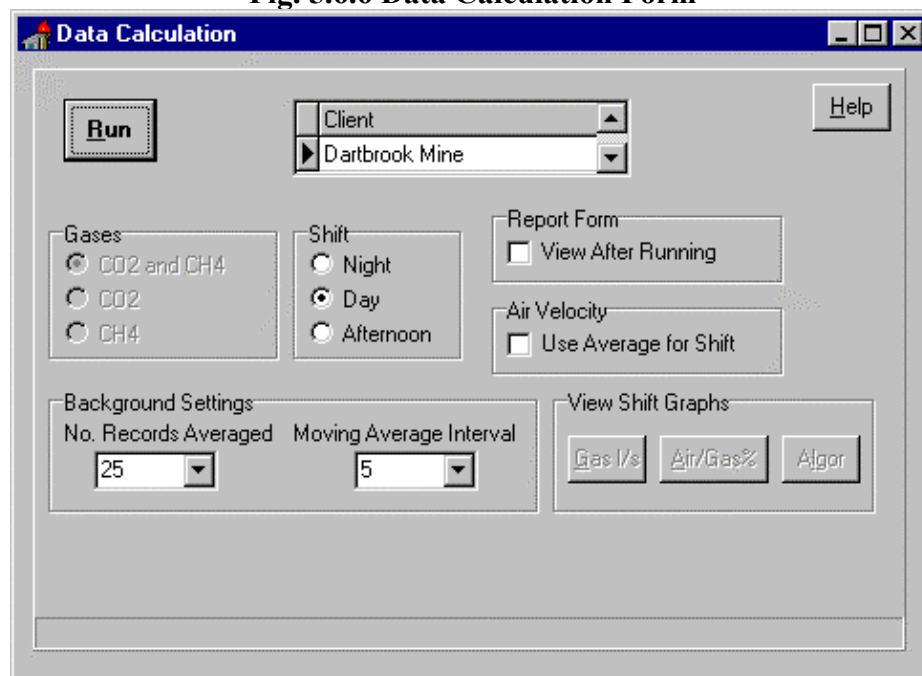
Load the ‘**Data Calculation**’ form {File/Process New Data} (figure 5.6.5).

Fig. 5.6.5 Accessing “Process New Data”



Select the required shift using the radio button options (figure 5.6.6).

Fig. 5.6.6 Data Calculation Form

A screenshot of the 'Data Calculation' form. The window has a blue title bar. It contains several sections: a 'Run' button; a 'Client' dropdown menu set to 'Dartbrook Mine'; a 'Help' button; 'Gases' section with radio buttons for 'CO2 and CH4' (selected), 'CO2', and 'CH4'; 'Shift' section with radio buttons for 'Night', 'Day' (selected), and 'Afternoon'; 'Report Form' section with a checkbox for 'View After Running'; 'Air Velocity' section with a checkbox for 'Use Average for Shift'; 'Background Settings' section with 'No. Records Averaged' set to 25 and 'Moving Average Interval' set to 5; and 'View Shift Graphs' section with buttons for 'Gas l/s', 'Air/Gas%', and 'Algor'.

Use the check box **‘View After Running’** to display the result immediately after execution of the calculation. Alternatively, the result can be selected after the calculation is performed {View/Results/Summary}.

You have the option of using the average velocity for the shift or the measured velocity. In most cases, using each velocity measurement creates considerable additional noise in the data. It is a good idea to try both options and establish the best approach for the application in question.

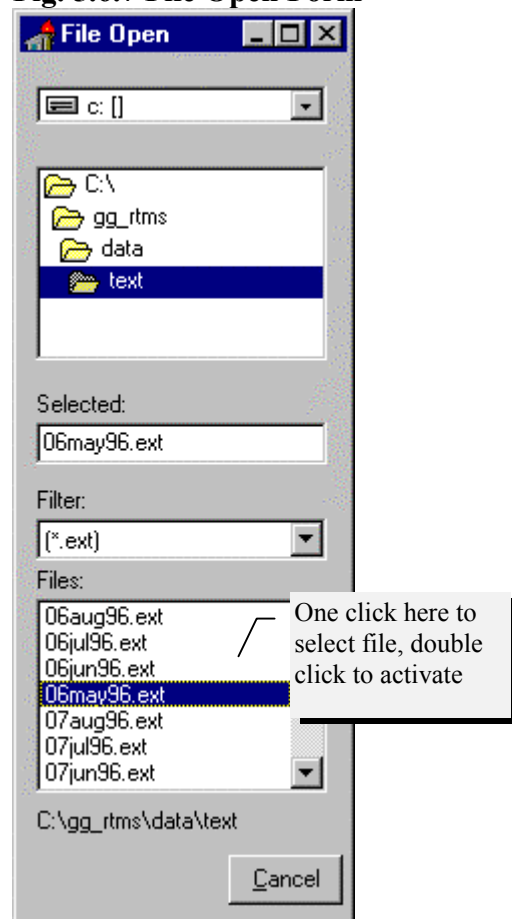
‘Background Settings’ are more fully explained in the section “The Background Algorithm”. These enable reasonable control over where the computer determines the background emission, the most critical part of the calculation. As a starting point, set **‘No. Records Averaged’** to 200 for variable air quantity and 25 for average (fixed) air quantity. Set **‘Moving Average Interval’** to 5.

Click on **‘Run’**, to begin the process. From the **‘File Open’** form (figure 5.6.7), select (single click) a text file. Activate it by double clicking. The directory should automatically open to where your data files are stored.

During running of the program, the data file is checked for gaps in the logging sequence. If any are found, they are deleted and a message given via an OK Dialog Box “Blank records have been found, they have been deleted”. The number of valid records as a percentage of the total available is one of the criteria reported at the end of the calculation (refer to “Result Checking”).

At the completion of running, the resulting options depend upon the setting originally selected. The “Summary Results” report will be visible if you have previously checked the **‘View After Running’** checkbox. Either two or three buttons in the “View Shift Graphs” group will be enabled. If **‘Use Average for Shift’** air velocity was checked, the “Gas/s” and “Air/Gas%” graph buttons will be enabled. Otherwise, the “Algor” button (short for algorithm) will be also enabled.

Fig. 5.6.7 File Open Form

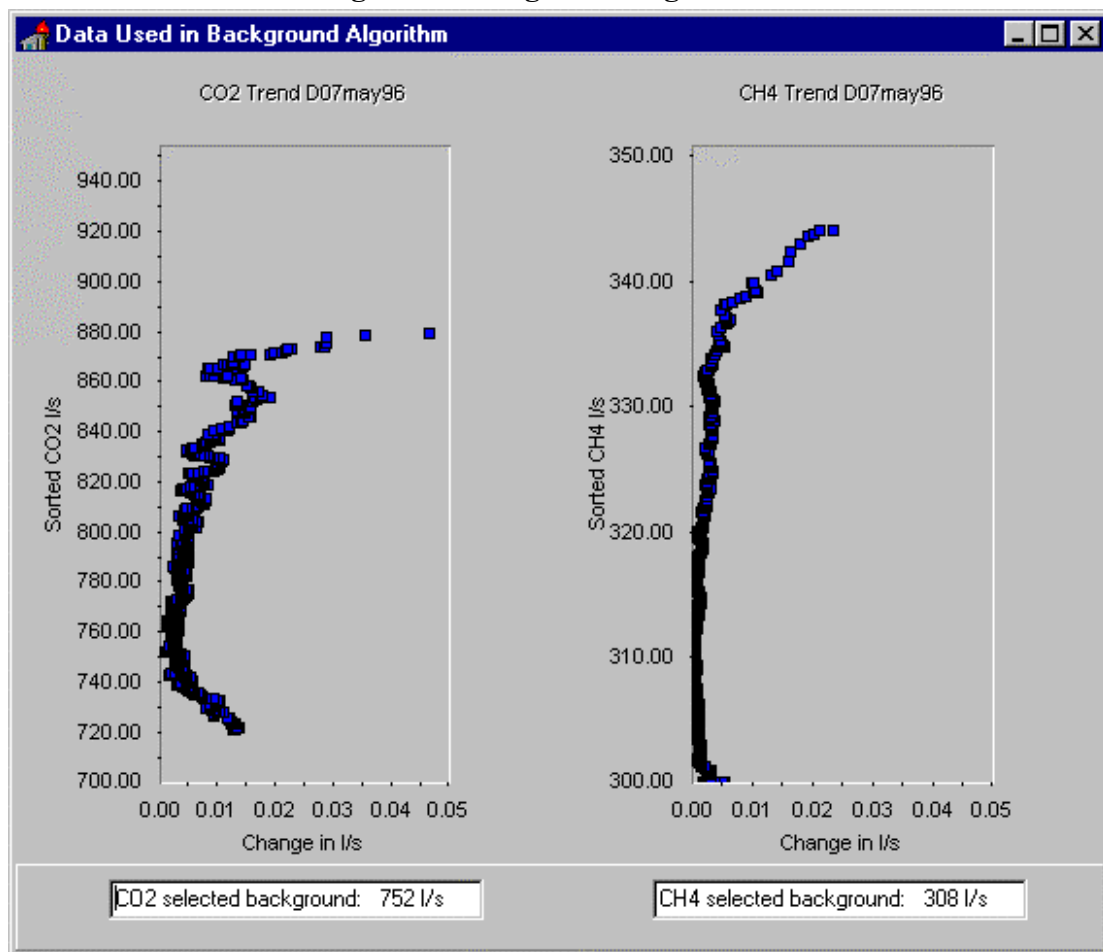


5.6.8. The Background Algorithm

It is fundamental to the calculation of gas emission in the face area, that gas emission from sources outbye the face be differentiated.

Ideally, when there is no mining, the gas emission trace is constant, and this defines the back ground level. This is often not the case. Spurious emission events result from transient ventilation changes (opening doors, turning a fan on and off), drilling and bore hole maintenance and data glitches (spikes and troughs). The pattern of such changes needs to be recognised and filtered from the data.

Fig. 5.6.8 Background Algorithm Data

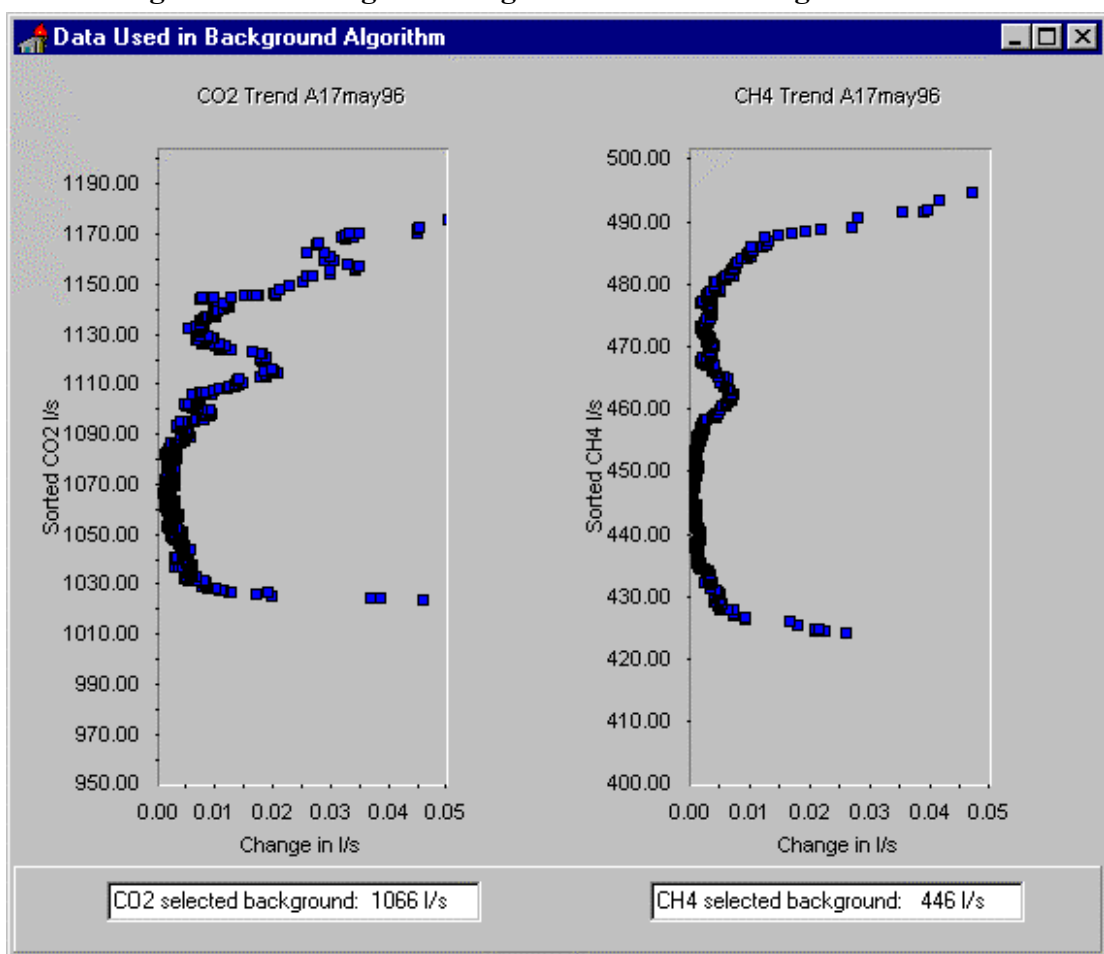


If all the values logged and calculated in l/s are sorted, traces as shown in figure 5.6.8 are revealed. The spurious low value data are defined by the lowest values with the greatest difference between those values (eg the values below 750 l/s for CO₂ and 303 l/s for CH₄ in figure 5.6.8). The algorithm works on the principal that the most consistent values as defined by the least difference between them, will define the background emission. In figure 5.6.8, the computer has calculated these values as 752 l/s for CO₂ and 308 l/s for

CH₄. Values above this level are deemed to reflect gas emission from the face area.

Occasionally, the algorithm will pick a background level that is too high. This occurs in circumstances where there are two minima in the sorted trace (figure 5.6.9). In this case, the algorithm has picked the correct value of 1066 l/s CO₂, but there are situations where the minima at 1130 l/s CO₂ could be picked. This can be avoided by specifying a range of the lowest number of samples for inclusion in the sort. Eg in figures 5.6.8 and 5.6.9, 900 was selected in the drop down box for the number of records averaged in the background calculation. The preferred procedure is to select only the lowest 200 records as outlined in the procedure covered in the section “Processing New Data”.

Figure 5.6.9 Background Algorithm Data Showing Two Minima



The other control the user has in selecting background levels is in defining the number of records included in the moving average. This controls the range over which the differences between the sorted l/s values are calculated.

5.6.9. Creating a Validated Report

This section described the process by which a validated report is created. It is easy to provide a report but without going through the process defined in this section, the results could be completely wrong. It is important to know when data are acceptable or not, and when to reject them.

The overall process involves:

- Running the calculation (see “Process New Data”).
- Viewing the graphs to confirm or otherwise that the background algorithm has worked properly and to identify abnormalities in emission.
- Viewing the checks section of the “Return Gas Monitoring Report” form.
- Annotating comments in the “Return Gas Monitoring Report” form.
- Making a decision on the category of gas emission.

If the “View After Running” box is checked (figure 5.6.6), the “Return Gas Monitoring Report” is automatically displayed (figure 5.6.10) after the “Process New Data” calculation is completed. Alternatively, the form can be accessed from the main form {View|Results}.

The top two rows of the form contain identification data taken from the “Client Provider Details” form (figure 5.6.4).

Fig. 5.6.10 Summary Results Form

Return Gas Monitoring Report

Client: Dartbrook Mine Fanet: 102 To: R. Holland Title: Technical Services Manager

Service Provider: GeoGAS Systems Pty. Ltd. From: R. Williams Title: Principal Consultant

Date: 10/05/96 Shift: D Production: 319.2 Anomalous Emission?: N/A Your Comments:

A. Shift Results:

CO ₂ quantity (m ³) in face area	2663 Abnormally high emission	CH ₄ quantity (m ³) in face area	972 Abnormally high emission
CO ₂ gas make (m ³ /t) in face area	8.34 Abnormally high emission	CH ₄ gas make (m ³ /t) in face area	3.04 Abnormally high emission
CO ₂ peak emission (l/s) in face area	228 Normal emission, higher than average	CH ₄ peak emission (l/s) in face area	81 Normal emission, higher than average

B. Checks and Settings:

Background Emission	CO ₂ (l/s): 734	CH ₄ (l/s): 299	Records logged	Velocity: 960	CO ₂ : 960	CH ₄ : 960
CO ₂ Ratio comparison	Quantity: 0.73	Peak: 0.74	Background: 0.71	Average or variable air velocity: AvgAir		
Value ranges...	Minimum	Average	Maximum	Background calculation...		
Velocity (m/s)	3.60	3.80	4.20	Number samples used: 25		
CO ₂ %	0.90	1.00	1.20	Number samples averaged: 5		
CH ₄ %	0.40	0.40	0.50			

The next row contains the Data, Shift and Production data, the latter taken from the “Production” form (figure 5.6.3) during the calculation.

The “Anomalous Emission?” drop down box contains four options:

- “N/A” - the data are rejected due to quality or missing points.
- “Yes” - Anomalous emission due to mining is clearly recognised. This does not include anomalous emission from non mining events.
- “No” - Emission during mining is clearly normal.
- “Unsure” - Emission may be normal or abnormal. The data are good, but you cannot decide.

Note: The computer will also characterise the emission in terms of normal and abnormal (refer “Computer Rating the Gas Emission Results”).

In the “Your Comments” box, type in any comments you feel are relevant to the accuracy, confidence and application of these results.

Follow these steps in characterising the emission:

1. From the “Data Calculation” form (figure 5.6.6), press the button “Air/Gas%” to display graphs of CH₄%, CO₂% and air quantity.

Do the gas concentration traces clearly show mining and non mining periods? Is the noise level low?

Is the air velocity relatively constant over the shift? If it changes, does the gas concentration change with it?

2. Press the “Gas/l/s” button to view the trends of CH₄, CO₂ in l/s and the ratio of CO₂/CH₄+CO₂. The computer generated background level will also be drawn on the graph (figure 5.6.11).

Does the background level look right? It should exclude the lower most values.

Are there emission abnormalities due to mining or non mining events?

Are the data all there, or are there gaps or a flat trace for sections of it (no data recorded)?

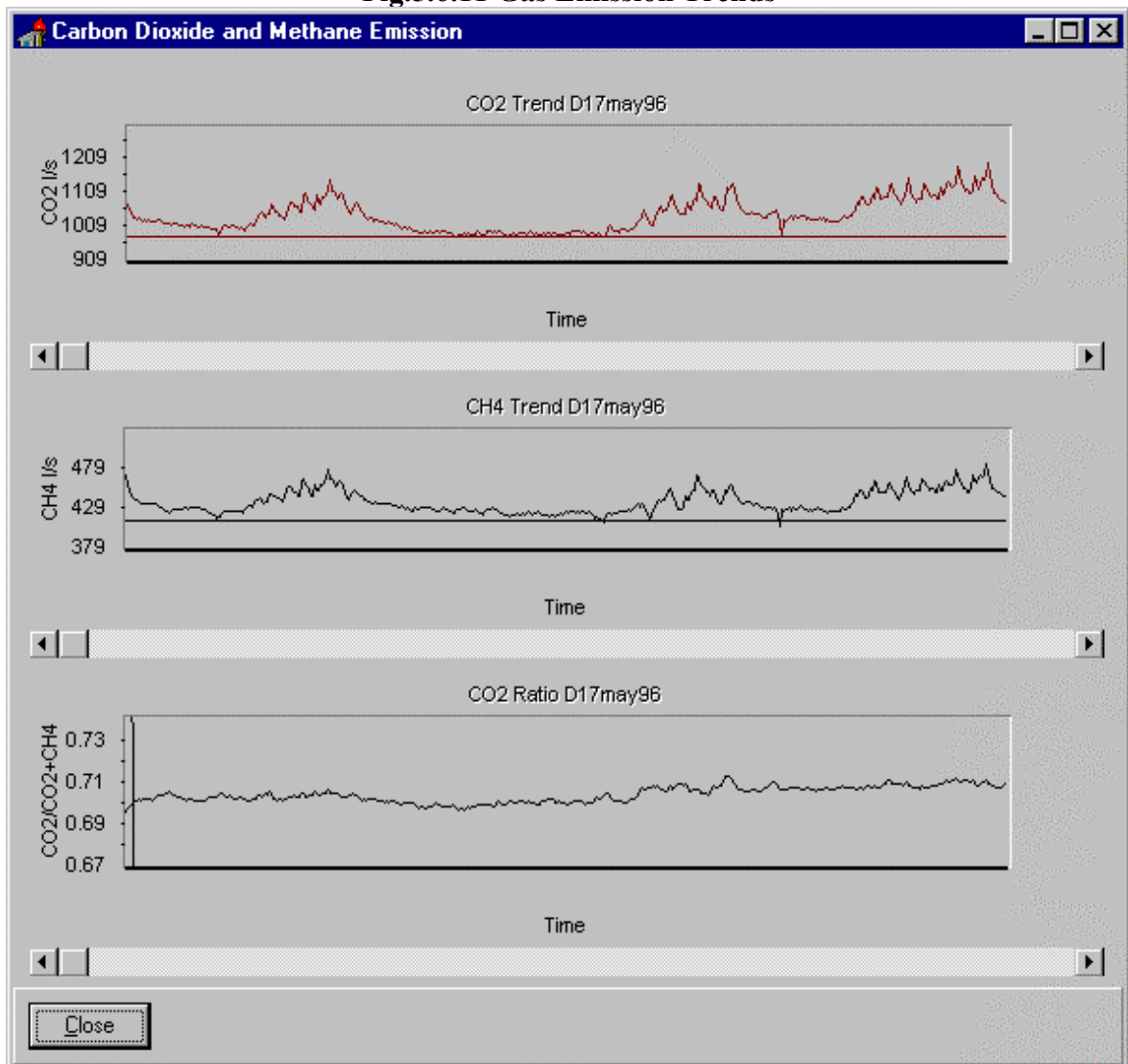
The “l/s” traces will be a lot noisier than the gas concentration traces, due to the fluctuation in air readings.

3. If the background level is obviously wrong, re-run the calculation, but change the background settings (figure 5.6.6). Repeat this until the background level looks right. Remember the setting used.

From the graphs, the background levels now look reasonable. Return to the “Return Gas Monitoring Report” form and look at the “CO₂ Ratio Comparison” boxes under the “B Checks and Settings” part of the form. If the back ground levels are reasonable, the CO₂ ratios (ie CO₂/CO₂+CH₄) should be consistent.

4. Scroll back to the previous shift report. How do the back ground levels and CO₂ ratios compare. Unless there has been a “flit”, the background level should have risen slightly over the previous shift. The CO₂ ratios should be the same. Check a few reports, then return to the current result.
5. Are all the data there? Check that the number of points logged (“Records Logged” under “B Checks/Settings”) is close to the maximum that can be logged according to the PLC/CITECT settings you have used. Look at the maximum/minimum values for gas concentration and air velocity. How wide is the difference? Is this natural or due to spurious effects (eg power off).
6. Now fill in the “Your Comments” box and make a selection from the “Abnormal Emission?” drop down box.

Fig.5.6.11 Gas Emission Trends



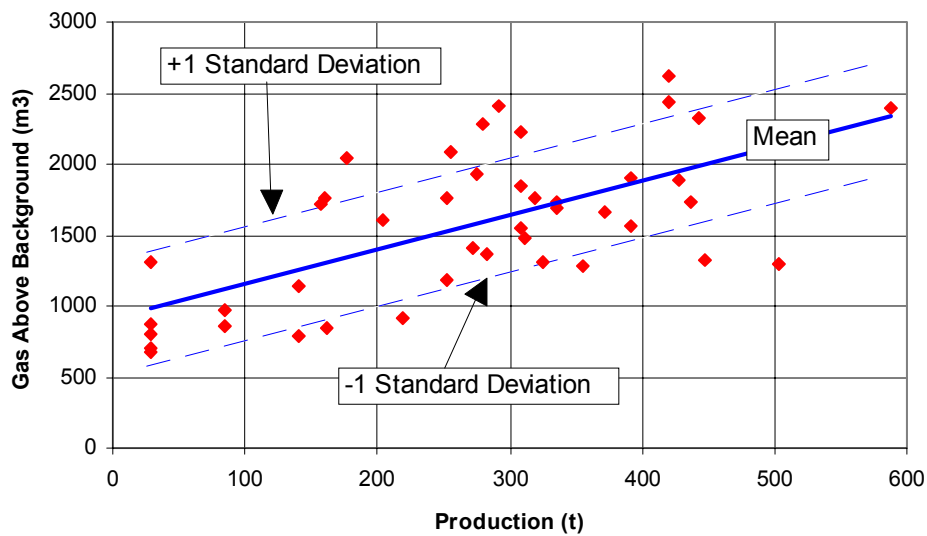
The section of the “Return Gas Monitoring Report” under “A Shift Results” is the computer’s assessment of gas emission.

The following categories are assigned to each value:

- Abnormally high emission
- Normal emission, higher than average
- Normal emission, lower than average
- Abnormally low emission.

How a reading compares to “normal” rests with comparisons of past data for this panel. Values lying within one standard deviation from the mean are regarded as “normal”. Values outside one standard deviation from the mean are “abnormal”.

Example 1 Gas Quantity Above Background



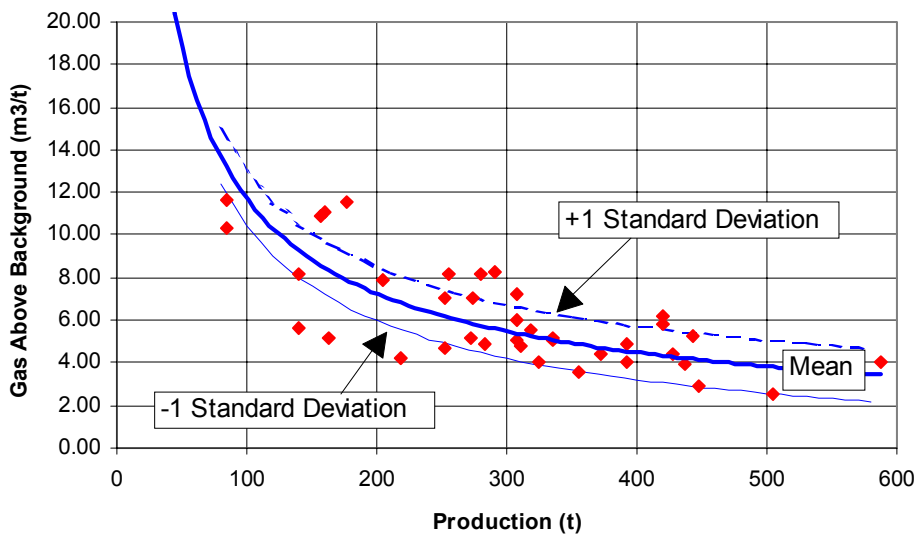
avgvel.xls

In Example 1, values plotting higher than one standard deviation from the mean are “Abnormally high emission”. Values above the mean but less than one standard deviation are “Normal emission, higher than average”. Values below the mean but less than one standard deviation are “Normal emission, lower than average”. Values plotting lower than one standard deviation from the mean are “Abnormally low emission”.

These relationships are defined using regression analysis in EXCEL on the file Result.dbf. This dBase file can be directly read by EXCEL.

Example 2 shows the standard deviations associated with the power function describing the relationship between gas make and production. Note that gas make values cannot be directly compared unless production is taken into account.

Example 2 Gas Make Above Background



avgvel.xls

Fig. 5.6.12 Form for Entering Historical Data Coefficients for the area in Question

Client Provider Details and Historical Emission Coefficients

This record must have "Yes" to signify correct factors Yes

Client: Dartbrook Mine
 Panel: 102
 Service Provider: GeoGAS Systems Pty. Ltd.

Report To: R. Holland
 Title: Technical Services Manager
 Report From: R. Williams
 Title: Principal Consultant

Data Coefficients (Average Velocity)

	CO2 "A"	CO2 "B"	Stdev	CH4 "A"	CH4 "B"	Stdev
Quantity	2.4157	917.99	398	0.9894	299.44	186
Make	283.61	-0.6921	1.27	98.469	-0.6889	0.59
Peak	0.1644	148.26	45.71	0.067	54.567	23.01

Quantity (m3) = "A" * Tonnes + "B"
 Gas Make (m3/t) = "A" * Tonnes ^ "B"
 Peak Emission (l/s) = "A" * Tonnes + "B"

Data Coefficients (Variable Velocity)

	CO2 "A"	CO2 "B"	Stdev	CH4 "A"	CH4 "B"	Stdev
Quantity	2.4157	917.99	398	0.9894	299.44	186
Make	283.61	-0.6921	1.27	98.469	-0.6889	0.59
Peak	0.1644	148.26	45.71	0.067	54.567	23.01

Quantity (m3) = "A" * Tonnes + "B"
 Gas Make (m3/t) = "A" * Tonnes ^ "B"
 Peak Emission (l/s) = "A" * Tonnes + "B"

The standard deviations are shown as being constant, regardless of production. For Example 2, the standard deviation increases with decreasing production. These standard deviations shown apply to production rates in excess of 200 tonnes per shift. A future refinement will be to define and apply the change in standard deviation with production.

The coefficients that describe these relationships are entered onto the “Client Provider Details and Historical Coefficients” form {Edit|Client/Coefficients} (figure 5.6.12).

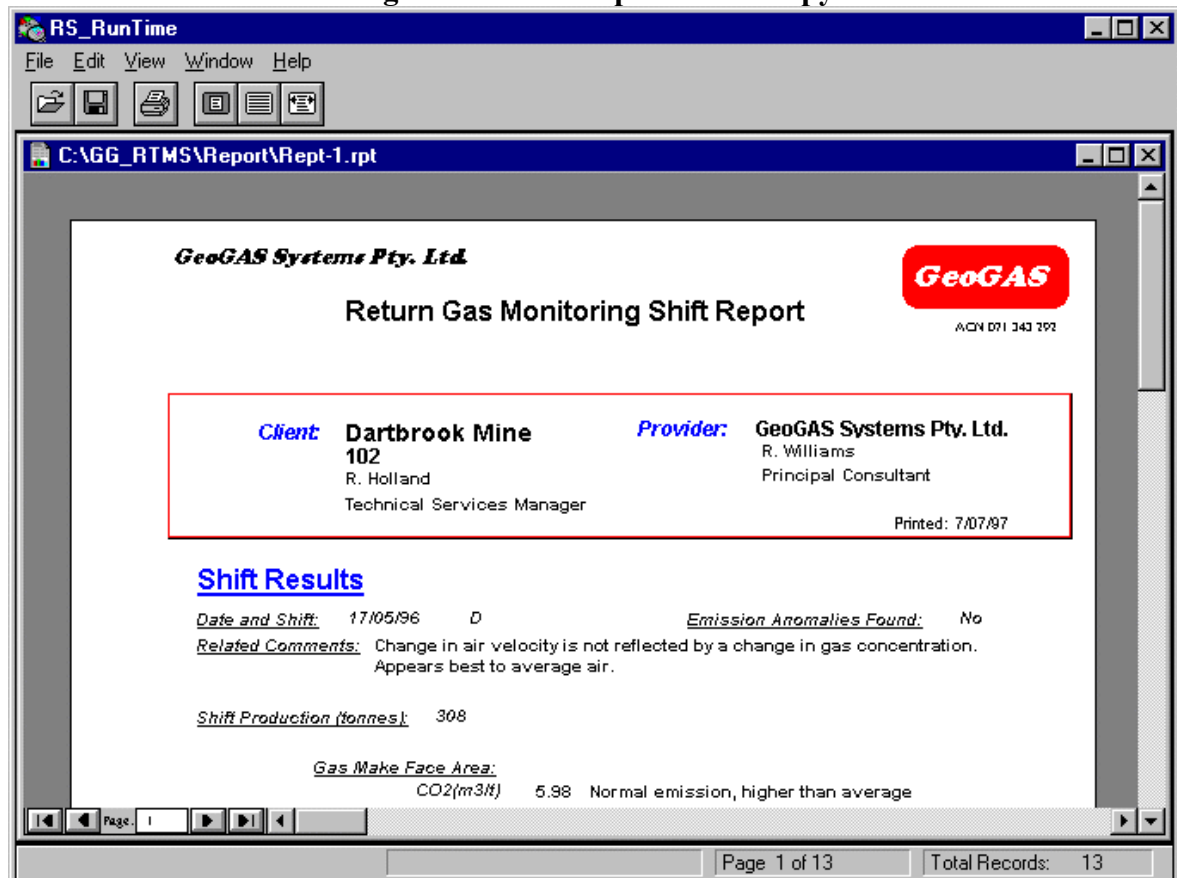
5.6.10.Hard Copy Report

A hard copy report for the shift is created by selecting {Reports|Shift} from the main form.

The report contains the same data as presented on the “Return Gas Monitoring Report” form, but is reformatted to fit on an A4 sheet and can be printed. The top part of a report is shown in figure 5.6.13.

ReportSmith RunTime Help describes the functionality of this item.

Fig. 5.6.13 Shift Report Hard Copy

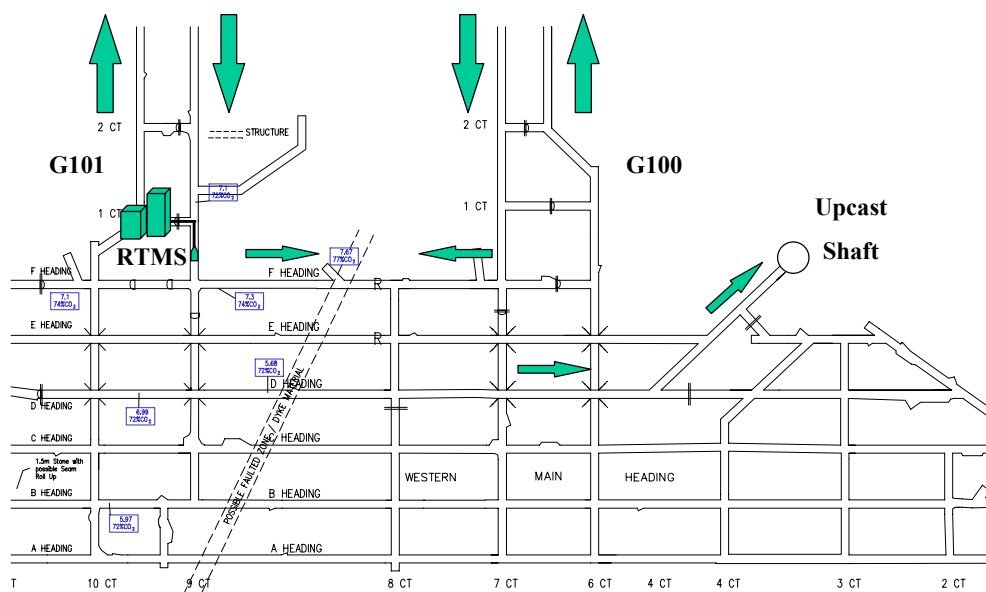


5.7. System Site Requirements

5.7.1. Underground Site, Equipment and Manning

The system is designed to operate adjacent to the single return heading of a long development panel. The system unit **must** be located in a non-hazardous intake environment. It should be sited as close as possible to the panel belt weighometer (usually outbye the panel drive-head). A typical application was the site of the 2nd trial in Dartbrook's Longwall 1 Maingate development, G101 Panel (figure 5.7.1).

Fig. 5.7.1 Site Plan Dartbrook Mine



Specific requirements are :-

- A non-hazardous zone, underground site for system cabinets (outbye intake-side cut-through).
- Hazardous zone underground site for the gas sampling tube head and air velocity sensors (outbye return-side, <30m from system cabinets).
- Non-hazardous zone underground site for weighometer frame.
- Location for tachometer to measure the belt speed (typically a proximity switch on a 'Snubber Roller' outbye the monitoring cabinet on the intake side. Any non-driven, clean side (return) roller will do (but not an idler) with either cut slots or lugs in roller to generate the pulses).
- 240 V power - locally isolated (ie. crib room transformer).

- Overhead fluorescent lighting.
- Transport barrier in the cut-through.

The system power is “latched-off” on all power interruptions. Personal intervention by appointed colliery personnel is required to restore power to the system. Power-up procedures are posted on the door of the RGMS system cabinet (refer section on “**Safe Operation**”).

For this reason continuous operation of the system is dependent on “adoption” by the concerned panel deputies and electricians. Most panels will be powered-down over weekends or dispute periods. It is necessary that inspection and power-up of the machine becomes part of the routine “pre-shift” work orders.

5.7.2. Surface Equipment and Communications

Communications between the underground system and the surface monitoring PC is effected by connection of 2 Mikan Short Haul Modems. These modems communicate to the PLC and PC using RS-232 protocol, but between themselves using RS-422 “half-duplex” protocol (with an effective line limit of 6000 m).

Access is required to:

- The mine’s signal cabling trunk, with two twisted pair (or a minimum of 4 cores globally shielded) from the underground site to the surface ‘junction box’ to surface PC site.
- A surface location for monitoring PC (ie. power point, desktop space and access to underground communication cabling).

Optional access to an external telephone line allows remote system control and support, and access to system data.

6. Risk Assessment

A formal risk assessment of the system was conducted in December 1994 prior to the underground installation of the equipment at Tahmoor Colliery. It was aimed at ensuring the system incorporated sufficient designed safeguards against hazardous operations in an underground environment and to make recommendations for any further safeguards deemed appropriate. A separate risk assessment report was compiled by the facilitator, Mr. Ken Tuckey of Vale Engineering.

The Risk Assessment team have highlighted 6 minor items of system design and implementation as warranting further action.

1. Check 240V CRITEC power conditioning unit to assess level and duration of stored charge during power down and ventilation off conditions. **ACTION:** Glen Jones (Quality Data) to approach manufacturer for certification of level and duration of stored charge. **STATUS:** Done. Appended to Risk Assessment.
2. Check 240-12V TROLEX I/S power supply unit to assess level and duration of stored charge during power down and ventilation off conditions. **ACTION:** Ron Cairns to approach Australian distributors for certification of level and duration of stored charge. **STATUS:** Done. Flameproof implementation of this power supply carries warning "not to be opened for 5 minutes after unit has stopped being energised". This is a worst case time where an output was not directly connected. Appended to Risk Assessment. Operator will ensure 5 minutes has expired since system shutdown before cabinet is opened.
3. Shroud line side (240V) of door switch to prevent accidental electrocution. **ACTION:** Glen Jones to source optional fitted shrouds. Mike Slater to install and test. **STATUS:** Done.
4. Fit / certify IS battery status with PLC CPU. **ACTION:** Glen Jones to seek certification of battery type from manufacturers. Mike Slater to clear with Tahmoor Electrical Engineering Dept. **STATUS:** Done. Appended to Risk Assessment.
5. Certify necessity of Aluminium cylinder for Span Gas with BOC Gases. **ACTION:** Mike Slater to approach BOC Gases for certification. **STATUS:** Done. Appended to Risk Assessment.
6. Fit in-line 'ceramic type' fuse between power supply and cabinet ventilation fan. **ACTION:** Glen Jones to source. Mike Slater to install and test. **STATUS:** Done.
7. Zero and Span Gas cylinders must be removed from the monitoring system while it is being transported. The cylinders must be transported underground securely within steel boxes. **ACTION:** Mike Slater to source steel 'crib tins'. **STATUS:** Done. Steel tool chest will be used to transport bottles whilst underground.

7. Site Trials and Data Analysis

7.1. Tahmoor Colliery

7.1.1. Introduction

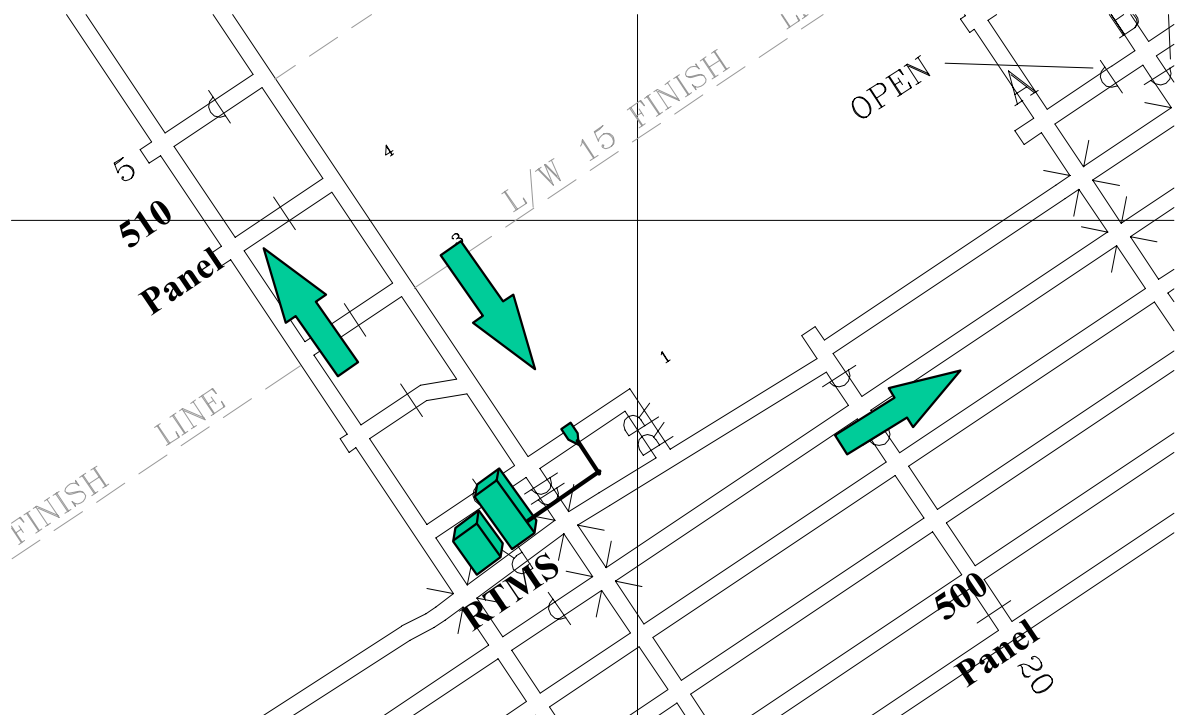
Tahmoor Colliery agreed to provide a site for trials and financial assistance. 510 Panel was the first project field trial site (figure 7.1.1).

The work was conducted over an 8 month period from 13th February 1995 to the 13th October 1995. Allowing for commissioning and decommissioning and delays, actual monitoring took place for the months of June, July and August.

This report provides an account of the work carried out at Tahmoor Colliery, and results and recommendations from the technical work program.

The Bulli seam is mined at a height of 2.2 m. The virgin gas content is around 12 m³/t at 80% CO₂ and 20% CH₄, but has been predrained to less than half this value.

Fig. 7.7.1 Tahmoor Monitoring Site



7.1.2. Logs of Activities and Events

Feb 13th Installation of monitoring system at U/G site completed (B hdg, 1 c/t 510 Panel).

March 17th	240V power connected to U/G site
March 24th	Weightometer installed at site and calibrated
March 28th	Commissioning and calibration of monitoring system completed
April 4th	Remote communications from GeoGAS, Wollongong to Tahmoor monitoring system established
May 1st	Problems with power-down of monitoring system flagged with colliery
May 22nd	Surface PC upgraded
May 23rd	Weightometer topples off footings
May 24th	Weightometer re-leveled and braced with chains
May 31st	Maintenance of Trolex Velocity head, servicing of analysers and filters, re-zeroing of weightometer
June 1st	Data analysis highlights PLC programming bug with handshake flags
June 9th	Citect application data format re-configured
June 15th	Weightometer damaged
July 3rd	Surface power problems in control room. Surface monitoring PC dysfunctional.
July 19th	Control room power fixed. Surface monitoring PC functioning
July 20th	Evening - night shift gas release monitored
August 25th	Logging of data ceases at Tahmoor
Oct 13th	Retrieval of all equipment from underground site at 510 Panel Tahmoor
Oct 18th	Transport of equipment to GeoGAS Hunter Valley office (HVO) at Muswellbrook for clean and overhaul of monitoring system followed by surface testing.
From Nov 14th	Data reduction from Tahmoor site trial.

7.1.3. Breakdown of Data Set

The three month data set of real-time monitoring extends from afternoon shift of Friday, 9th June to evening shift of Friday 25th August. Once communications had been established between the underground system and the surface monitoring PC only interruptions to the power underground and on the surface stopped data logging.

Between July 3rd and July 19th, power interruptions as often as once each half hour were experienced in the control room. Initially, logging of data continued intermittently but for most of this period the surface PC was powered down (to protect it and improve power to more vital colliery monitoring). On July 19th a line power conditioner was installed and, while not eliminated, the power losses became much less frequent.

In the period August 7th to August 21st there was no production in 510 panel due to high gas levels. The principal activity at this time was gas drainage and many of the 'lost' data shifts occurred as power was discontinued.

Power interruptions to the belt starter at 510 Panel would "latch-off" power to the monitoring system, requiring intervention of underground staff to reset. Most of the 'lost' data shifts resulted from delays in resetting the system after scheduled (and un-scheduled) power interruptions.

	Shifts		% of Total
June 9th - 30th	86	Total for period (43 on production)	
	-46	Complete shift data sets	53.5
	-8	Un-powered weekend shifts	9.5
	32	'Lost' data shifts	37
July 1st - 31st	124	Total for month (46 on production)	
	-35	Complete shift data sets	28
	-24	Un-powered weekend shifts	19.5
	-48	Control room power failure	39
	17	'Lost' data shifts	13.5
August 1st - 25th	100	Total for month (19 on production)	
	-41	Complete shift data sets	41
	-24	Un-powered weekend shifts	24
	35	'Lost' data shifts	35

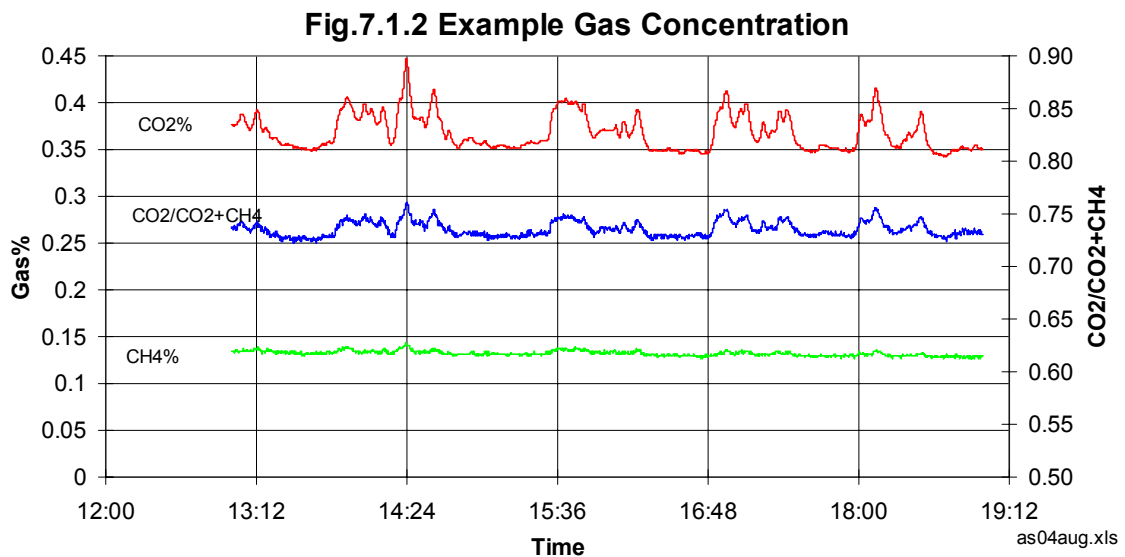
Only complete data shifts have been tabled, there were many shifts (particularly at the week start and end) where data were logged for partial shifts only.

The belt weightometer component of the system was deemed to be essentially inoperable. It was not suited to a suspension belt assembly, having been designed around the belt structure at West Cliff Colliery - where the system was originally scheduled.

7.1.4. Analysis of Data

7.1.4.1. General Description of Emission Response

An example CO₂, CH₄ and CO₂/CO₂+CH₄ Ratio chart is given in figure 7.1.2. For the area being mined, the gas composition was approximately 73% CO₂ and 27% CH₄. Note the increase in CO₂/CO₂+CH₄ ratio with mining. This probably reflects the faster rate of CO₂ desorption compared to CH₄.



Rhythmic fluctuations in air velocity are a significant source of noise (figure 7.1.3). Rapid changes are evident from 45 m³/s to 43 m³/s (in the case of this example). These transient changes are not reflected in corresponding CO₂ and CH₄ gas concentration readings, resulting in a higher level of “noise” in the CO₂ and CH₄ gas flow results (figure 7.1.4 CO₂ example). At 0.35% CO₂, a change in air quantity from 45 m³/s to 43 m³/s results in changes in CO₂ flow of 150.5 l/s to 157.5 l/s.

The noise is partially controlled by the PLC’s data averaging and moving average settings. There is further scope to adjust these settings.

Fig.7.1.3 Example Air Quantity

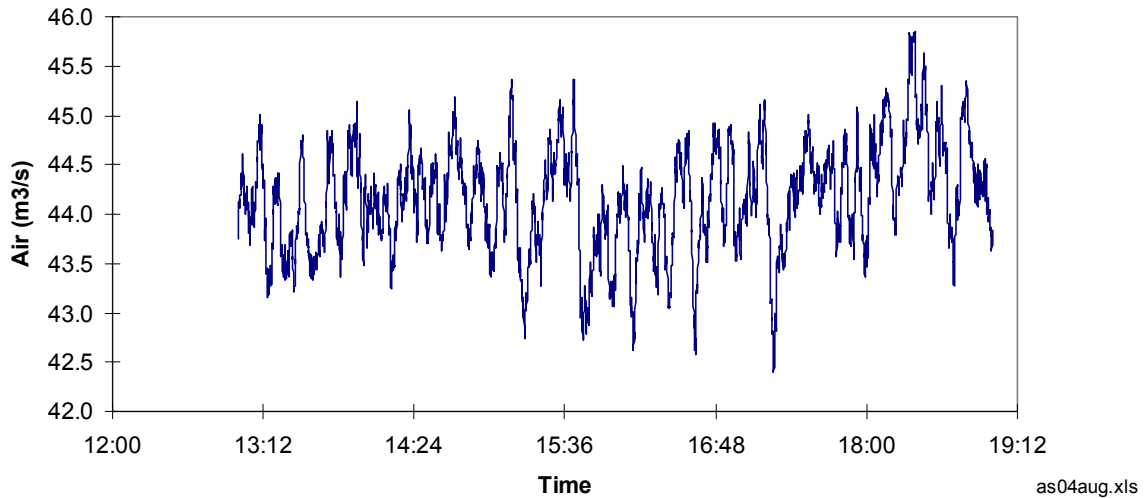
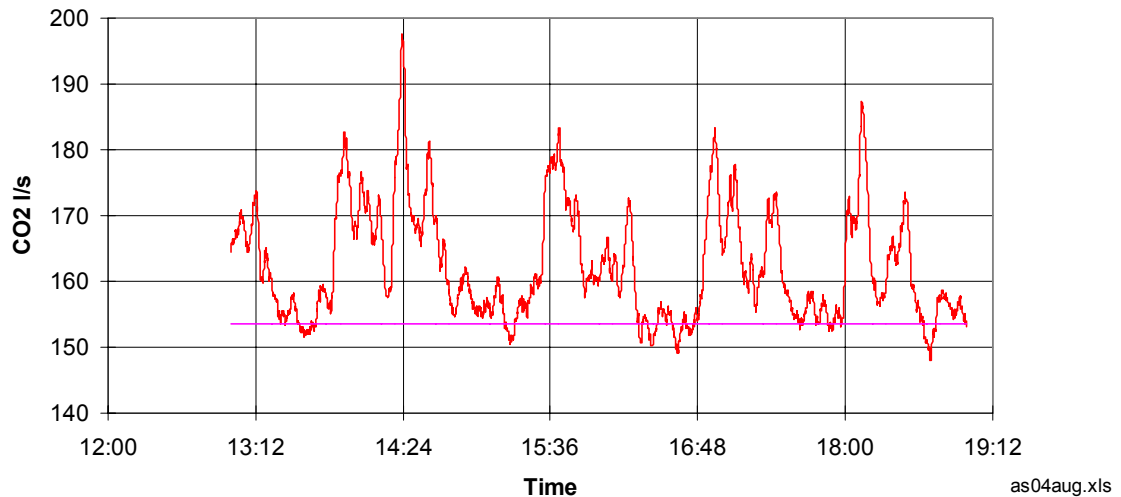


Fig. 7.1.4 Example CO2 Flow



7.1.4.2. Routine Shift Based Data Reduction

The EXCEL MACRO H:\TAHMOOR\RTMS\RT-MACRO.XLS is run to convert the basic CITECT logged ASCII data to an EXCEL spreadsheet doing the following operations:

- Import and parse the ASCII file
- Create additional columns for air quantity, CO₂ quantity and CH₄ quantity.
- Optionally generate graphs of CO₂%, CH₄%, CO₂/CO₂+CH₄ Ratio, CO₂ l/s, CH₄ l/s
- Calculate the background emission levels for CO₂ and CH₄ and the total m³ emission above background level.
- Write summary data to file (\TAHMOOR\RTMS\RW-SUMMARY2.XLS).

Note: The EXCEL MACRO was part of the prototyping process. This type of analysis would be carried out using the compiled Delphi 32 bit program as described under "Data Processing Software".

7.1.4.3. Treatment of Background Emission

The main task is to separate the back ground emission from the face area emission.

Definition of a computerised algorithm (or algorithms) to objectively achieve this is a significant part of the research work.

The simplest method of determining the back ground level is to allow the computer to identify the minimum level of gas emission for the shift in question, and assign this as the back ground level. Complications with this approach are:

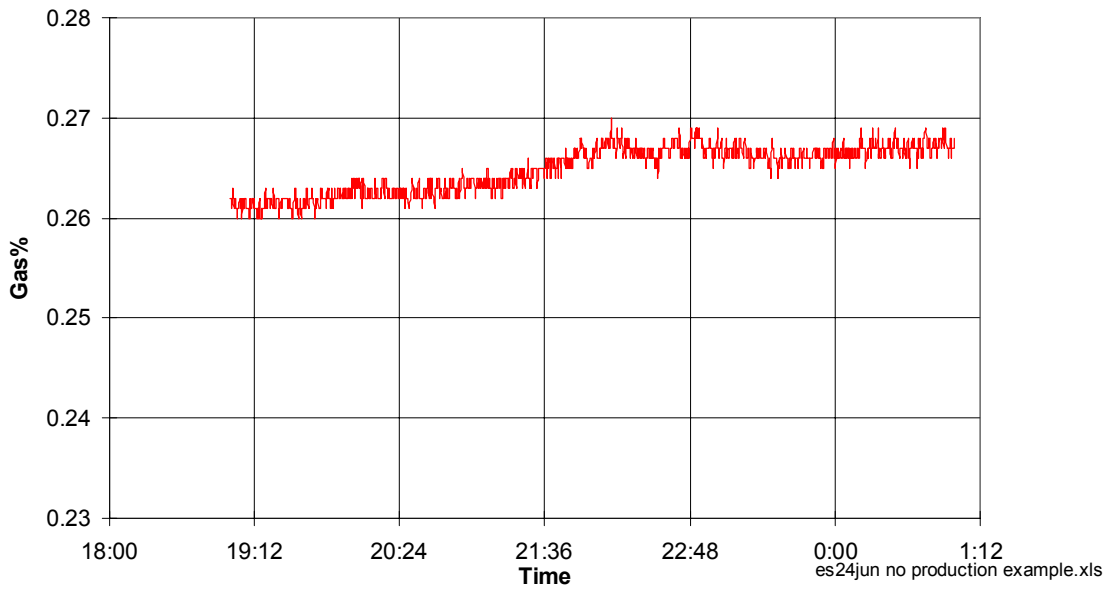
- Differentiation of spurious emission events, particularly sudden low gas emission levels, corresponding to transient ventilation changes (opening doors, turning a fan on and off) or data glitches (spikes and troughs). The pattern of such changes needs to be recognised and filtered from the data.
- The time interval considered compared to the period of production. The difficulty is that the back ground level is never static. Ideally, for the period in question, the background level should have reached a near steady state level, prior to the next mining period. For normal rates of mining in moderately gassy conditions, the gas emission from the previous period of mining is still tailing down when mining recommences. With prolonged mining periods, it may not be possible to identify the background emission level for the shift in question.

Non mining periods were examined to determine the inherent variability in the data. Relatively consistent gas concentration trends (figure 7.1.5) are translated into somewhat "noisy" gas flow trends (figure 7.1.6). For example, the range in CO₂ gas concentration was only 0.270% to 0.265%, this translating into a range in CO₂ flow of 126.4 l/s to 133.1 l/s from a change in air quantity of 47.7 m³/s to 49.9 m³/s.

A number of methods were devised and tested, to automatically set background levels. For this trial, the "Rate of Change" algorithm was developed and applied. It involves the following:

1. Mapping the distribution of each gas flow value (CO₂ l/s and CH₄ l/s), against the rate of change between values (figure 7.1.7). {The actual change over a moving average of 5 consecutive readings, divided by the elapsed time in seconds}. The background emission level in l/s is that corresponding to the minimum rate of change value.
2. Subtracting the area under the total emission graph, by the area under the background emission line.

**Fig. 7.1.5 Example CO2 Concentration
No Production and Good Data**



**Fig. 7.1.6 Example CO2 Emission
No Production and Good Data**

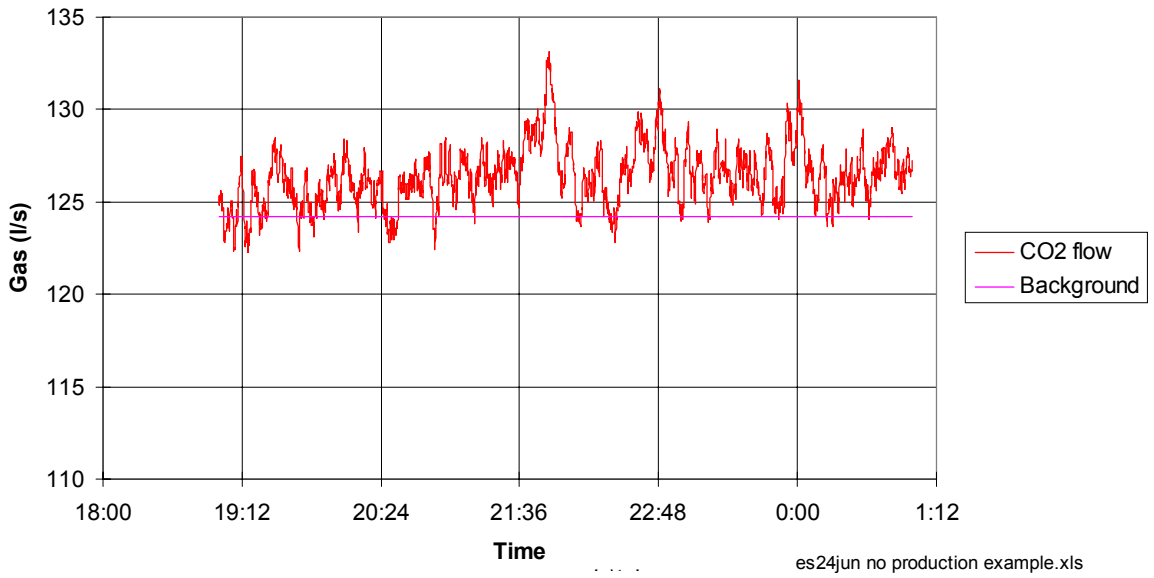
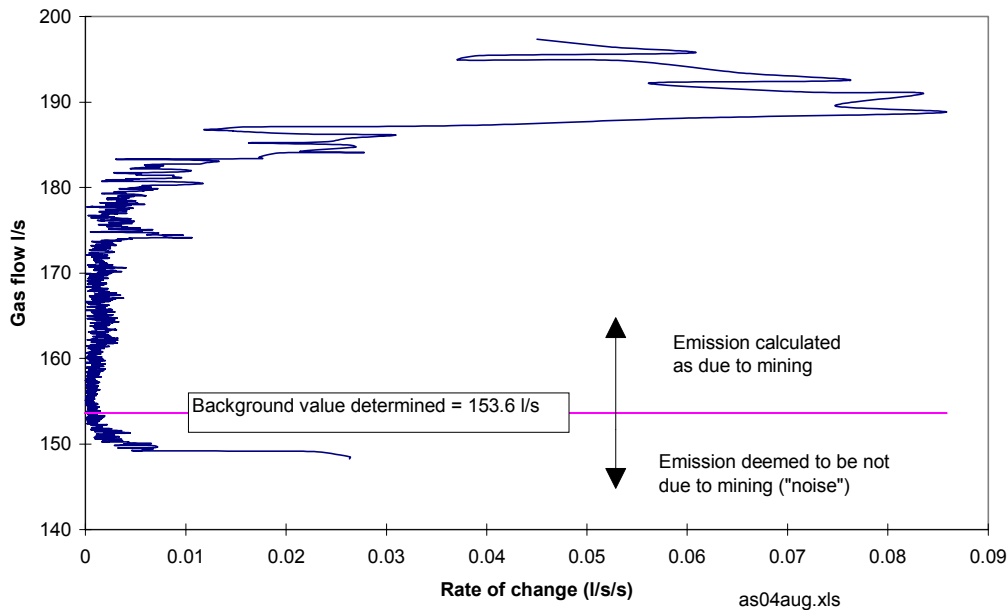


Fig. 7.1.7 Analysis of Rate of Change



Using this method, the background emission line is drawn within the group of lower values, excluding what are deemed to be anomalously low values (figure 7.1.4 - horizontal line at 153 l/s).

7.1.4.4. Reported Values

After automatically determining the background levels, the program (an EXCEL Visual Basic MACRO) writes the summary data to file (\TAHMOOR\RTMS\RW-SUMMARY2.XLS). CO₂ and CH₄ are calculated separately. The summary data are:

- Absolute Peak emission (l/s)
- Background emission (l/s)
- Shift gas volumes above background (m³)

These data are combined with shift production statistics to produce gas make values (m³/t). Additional calculated columns show the CO₂/CO₂+CH₄ ratio and the net peak emission (subtraction of background emission from absolute peak emission).

The final data summary is given in Table 7.1.1, after removal of incomplete and spurious data (see next section).

TABLE 7.1.1 SUMMARY OF SHIFT BASED EMISSION DATA

rw-summary2.xls

Date	Shift	Peak Emission		Background Emission		Shift Volume		Tonnes	Gas Make		CO ₂ / CO ₂ +CH ₄	Net Peak Emission	
		CO ₂ l/s	CH ₄ l/s	CO ₂ l/s	CH ₄ l/s	CO ₂ m ³	CH ₄ m ³		CO ₂ m ³ /t	CH ₄ m ³ /t		CO ₂ l/s	CH ₄ l/s
27-Jun-95	DS	178	55	157	50	36	41	0			0.46	20.9	5.1
15-Jun-95	NS	109	40	99	37	39	23	0			0.63	9.4	3.2
10-Jun-95	NS	110	42	104	39	42	22	0			0.65	5.7	3.3
12-Jun-95	DS	99	39	92	36	42	23	0			0.65	7.3	3.2
25-Jun-95	DS	133	50	126	45	42	33	0			0.56	7.7	4.6
24-Jun-95	DS	132	49	124	44	42	34	0			0.55	8.2	4.8
12-Jun-95	NS	98	39	93	36	42	24	0			0.64	4.8	3.0
11-Jun-95	ES	100	39	94	36	44	21	0			0.68	5.9	2.9
24-Jun-95	AS	132	50	125	46	46	28	0			0.62	7.3	4.0
14-Jun-95	ES	104	40	98	36	47	27	0			0.64	5.7	3.7
24-Jun-95	ES	133	49	124	45	48	27	0			0.64	8.9	4.1
23-Jul-95	ES	128	54	121	50	49	30	0			0.62	6.8	4.0
14-Jun-95	AS	105	40	99	36	50	29	0			0.63	6.4	3.8
23-Jul-95	AS	137	58	127	52	51	39	0			0.56	10.3	5.8
11-Jun-95	DS	105	41	99	38	52	23	0			0.69	6.6	2.9
24-Aug-95	AS	147	52	134	48	52	27	0			0.66	13.4	3.4
10-Jun-95	ES	108	42	101	39	54	27	0			0.67	6.8	3.5
18-Aug-95	NS	134	54	124	49	55	36	0			0.60	9.9	4.2
25-Jun-95	AS	133	50	125	46	56	23	0			0.71	8.5	4.1
12-Jun-95	AS	98	39	91	36	57	25	0			0.69	6.3	3.1
23-Jul-95	DS	138	57	129	53	58	34	0			0.63	8.6	4.2
22-Jul-95	ES	137	57	128	53	62	27	0			0.69	8.2	3.6
10-Jun-95	AS	111	43	102	39	63	32	0			0.67	8.3	3.8
2-Aug-95	ES	151	59	139	55	64	29	0			0.69	11.9	4.7
14-Jun-95	DS	104	41	97	37	64	22	0			0.74	7.6	4.5
10-Jun-95	DS	115	43	104	39	66	34	0			0.66	11.3	4.5
30-Jul-95	ES	144	61	135	56	67	44	0			0.60	9.0	4.8
22-Jul-95	NS	145	59	133	55	69	32	0			0.68	11.4	4.6
30-Jul-95	DS	138	59	129	54	69	34	0			0.67	8.8	4.5
18-Aug-95	AS	134	54	124	51	70	21	0			0.76	10.0	3.0
23-Aug-95	ES	173	62	150	55	71	44	0			0.62	23.2	7.0
16-Jun-95	AS	113	42	103	38	73	26	0			0.74	10.9	4.0
24-Aug-95	NS	152	58	141	54	73	29	0			0.72	11.3	3.7
11-Aug-95	DS	172	68	154	58	73	63	0			0.54	18.2	10.5
12-Jun-95	ES	94	38	86	34	74	35	0			0.68	7.8	3.6
17-Aug-95	ES	132	54	122	50	75	26	0			0.74	10.1	3.6
30-Jul-95	AS	142	60	132	56	76	32	0			0.71	9.1	4.0

TABLE 7.1.1 SUMMARY OF SHIFT BASED EMISSION DATA (continued)

rw-summary2.xls

Date	Shift	Peak Emission		Background Emission		Shift Volume		Tonnes	Gas Make		CO2/ CO2+CH4	Net Peak Emission	
		CO2 l/s	CH4 l/s	CO2 l/s	CH4 l/s	CO2 m3	CH4 m3		CO2 m3/t	CH4 m3/t		CO2 l/s	CH4 l/s
29-Jul-95	AS	133	53	123	49	77	33	0			0.70	10.0	4.1
17-Aug-95	AS	174	56	129	52	79	22	0			0.78	44.7	4.1
25-Aug-95	NS	149	54	134	49	79	37	0			0.68	15.1	4.6
11-Jun-95	AS	105	41	97	38	80	25	0			0.76	7.8	3.1
28-Jul-95	NS	159	58	143	53	82	31	0			0.73	16.3	4.6
2-Aug-95	AS	161	61	146	57	84	26	0			0.77	15.3	4.4
2-Aug-95	NS	168	59	146	55	84	28	0			0.75	22.1	4.1
22-Jul-95	AS	141	59	131	54	85	43	0			0.66	10.3	5.2
22-Jul-95	DS	141	59	131	54	86	42	0			0.67	10.1	5.2
14-Jun-95	NS	124	53	101	38	88	31	0			0.74	22.8	15.2
29-Jul-95	ES	135	57	125	50	98	64	0			0.61	10.7	6.5
28-Jul-95	DS	156	57	138	53	100	26	0			0.80	18.2	3.9
29-Jul-95	NS	141	55	127	50	101	33	0			0.75	14.1	4.2
18-Aug-95	DS	140	54	122	50	106	35	0			0.75	17.5	4.4
27-Jul-95	ES	150	56	136	52	107	39	0			0.73	14.1	4.2
27-Jul-95	AS	169	63	142	54	109	35	0			0.76	27.1	9.2
25-Aug-95	AS	184	62	131	50	110	46	0			0.71	53.2	12.2
3-Aug-95	DS	235	80	136	53	113	37	0			0.75	98.4	27.2
11-Aug-95	NS	175	62	151	58	118	26	0			0.82	24.0	4.7
3-Aug-95	NS	179	60	138	55	127	27	0			0.83	40.9	4.9
23-Jul-95	NS	146	63	132	55	129	75	0			0.63	14.3	8.3
3-Aug-95	AS	160	61	135	53	138	39	0			0.78	25.4	7.9
25-Aug-95	DS	143	54	128	49	151	44	0			0.78	15.4	5.1
30-Jul-95	NS	145	62	131	55	153	80	0			0.66	14.0	7.1
2-Aug-95	DS	163	74	140	54	154	48	0			0.76	22.9	19.5
27-Jun-95	NS	171	55	145	50	155	35	0			0.82	25.7	4.9
24-Jun-95	NS	143	51	123	44	156	48	0			0.77	20.3	6.2
24-Jul-95	DS	167	67	124	49	94	35	24	3.89	1.45	0.73	43.4	17.8
9-Jun-95	AS	122	43	105	38	87	25	33	2.64	0.75	0.78	17.4	4.8
6-Jul-95	ES	189	60	172	55	32	8	70	0.46	0.12	0.79	17.4	4.9
19-Jun-95	NS	125	42	102	37	54	16	77	0.70	0.21	0.77	22.7	4.9
26-Jun-95	ES	163	54	144	49	91	29	92	0.99	0.31	0.76	19.1	4.3
26-Jun-95	AS	186	57	151	49	131	49	97	1.35	0.51	0.73	35.8	7.6
24-Jul-95	AS	148	56	127	51	107	31	99	1.08	0.31	0.78	21.0	5.4
13-Jun-95	NS	115	40	89	35	137	36	99	1.39	0.36	0.79	25.5	4.9
23-Jun-95	ES	154	52	128	46	150	36	99	1.52	0.37	0.80	25.2	6.4
22-Jun-95	AS	150	46	122	40	86	37	101	0.85	0.37	0.70	28.8	5.9

TABLE 7.1.1 SUMMARY OF SHIFT BASED EMISSION DATA (continued)

rw-summary2.xls

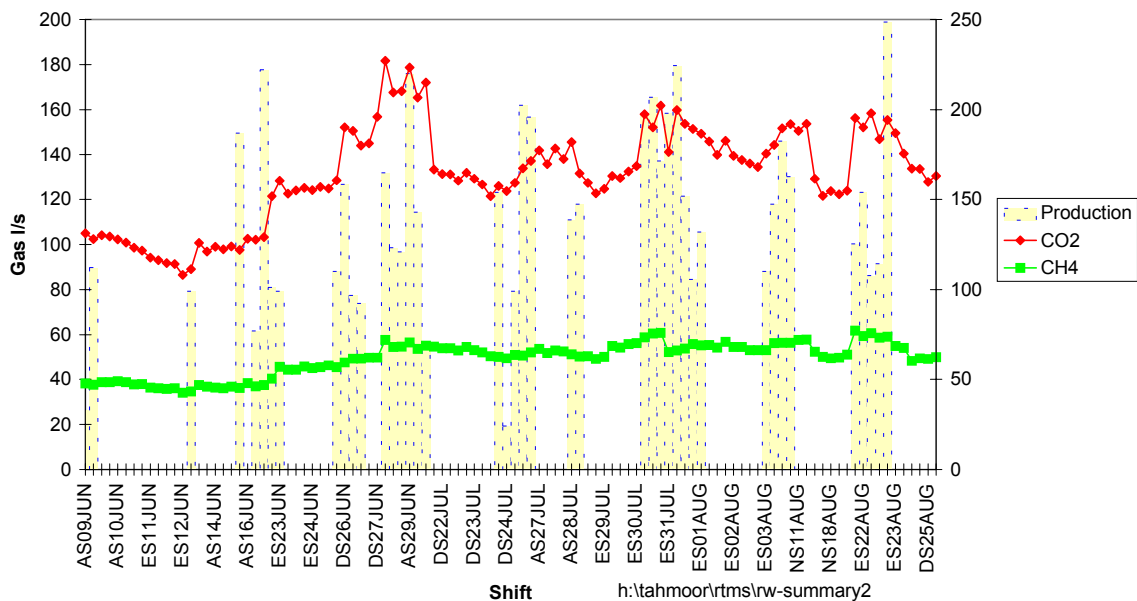
Date	Shift	Peak Emission		Background Emission		Shift Volume		Tonnes	Gas Make		CO ₂ /CO ₂ +CH ₄	Net Peak Emission	
		CO ₂ l/s	CH ₄ l/s	CO ₂ l/s	CH ₄ l/s	CO ₂ m ³	CH ₄ m ³		CO ₂ m ³ /t	CH ₄ m ³ /t		CO ₂ l/s	CH ₄ l/s
1-Aug-95	AS	198	64	151	56	202	45	106	1.91	0.43	0.82	47.0	8.6
23-Aug-95	NS	208	69	158	61	219	51	108	2.03	0.47	0.81	49.2	8.2
3-Aug-95	ES	168	59	140	53	133	52	110	1.21	0.47	0.72	27.6	5.8
26-Jun-95	NS	160	53	129	45	229	54	110	2.08	0.49	0.81	31.3	7.8
9-Jun-95	ES	131	43	102	38	152	38	112	1.35	0.34	0.80	28.8	4.9
23-Aug-95	DS	203	67	147	59	208	43	114	1.82	0.38	0.83	56.4	8.2
29-Jun-95	NS	204	61	168	55	137	38	121	1.13	0.31	0.78	36.2	6.7
28-Jun-95	ES	200	61	168	55	131	49	123	1.06	0.40	0.73	32.2	6.4
22-Aug-95	AS	198	70	156	62	155	39	125	1.23	0.31	0.80	41.7	8.4
1-Aug-95	ES	199	64	149	55	229	54	132	1.73	0.41	0.81	49.6	8.8
29-Jun-95	ES	205	61	165	54	196	47	143	1.37	0.33	0.80	40.1	7.6
28-Jul-95	ES	161	55	132	50	213	37	147	1.44	0.25	0.85	28.8	4.5
4-Aug-95	NS	186	62	144	56	296	36	147	2.01	0.25	0.89	42.0	5.4
1-Aug-95	DS	200	63	154	54	195	57	152	1.28	0.38	0.77	46.0	9.1
24-Jul-95	NS	172	66	126	50	156	39	154	1.01	0.25	0.80	46.2	15.7
22-Aug-95	ES	196	68	152	59	205	51	154	1.33	0.33	0.80	43.6	8.2
4-Aug-95	AS	198	64	154	56	195	42	163	1.20	0.26	0.82	43.9	7.3
28-Jun-95	AS	233	66	182	58	217	55	165	1.32	0.33	0.80	50.9	8.3
31-Jul-95	AS	198	70	162	61	209	78	172	1.22	0.45	0.73	35.8	8.8
4-Aug-95	DS	192	63	152	56	199	35	183	1.09	0.19	0.85	39.8	6.9
15-Jun-95	DS	125	43	98	36	152	42	187	0.81	0.22	0.78	27.1	6.3
25-Jul-95	NS	166	59	137	52	159	32	196	0.81	0.16	0.83	29.1	7.0
31-Jul-95	ES	206	62	141	52	205	46	198	1.03	0.23	0.82	64.5	10.2
24-Jul-95	ES	160	57	134	51	147	45	202	0.72	0.22	0.77	26.5	6.2
31-Jul-95	DS	193	69	152	61	288	74	207	1.39	0.36	0.80	40.5	8.2
29-Jun-95	AS	228	64	179	57	191	47	220	0.87	0.21	0.80	49.5	7.3
19-Jun-95	DS	130	43	103	38	155	26	222	0.70	0.12	0.86	26.5	5.5
1-Aug-95	NS	196	63	160	53	177	74	224	0.79	0.33	0.71	36.5	10.2
23-Aug-95	AS	210	68	155	59	488	61	249	1.96	0.25	0.89	54.1	9.3

7.1.4.5. Relationships Defined

7.1.4.5.1. Background Emission

The object is to define the gassiness of the coal being cut. With increased rates of mining, the background emission algorithm selects higher values for the background emission - as it is supposed to do (figure 7.1.8).

Fig. 7.1.8 Back Ground Emission



Background emission is affected by changes in gas content and permeability. In the assessment of outburst proneness, anomalous drops in background emission may be indicative of the coal permeability dropping - a more hazardous situation. For example, the more sudden drop in background emission for shifts around the 17th August (figure 7.1.8). *{This is put forward as a technical example only - and is not to be construed as recognition of an unsafe mining condition in this instance}.*

7.1.4.5.2. Shift Gas Quantity and Gas Make

Plotting the total gas liberated for the shift against production defines an envelop of values which is characteristic of the area being mined (figure 7.1.9).

The area being monitored (510 Panel), is subjected to the constraint of only being permitted to mine when the gas content threshold (as defined by GeoGAS gas content tests) is below a threshold value. For the gas compositions determined on the gas content tests in 510 Panel, the threshold value varied between 6.95 m³/t and 6.70 m³/t for gas composition ranges of 0.73 and 0.80 (CO₂/CO₂+CH₄).

During the monitoring period, 510 Panel mining was periodically delayed by gas content tests not achieving the required threshold value. The maximum shift gas content plots would therefore be indicative of the threshold values that would be applied using the real time monitoring system (figure 7.1.9). While more data and further analysis is required in defining threshold values for the real time monitoring system, it does give an indication of how thresholds can be applied to the continuously monitored data.

Fig. 7.1.9 Shift Gas Quantity (CO₂+CH₄)

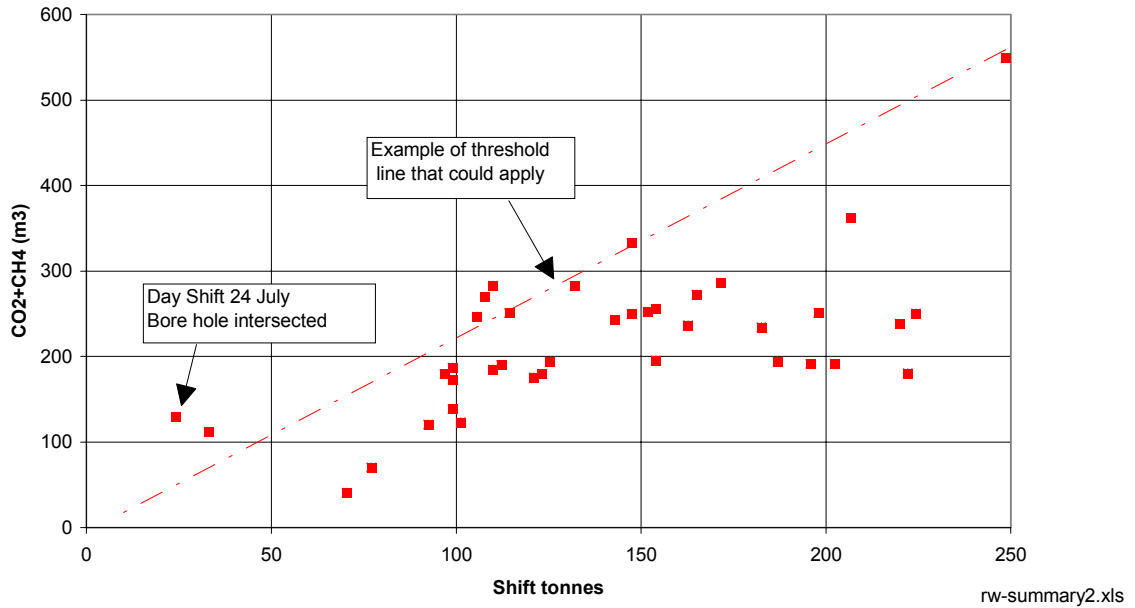
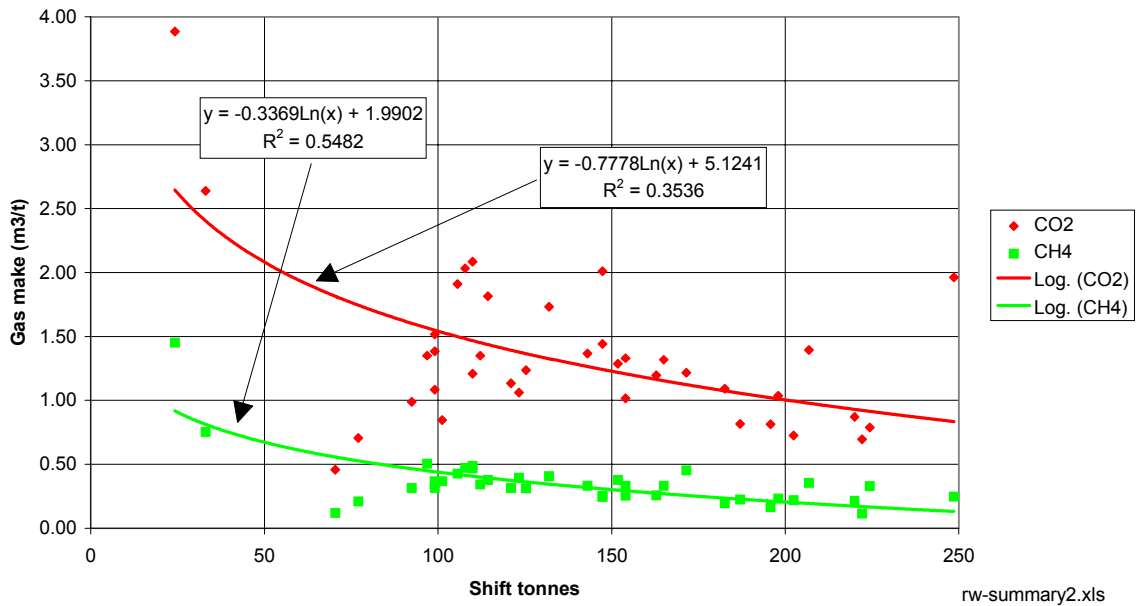


Fig. 7.1.10 Shift Gas Make



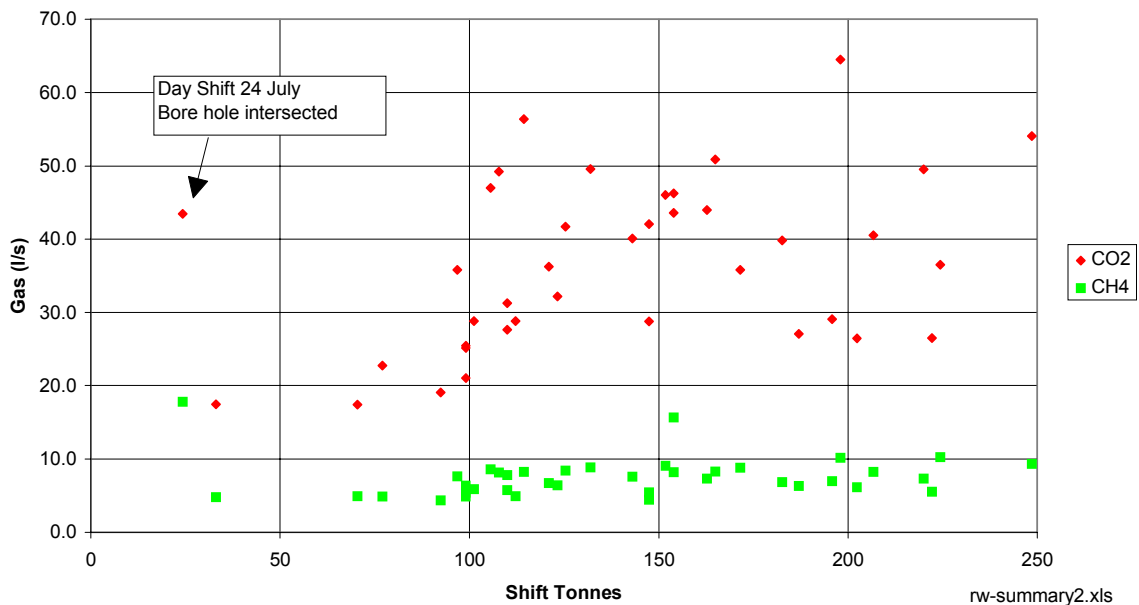
Plotting production against m^3/t produces the gas make curves of figure 7.1.10. For constant levels of inherent gassiness, the gas make varies according to the level of production. Average values are given as the regression equations in figure 7.1.10. Given that mining cannot proceed unless gas content threshold conditions are met, a threshold value line for this graph could be drawn through the higher sets of values (not shown in figure 7.1.10).

7.1.4.5.3. Net Peak Gas Emission

The rate of gas emission is a particularly important outburst proneness indicator. Peak emission from coal being cut reflects both the gas content of the coal and any inherent characteristics the coal has that may dispose it towards a higher rate of gas desorption.

The peak emissions similarly provide an envelop of values that enable assessment of how the current shifts mining appears in relation to past mining (figure 7.1.11).

Fig. 7.1.11 Peak Emission Rate Beyond Back Ground Emission



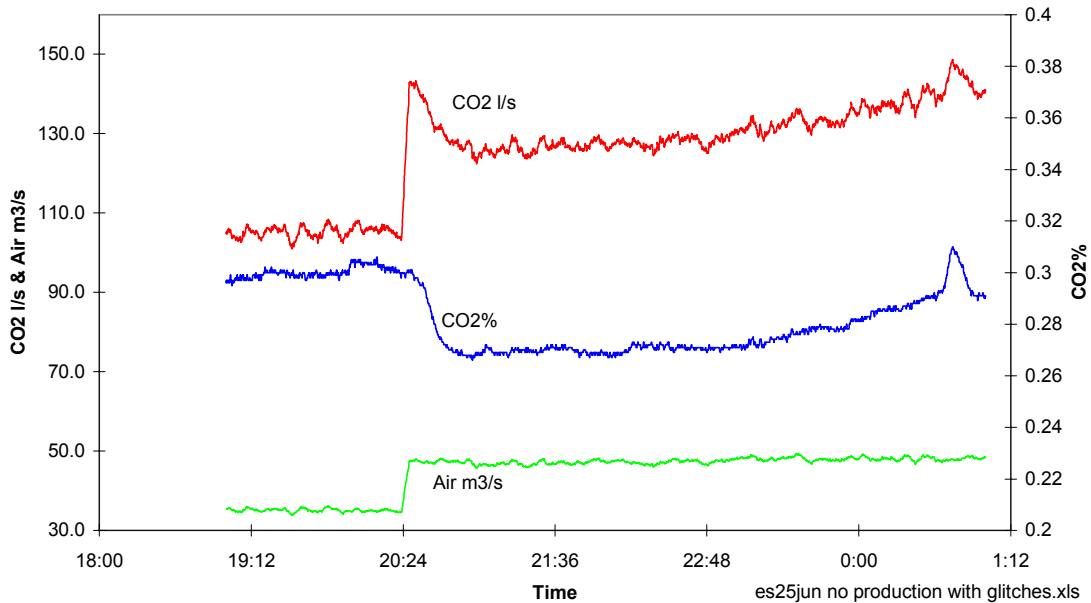
7.1.4.6. Identifying Incomplete and Anomalous Data

Sudden changes in air quantity are not sufficiently matched by a corresponding change in gas concentration to enable a reasonably continuous gas emission flow rate (figure 7.1.12). Probable causes are:

- The factors converting air velocity to air quantity may not apply over the range of air velocities measured.
- The additional air entering the panel brought with it, additional gas from outbye the panel, increasing the total panel gas flow. Eg, in figure 7.1.12, an extra 10 m³/s of air bringing into the panel CO₂ at 0.2% would result in an additional 20 l/s into the system. This appears to be the likely source of the additional gas.

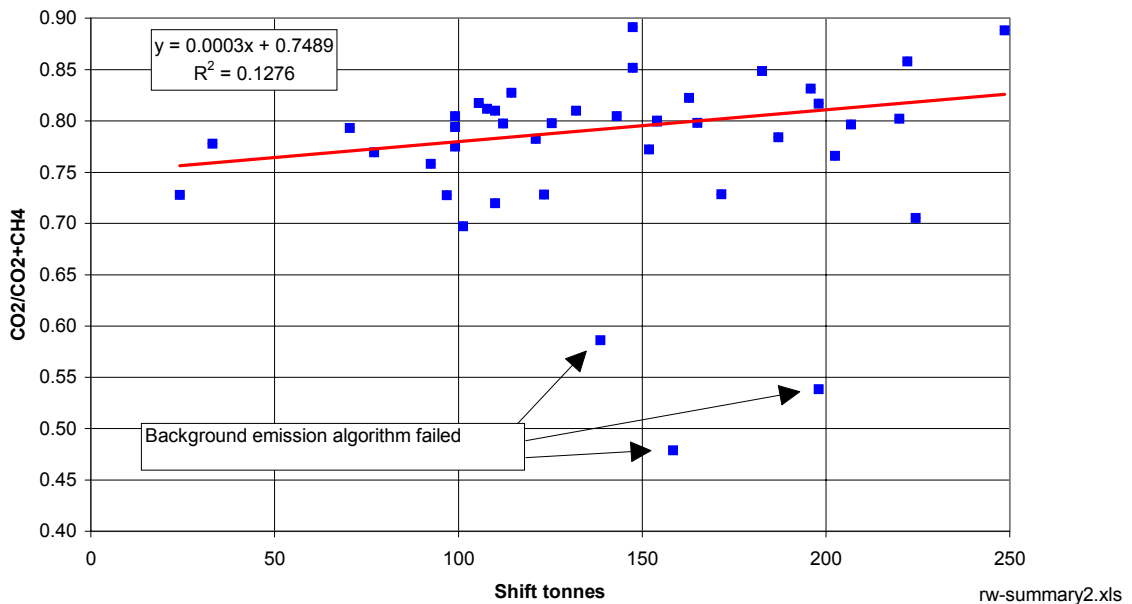
Changes to gas quantities entering the panel may require additional monitoring of the intake air to the panel, so that this effect can be discounted.

Fig. 7.1.12 Effect of Change in Air Quantity



The background emission algorithm failed in three instances, by assigning too high a background emission to the CO₂, resulting in anomalously low CO₂/CO₂+CH₄ ratios (figure 7.1.13).

Fig. 7.1.13 Effect of Production on Gas Composition



Applying the background emission algorithm to non mining periods results in a significant quantity of gas being calculated above background level (see zero tonnes data Table 7.1.1).

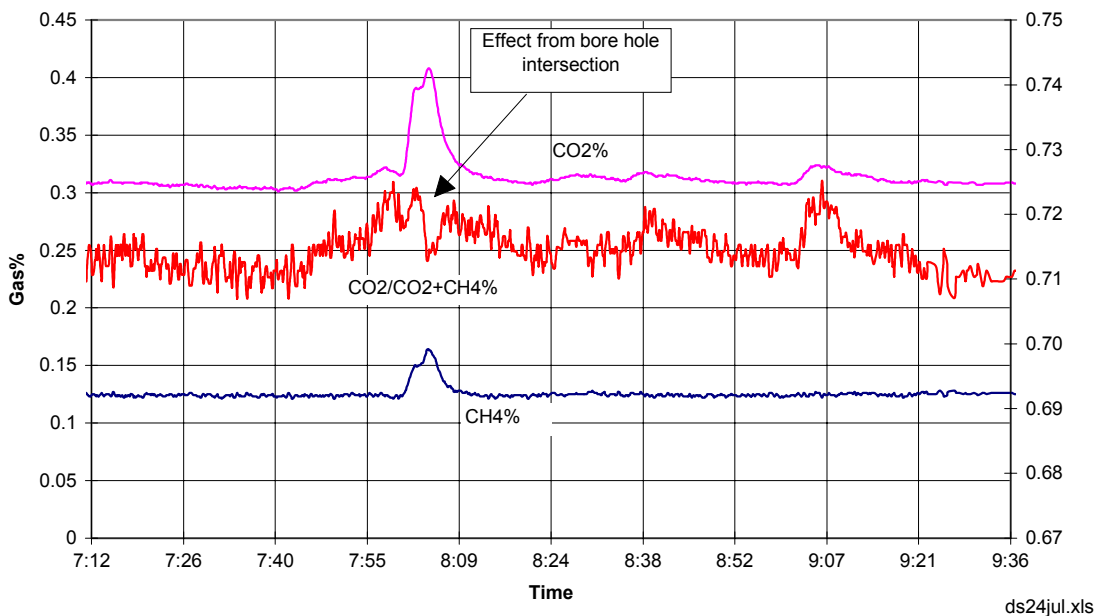
This gas is one factor placing a limitation on the ability of the system to make meaningful resolutions. Reasons for this are:

- The air velocity fluctuations introduce too much noise. A possible solution is to dampen the air velocity readings.
- Non mining periods genuinely create variable gas quantities, largely from drilling operations associated with coring and short term gas drainage.

The area has been quite thoroughly gas drained prior to mining to comply with outburst mining threshold limits. This creates less contrast between real events and noise. None the less, the system must be able to identify real differences in gas emission from coal close to the outburst threshold limit, if the system is to have relevance to this type of application.

Borehole intersections during mining can result in anomalous gas releases. A minor event on day shift 24th July is interpreted as the result of intersecting a borehole. Higher peak and shift gas quantities were calculated (see annotations DS24JUL, figures 7.1.9 and 7.1.11). Closer examination of this event identifies the gas release by a reduction in CO₂/CO₂+CH₄ ratio, in response to the CH₄ being generated from the borehole (figure 7.1.14). In gas drainage, CH₄ preferentially desorbs head of CO₂. For coal being cut at the face, the reverse is true.

Fig. 7.1.14 Example of an Interpreted Bore Hole Intersection



7.1.4.7. The Bore Hole Blow Out Event

On evening shift 20th July 1995, a significant gas release event occurred during mining in 510 Panel. The event was captured on the real time monitoring system. Mining uncovered a

long, in-seam borehole. The borehole apparently contained a blockage that prevented the gas from draining normally.

At the monitoring point, the gas concentration for CO₂ suddenly rose from 0.40% to 0.88%, and for CH₄, 0.15% to 0.58% (Table 7.1.2, figures 7.1.15 and 7.1.16). Between 23:01 hours on 20th July 95 and 06:43 hours on 21st July 95, the total CO₂ and CH₄ volume liberated was 1690 m³ and 1080 m³ respectively. While the peak concentrations are relatively low, the volumes of gas involved are commensurate with that released during actual outbursting (from previous monitoring of outbursts at Tahmoor Colliery).

That the gas originated from a borehole is additionally indicated by the sudden reduction in CO₂/CO₂+CH₄ ratio (figure 7.1.17). The pressures building up in the borehole favour the preferential desorption of CH₄ causing the borehole gas to be much richer in CH₄ (it has a much higher equilibrium sorption pressure than CO₂).

Table 7.1.2 Summary of Gas Readings

	CO ₂		CH ₄	
	% v/v	l/s	% v/v	l/s
Prior reading at 23:01:00	0.402	165.7	0.146	59.8
Peak reading at 23:04:20	0.882	359.8	0.580	236.6
Residual reading at 06:43:00	0.350	140.3	0.137	54.9

Fig. 7.1.15 CO2 Concentration
510 Panel - Evening and Night Shifts 20-21/07/95

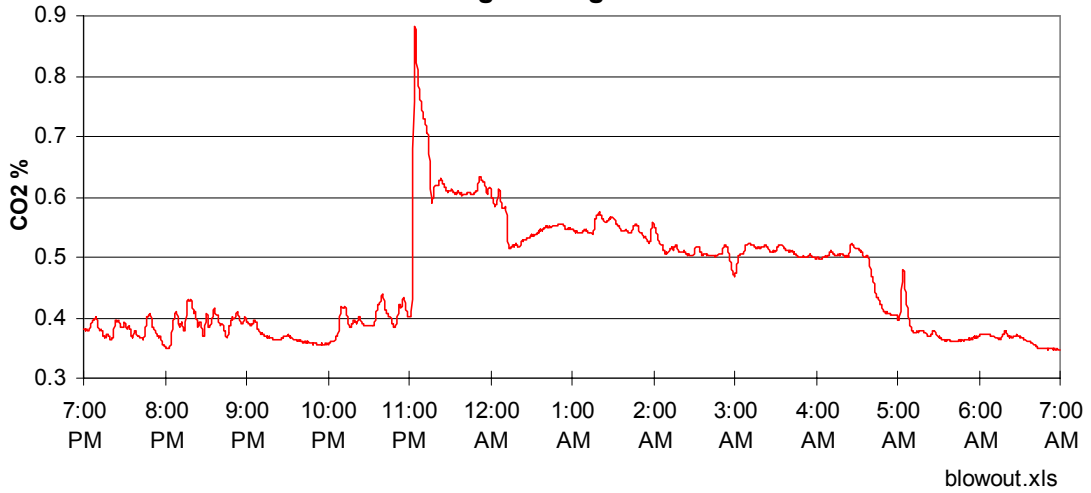


Fig. 7.1.16 CH4 Contentration
510 Panel - Evening and Night Shifts 20-21/07/95

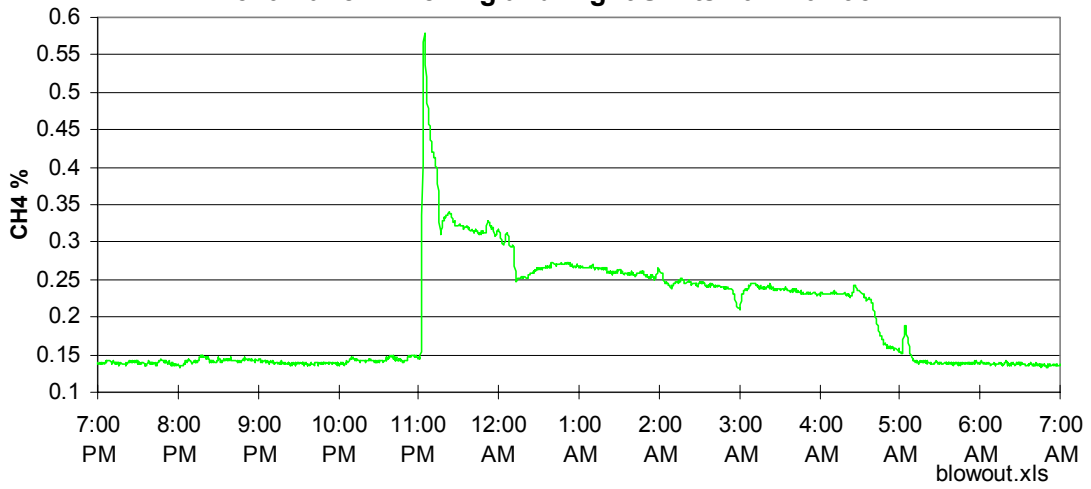
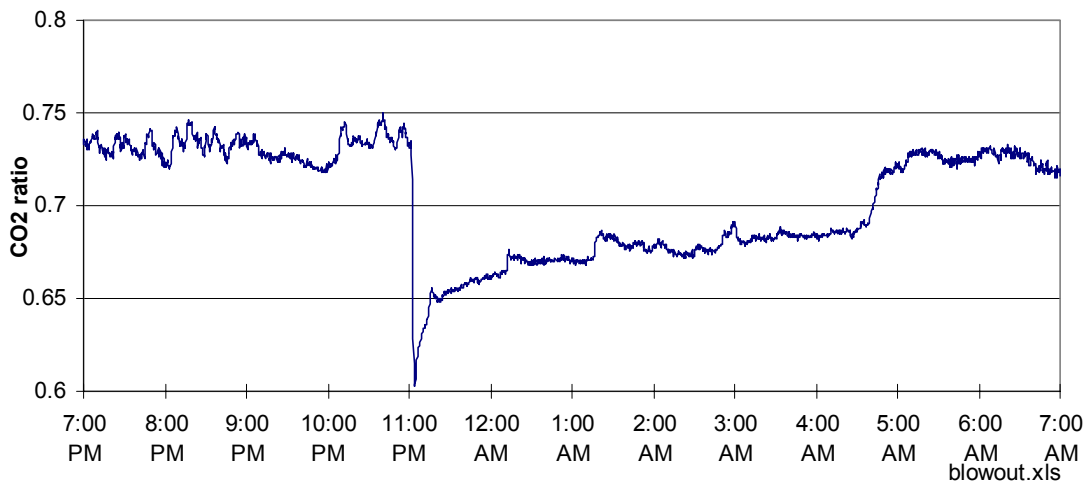


Fig. 7.1.17 Gas Composition Change
510 Panel - Evening and Night Shifts 20-21/07/95



7.1.5. Site 1 Conclusions

The following areas for improvement apply to the state of the system at the time of the Tahmoor Colliery trials. These are:

1. A much greater level of continuous system up time is required. The main operational problems has been in power interruptions, where system power is necessarily (for safety) latched-off, so that the system will not restart automatically on power up. Operation of the system is dependent on manual power reset (after safety checks) at the underground site. Training and procedures must be implemented to facilitate “adoption” of the system into the panel operations.
2. An important issue is the objective determination of background emission levels. The algorithm used for this set of data analysis, will need further refinement to automatically take account of the variety of non mining related emission events. The majority of data abnormalities can be made software recognisable.
3. Consideration needs to be given to upgrading the system to monitor the intake gas to the panel (*not the intake gas to the face within the panel*). A relatively low frequency of intake monitoring should suffice, with PLC actuated solenoids periodically switching between intake and return gas sampling. Such switching could be triggered by changes in air quantity.
4. Being able to recognise and quantify periods of production will enable software to be written around mining events. The lack of belt weightometer data for this site reduced the project to being able to report on a shift by shift basis, rather than on an intra shift basis (the latter being preferred, but not a required goal).
5. The belt weightometer installation needs to be tailored for belt structure type. Existing equipment will need repair, before re-incorporation within a floor standing belt structure. New load cells, under tension, will be required for a roof-suspended belt structure. The next weightometer installation should be as far as practicable from the drive-head / belt starter.
6. Until the minimum software requirements are established, the best course of action is to continue with EXCEL MACRO's for data analysis. Once the routine has been established, the software can be rewritten for compiling under VISUAL BASIC *{this has been done but using Borland Delphi}* in the monitoring PC, and PLC programming. The main thrust for the next site must remain data analysis as the front end to rational system development.

Relationships between production rate and gas emission have been defined, with indications of potential threshold limits for safe mining given.

7.2. Dartbrook Mine

7.2.1. Introduction

Dartbrook Mine agreed to provide a site and financial assistance. G101 Panel was selected as the second project field trial site (figure 5.7.1).

The system was committed to the Dartbrook trial for a total of 11 months, from 13th October 1995 to the 14th September 1995. Installation was delayed initially by 3 months while Dartbrook drafted site-wide specification of belt weightometer equipment and installation. In early February, immediately prior to underground installation a battery within the system's PLC was removed to comply with Dartbrook's underground electrical conformance standards. This modification introduced delays initially, as substitute hardware components and software routines were implemented, and subsequently in reconfiguration of communications protocols.

Continuous monitoring took place from mid April to mid September. The data set related to production within the panel spans the period 25th April to 17th July 1996. In this time G101 panel developed from inbye 18 cut through to its termination at 25 cut through in essentially undrained, high gas conditions (figure 5.7.1).

Dartbrook operates three 8 hour shifts per day (two production and one maintenance shift scheduled each day) on a three week rotating roster. The gateroad developments extract to a height of 3.9 m from an essentially continuous 25 m sequence of coal. The gas content of the coal monitored averaged 7.8 m³/t with a composition of 75% CO₂ and 25% CH₄ .

Most mining conducted within the monitored period was "conditional". Production was halted and face drainage instituted twice as a result of gas levels in cores taken ahead of development. High face gas levels on development interrupted production in June and the panel was terminated in mid July shortly after connection of the Longwall 1 installation roadway.

7.2.2. Log of Activities and Events to November 1996

1995

- | | |
|----------|--|
| Oct 13th | Retrieval of all equipment from underground site at 510 Panel Tahmoor |
| Oct 18th | Transport of equipment to GeoGAS Hunter Valley office (HVO) at Muswellbrook. |
| Oct 31st | Clean and overhaul of monitoring system followed by surface testing. |
| Nov 1st | Meeting with Dartbrook personnel to discuss requirements for site trial of RGMS. Installation contingent on colliery decision regarding Longwall 1 |

belt weightometer specification and supply.

Nov 14th
to Dec 8th Data reduction from Tahmoor site trial.

1996

Jan 9th RGMS equipment and documentation inspected on surface by Brad Austin and passed for conformance with Dartbrook electrical standards.

Feb 8th RGMS system loaded at pit-top in EIMCO for transport to underground site. Chief Electrical Engineer requires modification of system PLC for conformance to Dartbrook standards.

Feb 26th PLC program 'burnt' into EEPROM (non-volatile memory) chip, PLC battery removed and EEPROM installed by Dartbrook's Projects Electrical Engineer.

Feb 28th RGMS system successfully tested on surface (after PLC memory modifications).

Mar 6th Delivery and physical installation of RGMS to underground site at 1 cut through G101 panel.

Mar 8th Connection of power to underground site.

Mar 11th Installation of wrong communication cabling to RGMS.

Mar 19th Commissioning of power, communication and velocity sensing head at underground site. RGMS found to be non-operational, suspected PLC fault.

Mar 20th Meeting at Dartbrook to discuss removal of system to South Bulli re urgent outburst need.

Mar 28th Aborted underground visit with Hunter Control electrical engineer to fault find PLC.

Apr 3rd Underground visit to fix PLC. Poor connection found between PLC and EEPROM card. PLC program operational but no communications with surface PC.

Apr 12th Surface and underground testing of cables and modems highlights PLC communication problem.

Apr 19th Underground visit to reconfigure PLC communications protocol with Quality Data electrical engineer. RGMS operational.

May 16th	Initial meetings at Dartbrook, with R.Holland and M.Grant, to discuss incorporation of RGMS (by Shell's PCS team) into site-wide process control system
Jun 5th	Final meeting at Dartbrook to discuss "porting" of RGMS application to CITECT ver 3.0 and adoption by PCS.
Jun 28th	RGMS application "cut across" to CITECT ver 3.0 and "on-line" for Dartbrook PCS.
Jul 2nd	Longwall holes into G101 panel. Installation road flow into G101 B hdg (total 82 m ³ /s).
Jul 17th	Development abandoned in G101.
Jul 21st	Reversal of longwall flow. Regulation of G101 B flow to 43 m ³ /s.
Aug 10th	Deregulation of G100 tailgate. G101 B flow reduced to 24 m ³ /s.
Sep 14th	Connection between surface and underground system terminated. Remote monitoring ceases.
Oct 29th	Preparation of new site in G102 2 cut through completed. System waiting to be relocated.
To mid Nov.	Underground system continues "local" monitoring.

7.2.3. Breakdown of Data Set

The three month data set of real-time monitoring extends from night shift of Thursday, 25th April to afternoon shift of Wednesday, 17th July. Once communications had been established between the underground system and the surface monitoring PC only interruptions to the power underground (principally weekend panel shutdowns) stopped data logging.

From its inception the system was "adopted" by the mine's engineering and mining staff. Work orders were issued to incorporate restart of the system on Monday pre-shift inspection and team leaders (panel deputies) routinely checked the system status and indicated gas levels before proceeding inbye to their districts each shift.

Of the 210 shifts within the period, where power was available within G101 panel, the system provided gas level determinations for all but 14, representing >93% "up-time". Of the 14 non-data shifts :-

- 4 immediately followed weekend breaks (presumably overlooked in pre-shift).

- 4 contiguous shifts were associated with power interruption accompanying establishment of the longwall ventilation circuit.
- Leaving 6 incomplete shifts attributable, it is assumed, to in-shift power interruptions which left the system powered down.

A complete summary of the shift data are tabled in the next section.

The system's own floor-mounted belt weightometer was damaged in the first trial when installed in a roof suspended belt system at Tahmoor Colliery. Dartbrook also employs suspended belt systems in the gateroad development roadways. It was intended that Dartbrook's weightometer system send duplicated analogue and digital output directly to the system PLC affording real-time production data.

Installation of the system at Dartbrook was initially delayed pending selection of appropriate belt weightometer units. The system was installed and commissioned in March and early April. After selection of the preferred belt weightometer system it was decided to delay underground installation to coincide with commissioning of the longwall (September) by which time the trial had been concluded.

Shift production has been calculated from metres mined, as logged in the panel deputies shift reports.

7.2.4. Analysis of Data

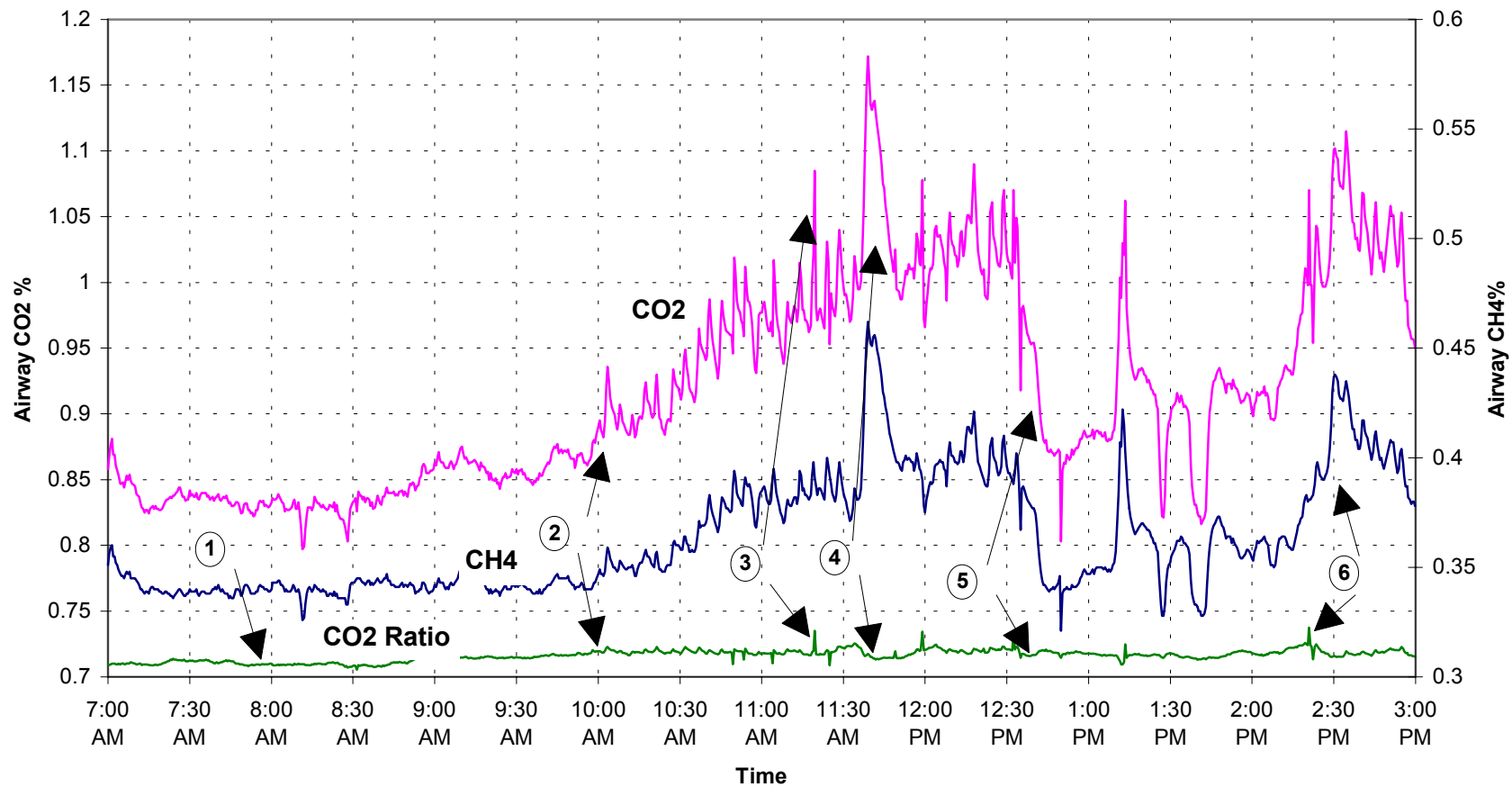
7.2.4.1. General Description of Emission Response

On day shift of Monday, 6th May the panel was developing mid-pillar 18 to 19 cut through in B heading (figure 7.2.1). Gas content testing in the immediate mining area indicated gas content of 8.1 m³/t, composed of approximately 71% CO₂ and 29% CH₄. With 442 tonnes of coal cut, this was the first production shift following the weekend shutdown, the preceding night shift being maintenance.

A number of observations of the emission response characteristics on this shift highlights features common to most of the shifts (figure 7.2.2) :

1. The CO₂ Ratio is seen to vary between 0.71 and 0.73 (in accord with the bore-core gas content composition). While the CO₂ and CH₄ traces initially exhibit some noise, the CO₂ Ratio trace can be seen to be essentially featureless until shortly before 9 AM. The deputy's report states that production commenced at about 8:45 AM. The face at this time was some 1775 m from the system sampling point, and given the air velocity, the lag in arrival of face gas would be 9 - 10 minutes. The elevated CO₂ Ratio and CO₂ levels accord with face gas behaviour. It is assumed that initial mining was slow and arrhythmic, as clearer signatures of production appear later.

Fig. 7.2.2 Airway CO2 % and CH4 % - Day Shift 6th May 1996



2. At about 10:00 AM regular “saw-tooth” ripples can be seen in the CO₂ Ratio trace and corresponding asymmetric spikes in CH₄ and particularly CO₂. These ripples consistently occur with production within the trial data set. In this shift, 36 - 38 of these ripples were counted (some partially superposed or obscured by other transient spikes), while the reported shift tonnage would suggest the equivalent of 40 cars were cut. The deputy’s report states that crib-break was taken at 11:45 AM and that production was halted between 12:30 AM and 2:15 PM while the face fan was extended and purged. These interruptions to, and resumption of, production can clearly be seen in the shift CO₂ Ratio trace, and to a lesser extent, within the gas concentration traces.
3. In addition to the mining-cycle related asymmetric spikes, sharper, more transient symmetric spikes can be seen superposed positively and negatively on all three traces. These spikes would appear to be mining related minor gas release events as :
 - They do not feature at all until 10:45 AM, when regular production had been underway for 45 minutes. They occur 7 times within two hours of almost continuous production, and immediately upon resumption of production at 2:15 PM (after almost 2 hours of idle time).
 - They appear rarely in breaks of production (a minor event in the crib break and one at 1:15 PM)
4. Coincident with the crib break at about 11:45 AM a gas release preferentially rich in CH₄ elevated the gas concentration and depressed the CO₂ Ratio trace for roughly 20 minutes. Similar CH₄ events in other shifts were attributed to the activity of in-seam drainage drilling crews within the panel. This is consistent with the preferential CH₄ release from boreholes already noted. It is possible here that crib break delayed connection of a fresh borehole to the drainage range.
5. At about 12:45 PM the deputy’s shift report notes that a tube extension was done on the face auxiliary fan tube. From this time until after 2:00 PM the CO₂ Ratio shows a quiescent “non-production” trace on a subtly downward trend. The gas concentration trends show marked swings from pre-production background to immediate post-production levels. These responses are consistent with the accumulation and subsequent purging of immediate face gas corresponding to interruptions in operation of the face ventilation fan.
6. At about 2:15 PM recommencement of production coincides with a transient “gas event” spike, followed by regular production (a sequence of 7 cars) until production stops for the shift (and exponential decay in gas levels is evident) at about 2:50 PM.

Additional signatures not apparent in this shift’s gas concentration traces, but also common, included sudden changes to the panel airflow (usually positive). Most resulted from “short-circuiting” of the panel (typically at 7 cut through double-doors) and produced “squared trough” depressions in gas concentration without affecting the CO₂ Ratio.

At noon each Wednesday, the system would automatically recalibrate the gas analysers under PLC control. During this 3 minute sequence the PLC would “latch” the gas levels immediately prior to the calibration, and subsequently smooth the gas readings with a 10 sample window. A spike attributable to the calibration was occasionally seen.

As in the first trial air velocity data was seen to introduce noise (up to 5%) in raw emission rate determinations. The hardware buffering of air velocity was maintained at 100 samples (200 seconds) but additional “moving average” smoothing was applied in the analysis software. The seemingly random scatter exhibited about the mean might be expected, on a shift basis, to be less significant.

Of more concern was drift in the air velocity response (refer section on “Air Velocity Sensor”). Stone dust from the airflow and adjacent stone dust barrier racks progressively fouled the sampling chamber of the velocity head, drifting the indicated value by approximately 0.005 m/s per day.

In one incident, the readings failed suddenly after the sampling station was completely “dusted” in an outbye, weekend, stone dusting exercise.

Calibration factors were incorporated within the analysis software to cope with the drift experienced. Weekly cleaning of the air velocity head may be an alternative in future trials.

7.2.4.2. Shift Based Data

The data were originally processed using an EXCEL MACRO program, but were re-evaluated using the Dephi compiled data reduction software (refer section “Data Processing Software”).

Because of additional noise created from air velocity variability and changes to air quantity not being reflected in changes to gas concentration, average shift air velocities were applied to the data. Each shift was calculated and examined according to the procedure outlined in the section “Data Processing Software”. To obtain a data set that typified the emission process, poor data were rejected. Poor data were caused/manifested as:

- Incomplete data logging for the shift
- Spurious changes in gas emission that are unrelated to mining. These are primarily gas drainage bore hole maintenance and switching off and on of auxiliary ventilation.
- Large changes in ventilation quantity over the shift.

The accepted data set is shown in Table 7.2.1.

Table 7.2.1 Accepted Shift Based Emission Data

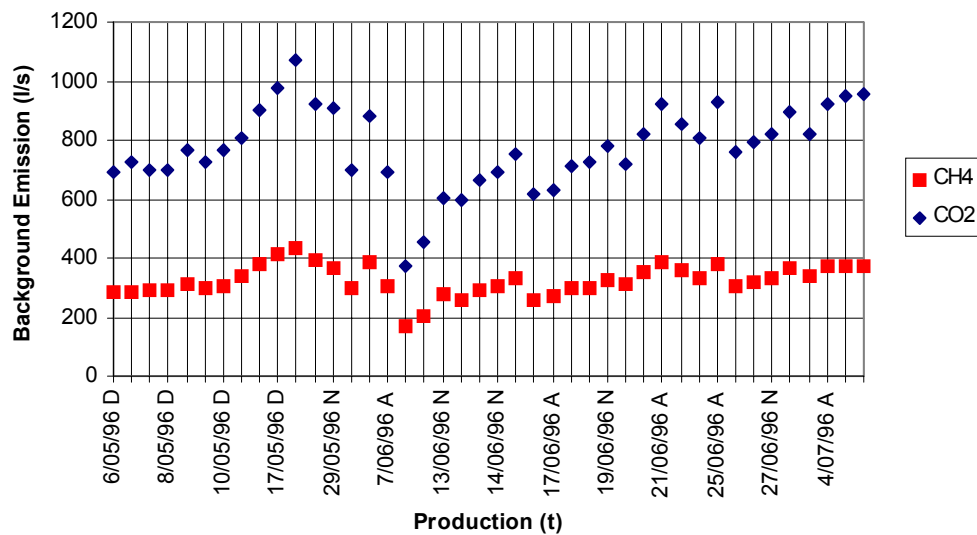
Date and Shift	Production (t)	Peak CH ₄ (l/s)	Peak CO ₂ (l/s)	CH ₄ Qty (m ³)	CO ₂ Qty (m ³)	CH ₄ Back grd (l/s)	CO ₂ Back grd (l/s)	CH ₄ (m ³ /t)	CO ₂ (m ³ /t)	CO ₂ Ratio Gas Qty	CO ₂ Ratio Peak Gas	CO ₂ Ratio Back grd
6/05/96 D	442	95	280	551	2325	287	689	1.25	5.26	0.81	0.75	0.71
7/05/96 D	336	66	240	715	1736	288	723	2.13	5.17	0.71	0.78	0.72
7/05/96 A	204	52	196	492	1605	294	701	2.41	7.85	0.77	0.79	0.70
8/05/96 D	420	56	222	640	2613	294	696	1.52	6.22	0.80	0.80	0.70
8/05/96 A	140	130	265	265	785	312	765	1.90	5.61	0.75	0.67	0.71
9/05/96 A	28	31	87	234	700	300	726	8.37	24.98	0.75	0.74	0.71
10/05/96 D	319	73	196	731	1762	307	766	2.29	5.52	0.71	0.73	0.71
10/05/96 A	311	121	254	330	1484	341	810	1.06	4.77	0.82	0.68	0.70
16/05/96 N	392	105	230	728	1567	382	904	1.86	4.00	0.68	0.69	0.70
17/05/96 D	308	77	220	671	1841	414	978	2.18	5.98	0.73	0.74	0.70
21/05/96 N	437	130	261	926	1735	437	1068	2.12	3.97	0.65	0.67	0.71
23/05/96 D	274	102	187	973	1924	391	921	3.55	7.01	0.66	0.65	0.70
29/05/96 N	588	101	204	1315	2395	368	906	2.24	4.07	0.65	0.67	0.71
4/06/96 N	308	87	217	917	2226	295	696	2.98	7.23	0.71	0.71	0.70
5/06/96 N	283	59	164	500	1371	386	880	1.77	4.85	0.73	0.73	0.69
7/06/96 A	252	51	148	418	1180	304	694	1.66	4.68	0.74	0.74	0.70
11/06/96 D	84	130	261	357	865	169	370	4.25	10.30	0.71	0.67	0.69
12/06/96 A	218	60	168	295	918	204	456	1.35	4.20	0.76	0.74	0.69
13/06/96 N	428	54	189	373	1885	276	602	0.87	4.40	0.83	0.78	0.69
13/06/96 D	28	45	98	332	674	260	599	11.87	24.06	0.67	0.68	0.70
13/06/96 A	504	80	153	427	1295	292	662	0.85	2.57	0.75	0.66	0.69
14/06/96 N	392	87	190	746	1901	303	691	1.90	4.85	0.72	0.68	0.70
14/06/96 D	84	50	132	272	978	333	751	3.24	11.64	0.78	0.72	0.69
17/06/96 N	448	73	194	506	1321	257	614	1.13	2.95	0.72	0.73	0.70
17/06/96 A	272	68	200	484	1404	268	628	1.78	5.17	0.74	0.75	0.70
18/06/96 N	420	83	250	833	2440	297	709	1.98	5.81	0.75	0.75	0.70
18/06/96 A	372	77	202	723	1658	301	723	1.94	4.45	0.70	0.72	0.71
19/06/96 N	356	68	159	584	1275	328	782	1.64	3.59	0.69	0.70	0.70
20/06/96 N	157	60	174	621	1715	314	722	3.96	10.94	0.73	0.74	0.70
21/06/96 D	28	35	92	243	877	355	820	8.69	31.32	0.78	0.72	0.70
21/06/96 A	336	54	159	721	1695	384	919	2.15	5.04	0.70	0.75	0.71
24/06/96 A	28	42	95	308	797	357	854	11.00	28.47	0.72	0.69	0.71
25/06/96 D	140	48	133	516	1139	333	806	3.68	8.13	0.69	0.74	0.71
25/06/96 A	308	54	156	517	1554	377	932	1.68	5.04	0.75	0.74	0.71
26/06/96 D	255	66	176	795	2078	302	761	3.12	8.16	0.72	0.73	0.72
26/06/96 A	162	53	127	290	839	316	794	1.78	5.16	0.74	0.71	0.72
27/06/96 N	28	75	205	418	1306	335	817	14.93	46.64	0.76	0.73	0.71
5/07/96 D	280	86	290	601	2277	368	892	2.14	8.13	0.79	0.77	0.71
4/07/96 D	252	71	194	599	1763	337	818	2.38	7.00	0.75	0.73	0.71
4/07/96 A	176	80	210	900	2042	371	920	5.10	11.57	0.69	0.72	0.71
8/07/96 A	325	78	221	466	1316	372	952	1.44	4.05	0.74	0.74	0.72
9/07/96 D	160	84	249	546	1762	374	954	3.42	11.04	0.76	0.75	0.72
17/07/96 N	291	55	231	447	2414	545	1382	1.54	8.29	0.84	0.81	0.72

7.2.4.3. Relationships Defined

Background emission comprises the majority of gas emission (80%). This is a very different gas emission response compared to Tahmoor Colliery, where background emission comprised 46% of the total emission. The contrast is even greater given that Tahmoor Colliery have predrained the seam and Dartbrook Mine have not. Such high background emission is due to the large gas reservoir at Dartbrook.

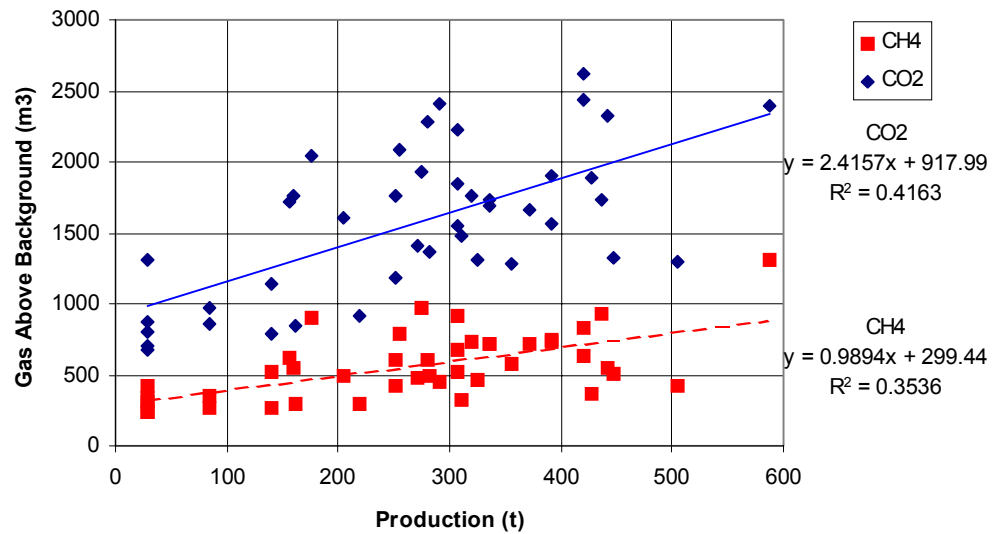
Rise and falls in background emission reflect varying mining rates and place changes (figure 7.2.3).

Fig. 7.2.3 Background Emission



avgvel.xls

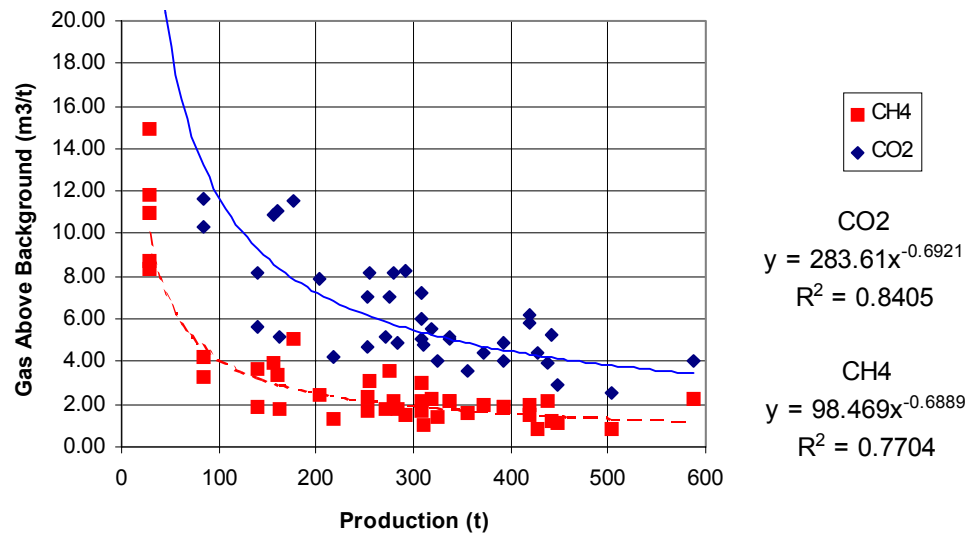
Fig. 7.2.4 Gas Quantity Above Background



avgvel.xls

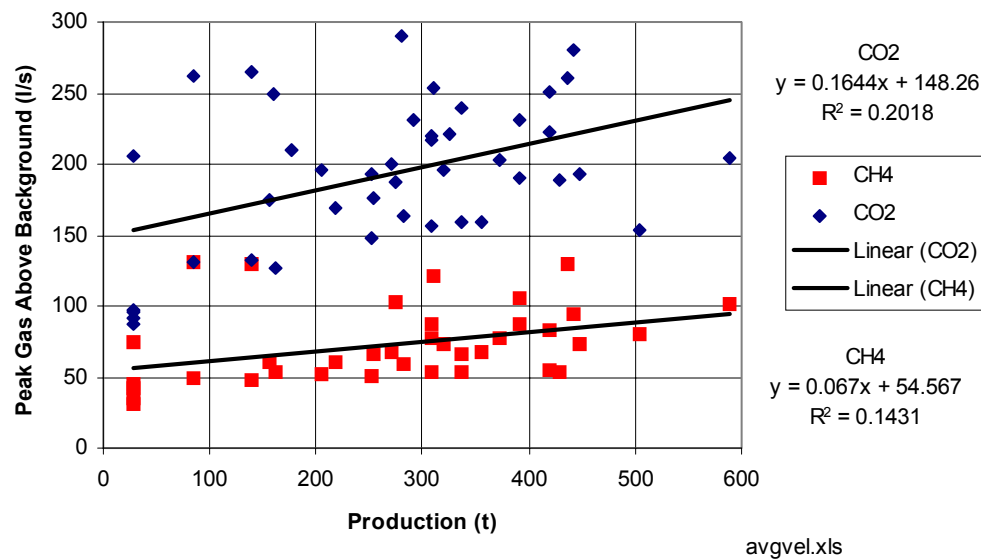
Compared to Tahmoor Colliery, gas quantities generated in the face area are around 5 times higher (figure 7.2.4). This appears to be the normal pattern for gas emission of undrained coal at Dartbrook Mine. No “abnormal” emissions (for Dartbrook) were recognised.

Fig. 7.2.5 Gas Make Above Background



avgvel.xls

Fig. 7.2.6 Peak Emission Rate Above Background



Gas makes and peak emissions above background are similarly high compared to Tahmoor Colliery (figures 7.2.5 and 7.2.6).

These data have been used to characterise Dartbrook's emission (normal, abnormal Examples 1 and 2 in section "Creating a Validated Report").

7.2.5. Site 2 Conclusions

Following on from work commenced, and lessons learned, during the first trial several goals and improvements to the system have been accomplished :-

1. The system logged and processed shift-based data for over 93% of the shifts when power was available. The high "up time" was principally due to the degree of enthusiasm and commitment given the system by the responsible technical and mining staff at the mine. The system was "adopted" by panel officials and electrical personnel as part of weekly and shift routines.

In the absence at power interruptions, the first trial showed the equipment, once properly installed and commissioned, to be robust and reliable. In this trial only four additional data shifts were lost, resulting from dust loading of the air velocity sensing head. Incremental drift in the indicated air velocity was accommodated in post-processing of data by way of calibration coefficients. A weekly clean of the head, and situating it as far as practicable from stone-dust barrier trays should suffice, in future, to maintain stability of air velocity data.

2. As part of the adoption of the system by underground and technical staff in day-to-day operations at Dartbrook, readings from the monitoring system were used to validate the performance of other surface based tube bundle and electronic transducer monitoring

systems at the mine. Output from the system was incorporated in the site-wide process monitoring and control system for display throughout the mine.

3. Shift based data analysis has been streamlined and made more rigorous by application of the purpose built data processing software.
4. Compared to Tahmoor Colliery:
 - Background (rib) emission accounts for the majority of gas emission.
 - Emission from the face area is up to 8 times higher than for Tahmoor Colliery.

The high gas emission is directly related to the far greater size of the gas reservoir. For each linear metre of advance, around 6 times the volume of coal is affected, accounting for the increased level of emission. There was no indication of abnormal, dynamic emission events that can occur associated with outburst prone conditions .

5. The dominant rib emission and the high quantities of air required to dilute this gas, result in a decreased sensitivity of the system to quantifying face gas quantities. Additional noise is created by outbye activities of drilling and borehole maintenance, given the intense level of activity in this area. Consideration needs to be given to shortening the “rib length noise” effect by occasionally moving the monitoring station to an inbye point. This needs to be evaluated on a case by case basis, and may not be warranted.

7.3. Comparative Monitoring South Bulli Colliery

7.3.1. Introduction

In GeoGAS's submission to ACARP, the argument was made in favour of gas analysers that were capable of accuracy at least to +/- 0.01% for mine air way concentrations, with a resolution to 0.001%.

The occurrence of a small outburst at South Bulli Colliery, provided the opportunity to compare what would be a standard mine based monitoring system with the ACARP/GeoGAS system, as well as use the technique in a real application.

The outburst occurred in 509 Panel at approx. 8:30 am 7th March 1996. The panel contains a cinder zone, estimated (at the time) to be 150 m across. At the time of the outburst, the face in B Heading had been driven 34 m into the cinder zone.

As part of the management plan to avoid a recurrence, real time return gas monitoring was set up to provide daily reports on gas make and to report on any unusual emission occurrences.

Monitoring commenced on 30th April 1996.

7.3.2. Mining and Gas Environment

7.3.2.1. Overview

The deputies reported that normal gas emissions were experienced whilst mining in coal (0.4% CH₄ general body). Upon mining in the cinder, there was a "sudden" (over 24 hours) change in gas emission to 0.8 - 1.0% CH₄ general body, which persisted from that time on. The continuous miner experienced several gas trips.

In the cinder zone, the seam thins from 2.5 - 2.7 m to 1.7-1.8 m. Approximately 0.5 m of floor was being cut to maintain height. The cinder is friable, highly fractured and damp.

Gas contents had been previously carried out in non cindered coal. Within a pillar of the outburst site, gas contents ranging from 4.4 m³/t to 7.5 m³/t at a composition of around 87% CH₄, 13% CO₂ were recorded. The highest gas content within a 300 m radius was 7.1 m³/t.

7.3.2.2. Test Results

7.3.2.2.1. Sampling

Gas content tests on coal in the general vicinity (previous section) were sufficiently low that no outburst should have occurred. Cinder is a completely different material to coal, so tests were undertaken to assess its gas sorption capacity. The cinder itself was extremely friable and not amenable to coring for gas content testing - another reason for employing real time monitoring.

The tests were conducted on four samples taken on 13th March 1996, in and around the outburst site as follows:

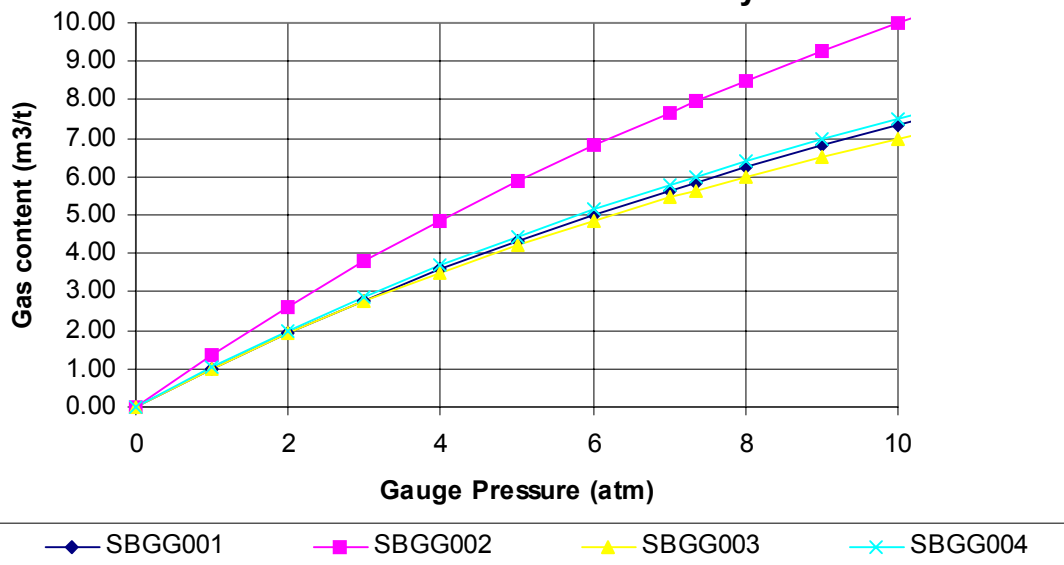
- Sample SBGG001 - cinder from the outburst cavity.
- Sample SBGG002 - cinder from the left hand side of B Heading, near the face.
- Sample SBGG003 - heat affected coal 4 m inbye the intersection of 4 cut through and B Heading, right hand rib.
- Sample SBGG004 - normal coal, left hand rib, intersection of 3 cut through and B Heading.

Additionally, samples for gas content testing were taken by in-seam coring (SB009, 10, 11, 12).

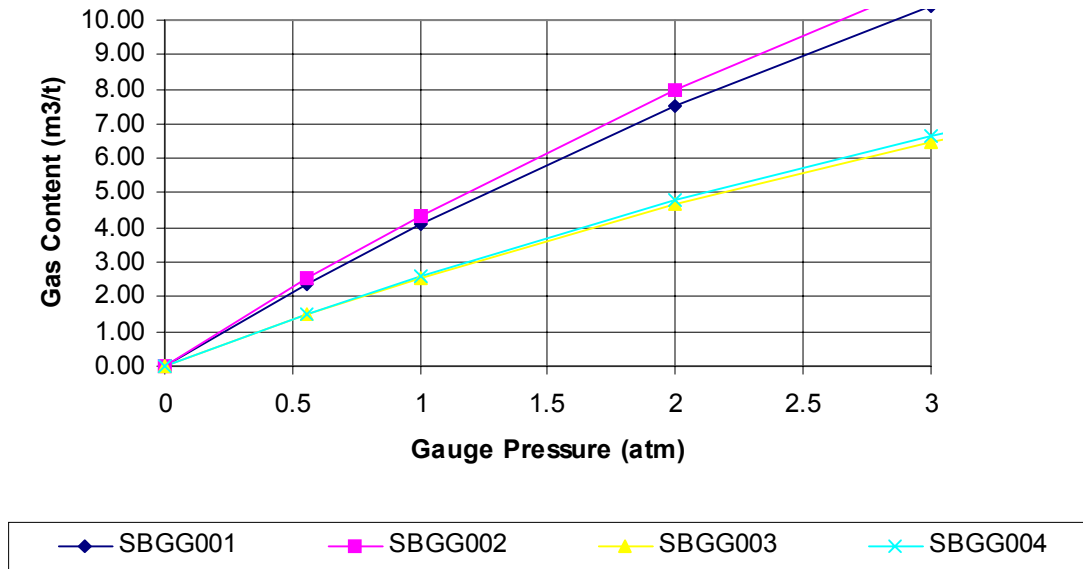
7.3.2.2. Sorption Isotherms

The gas sorption isotherms are required to determine how much gas the cinder and heat affected coal can hold relative to the normal coal. The tests were conducted by CSIRO at 27°C on “as received” material. Pressures are relative to 1 atmosphere.

**Fig. 7.3.1 CH₄ Sorption Isotherms
509 Panel South Bulli Colliery**



**Fig. 7.3.2 CO₂ Sorption Isotherms
509 Panel South Bulli Colliery**



The tests show that the gas holding capacity of the cinder is generally higher than that of normal and heat affected coal for equivalent pressures. For CH₄ (figure 7.3.1), one cinder sample had a significantly higher (30%) sorption capacity. For CO₂ (figure 7.3.2), both cinder samples had a higher sorption capacity (60% to 70% higher than normal coal).

This means that for a “normal coal” total desorbable gas content of 7.5 m³/t at 80% CH₄ and 20% CO₂, the total desorbable gas content for the cindered material can be up to 10.5 m³/t (Table 7.3.1). *The difference is actually much greater when the higher density of the cinder is taken into account by multiplying the gas content in m³/t by the density in t/m³ to give m³ of gas/m³ of substance.*

Note the change toward CO₂ enrichment from 20% in normal coal to up to 30% in cinder.

**Table 7.3.1
Estimated Gas Content Of Cinder Based On Gas Sorption Isotherms**

	CH ₄ m ³ /t	CO ₂ m ³ /t	Total m ³ /t	Total m ³ /m ³	CO ₂ / CO ₂ +CH ₄	CH ₄ kPa relative	CO ₂ kPa relative	Sample No
Normal Coal	6	1.5	7.5	10.4	0.80	743.54	56.73	SBGG004
Cindered Coal	7.96	2.55	10.51	17.1	0.76	743.54	56.73	SBGG002
Cindered Coal	5.86	2.39	8.24	14.5	0.71	743.54	56.73	SBGG001
Heat Affected Coal	5.64	1.48	7.12	10.4	0.79	743.54	56.73	SBGG003

7.3.2.2.3. Other Properties

The relatively high gas sorption capacity of the cinder is surprising given its high density and moisture content (Table 7.3.2).

Table 7.3.2 Other Material Properties

	SBGG001 Cinder	SBGG002 Cinder	SBGG003 Heat Affected	SBGG004 Normal
Density (cc/g)	1.76	1.63	1.46	1.38
Moisture% (adb)	8.6	5.2	1.3	1.2
Ash% (adb)	20.8	18.6	12.1	9.8
Volatile Matter% (adb)	3.1	4	12.9	23.6
Fixed Carbon% (adb)	67.5	72.2	73.7	68.4
Vitrinite Reflectance R _o max	N/A	N/A	2.03	1.23
Macerals - inertinite	N/A	N/A	76.0	84.2
Macerals - vitrinite	N/A	N/A	20.7	12.9

7.3.2.2.4. Direct Gas Content Test Results

Tests were conducted on what was identified as heat affected coal and cinder (Table 7.3.3).

Table 7.3.3 Gas Content Samples From B Heading Area 509 Panel

Sample No.	Location	Q1+Q2+Q3 m3/t	Q1+Q2+Q3 m3/m3	CO ₂ / CO ₂ +CH ₄	Relative Density cc/g	GeoGAS Des.Rate Index	Material
SB009	(1) Core depth 20m.	6.59	9.42	0.16	1.43	638	Appears heat affected
SB010	(1) Core depth 42-43.5m.	7.23	10.48	0.20	1.45	598	Appears heat affected
SB011	(1) Core depth 60m.	7.26	11.03	0.17	1.52	476	Appears heat affected
SB012	(2) Core depth 15.5m.	1.24	2.17	0.25	1.75	74	Appears cinder

(1) Collar in LHS rib of B heading, inbye 4cut through. Hole drilled 45° left of B heading centre line.
(2) Collar in face of B Heading (as at 15/4/96). Hole drilled straight ahead.

7.3.3. Monitoring System Overview

South Bulli Colliery's environmental monitoring uses the SCADA package "Factory Link V3.0". For 509 Panel. CO₂, CH₄ and air velocity are "continuously" monitored, as well as the status of the boot end feeder (on/off).

The system has 12 bit resolution, with output from the sensors full scale range, divided into 4096 bits. With initial monitoring, data were being recorded to 2 decimal places. This was subsequently improved to three decimal places.

The data were logged to disk every 30 seconds, this being a "snapshot" of the instrument reading (rather than being averaged, then written to disk).

CO₂ is monitored using an ADC2000 infra gas analyser. Instrument accuracy is rated at 2% of full scale deflection (0-2%).

CH₄ is monitored using a Status Mentor instrument Type CH₄-03. Its rated accuracy is +/- 0.1% v/v or +/- 8% of the true value.

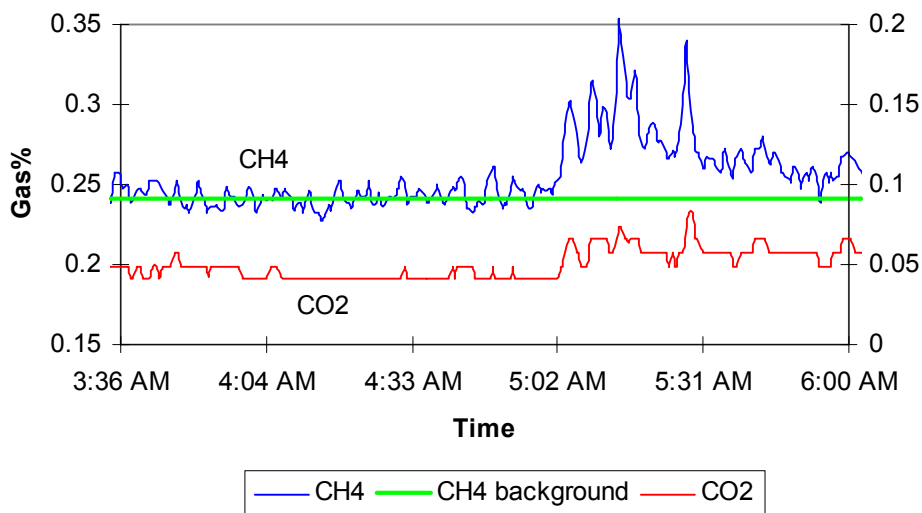
Air velocity is measured using a Status Mentor air velocity meter Type AV/02/030. It has a maximum range of 0-30 m/s. It was set on 0-5 m/s for this application. Accuracy is rated at 5% of the reading.

7.3.4. Data

The CH₄ and CO₂ concentration trends show the following characteristics (figure 7.3.3):

- The CH₄ trend during periods of no production is relatively noisy (figure 3 to 5:00 AM) with fluctuations around +/- 0.01%. The resolution to 0.001%, is negated by the noise level.
- The CO₂ data are logged with a much lower resolution (to 0.006%) that is probably in keeping with its noise level (figure 7.3.3 to 5:00 AM).

Fig. 7.3.3 509 Panel Monitoring 27th November 1996



7.3.5. Reporting

On a daily basis, the previous 24 hours data file was down loaded from South Bulli Colliery to GeoGAS via MODEM. Production figures were obtained by calling the Control room.

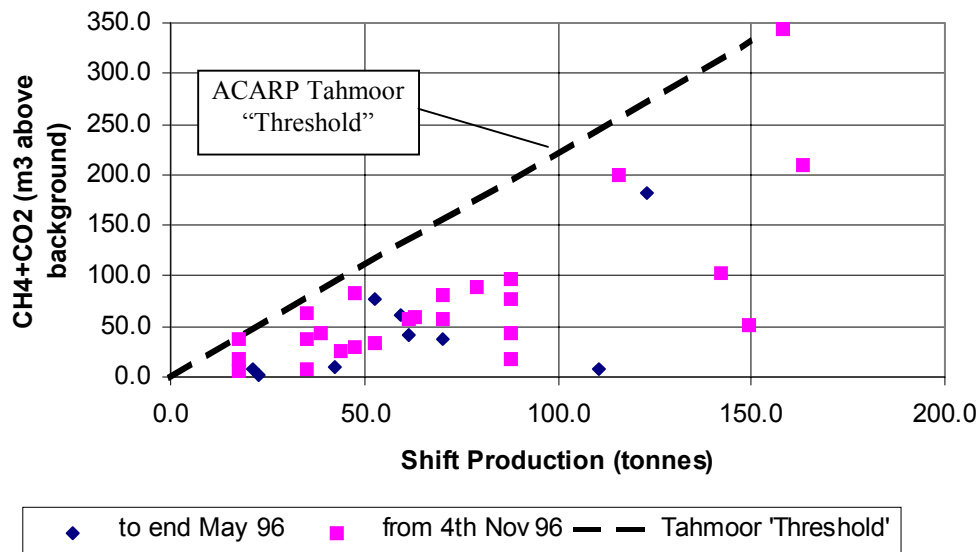
The data file was converted to an EXCEL spreadsheet and reports generated (Table 7.3.4, figure 7.3.4).

Table 7.3.4 Example Report

	Date:	21/6/96
	Shift:	Afternoon
Abnormal Emission		None Apparent
Peak CO2 Above Background (l/s)		6.4
Peak CH4 Above Background (l/s)		6.5
CO2 m3 Above Background		3.9
CH4 m3 Above Background		6.4
Ratio CO2/CO2+CH4		0.38
	CO2 m3/t	0.04
	CH4 m3/t	0.06
	Non Mining CO2%	0.07
	Non Mining CH4%	0.6
Average Air Quantity m3/s		20.9
at monitoring point		
Metres Mined		6.3
Coal equivalent tonnes		110.6

Mining in 509 Panel occurred in two phases after the outburst - to the end of May 1996 with very slow mining in cinder under difficult ground conditions, and from November 1996, with mining in cinder under improving conditions through to mining in normal coal (figure 7.3.4).

Fig. 7.3.4 509 Panel CH₄+CO₂ Emission



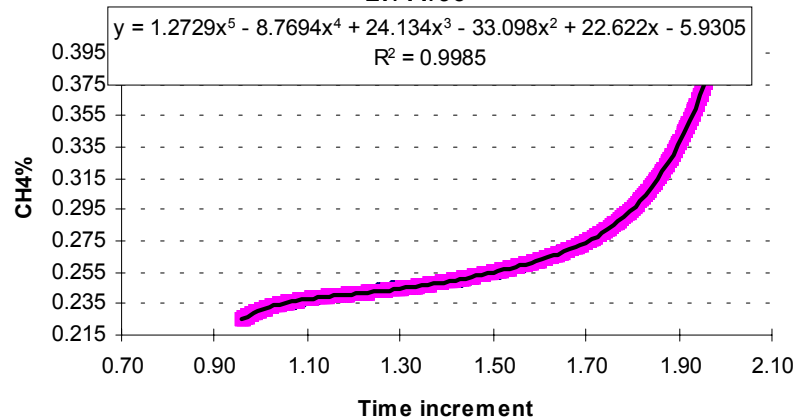
The “Tahmoor Threshold” line is taken from the monitoring at Tahmoor Colliery, where mining only occurs at gas levels below the mine’s gas content threshold. Although the total gas emission is similar (in this instance) for the two collieries, the “threshold” should not be directly applied to South Bulli Colliery because of the much lower proportion of CO₂ (70-80 % CO₂ Tahmoor, allowance for 25% CO₂ at South Bulli Colliery).

Because of the low resolution of the CO₂ data, CO₂ results were not quantified. In figure 7.3.4, CO₂ quantity is calculated from the CH₄ quantity - CO₂ = 0.25 x CH₄ / (1-0.25).

7.3.6. Algorithm to Define Back Ground Emission

An approach similar to that applied to Tahmoor Colliery was used to calculate the background emission. The gas concentration values for the shift were sorted and graphed (figure 7.3.5). A 5th order polynomial is used to define the line of best fit. The equation to that line is differentiated to find the slope for all values of X. The Y value corresponding to the minimum slope is the back ground emission. Values below the minimum slope are deemed to be noise, signal spikes and glitches.

**Fig. 7.3.5 Back Ground Emission Determination
27/11/96**



7.3.7. Comparison System Accuracy

An assessment of each systems (ACARP/GeoGAS and South Bulli Colliery) accuracy required defining the means and distributions of the following variables:

- Road way dimensions (width and height)
- Point air velocity (Status - South Bulli or Trolex GeoGAS)
- Average air velocity (as measured with a hand held anemometer).
- Gas analyser rated accuracy.

Results are given in Table 7.3.5 for the scenario modeled using the statistical modeling package @RISK. The range of values indicated, covers the combined probability distributions for 500 iterations on a set of random numbers generated according to the probability distributions for each input variable (details not given).

The comparison assumed all gas analysers reading 0.5% concentration.

Table 7.3.5 Comparison Accuracy GeoGAS/ACARP and South Bulli Systems

	<i>South Bulli Return Gas Monitoring</i>			<i>GeoGAS ACARP Monitoring</i>		
	Status Mentor Air m3/s	Ausdac ADC2000 CO2 l/s	Status Mentor CH4 l/s	Trolex TX1322 Air m3/s	Maihak Unor CO2 l/s	Maihak Unor CH4 l/s
Mean	27.0	135.1	135.1	27.0	135.1	135.1
95 percentile	28.9	150.0	161.4	28.9	145.3	144.4
5 percentile	25.1	122.1	109.7	25.3	126.2	125.8
+95%	1.8	14.8	26.3	1.9	10.2	9.3
-5%	1.9	13.1	25.5	1.7	8.9	9.4

Note that the air quantity distributions reflect similar characteristics for the air velocity transducers. The main difference is in the gas analysers - especially CH₄, where we can be 95% confident that the result is within +/- 26 l/s for South Bulli and +/- 9.5 l/s for GeoGAS.

For the ACARP/GeoGAS System, air velocity is the main contributor to CH₄ l/s variability (Table 7.3.6) {A sensitivity of 1 or -1 has the maximum effect ,0 has no effect}.

Table 7.3.6 GeoGAS System Input Variable Sensitivity

Name	Sensitivity (RSqr=.9994217)
Air m/s	0.683605
width	0.534822
height	0.475445
CH ₄ %	0.273476

For the South Bulli system, CH₄ accuracy is the most important contributor to CH₄ l/s variability (Table 7.3.7).

Table 7.3.7 South Bulli CH₄ System Input Variable Sensitivity

Name	Sensitivity (RSqr=.9983137)
CH ₄ %	0.946189
Air m/s	0.237793
width	0.18715
height	0.166071

The CH₄ analyser is a clear target for improvement in the South Bulli system.

For CO₂ l/s, the CO₂ analyser with its higher accuracy is not as great a contributor to CO₂ l/s variability compared to the CH₄ analyser. But it still is the greatest source of variability (Table 7.3.8).

Table 7.3.8 South Bulli CO₂ System Input Variable Sensitivity

Name	Sensitivity (RSqr=.9988199)
CO ₂ %	0.737745
Air m/s	0.460458
width	0.361609
height	0.319296

7.3.8. Conclusions

Mine monitoring systems employing standard gas detectors can provide additional information on the magnitude of gas emission. The gas make above back ground emission can be calculated and anomalous events identified - at least visually.

The extent to which these systems are useful, depends on the magnitude of the gas emission being assessed against the noise level. For South Bulli Colliery, gas analyser noise results in calculating emission above base level as high as 13 m³ for the shift. For the

ACARP/GeoGAS system, gas analyser noise results in calculation of 1.6 m^3 for the same air quantity.

These figures apply to an air quantity of $18 \text{ m}^3/\text{s}$. The same percentages in higher air quantities result in increased noise. Eg $70 \text{ m}^3/\text{s}$ of air (at Dartbrook Mine) increases the noise to 6.2 m^3 for the shift. The same air quantity for South Bulli Colliery increases the noise to 50 m^3 for the shift.

The need for instrument sensitivity and stability increases with increasing air quantity.

Superimposed on this noise level are real changes in gas emission level that are unrelated to production. The ability to identify production from the feeder breaker signal in the South Bulli Colliery system is useful in segregating production and non production effects. If the two cannot be differentiated, the data are rejected. With the ACARP/GeoGAS system, the high gas analyser sensitivity enables production and non production effects to be differentiated on the basis of the ratio of $\text{CO}_2 / \text{CO}_2 + \text{CH}_4$. (The belt weightometer would directly have indicated production, but was for the most part, inoperative).

8. Using This Approach to Determine Gas Drainage Effectiveness

This section addresses one of the project sub objectives “to define and document the process of using this data to back analyse gas drainage effectiveness”.

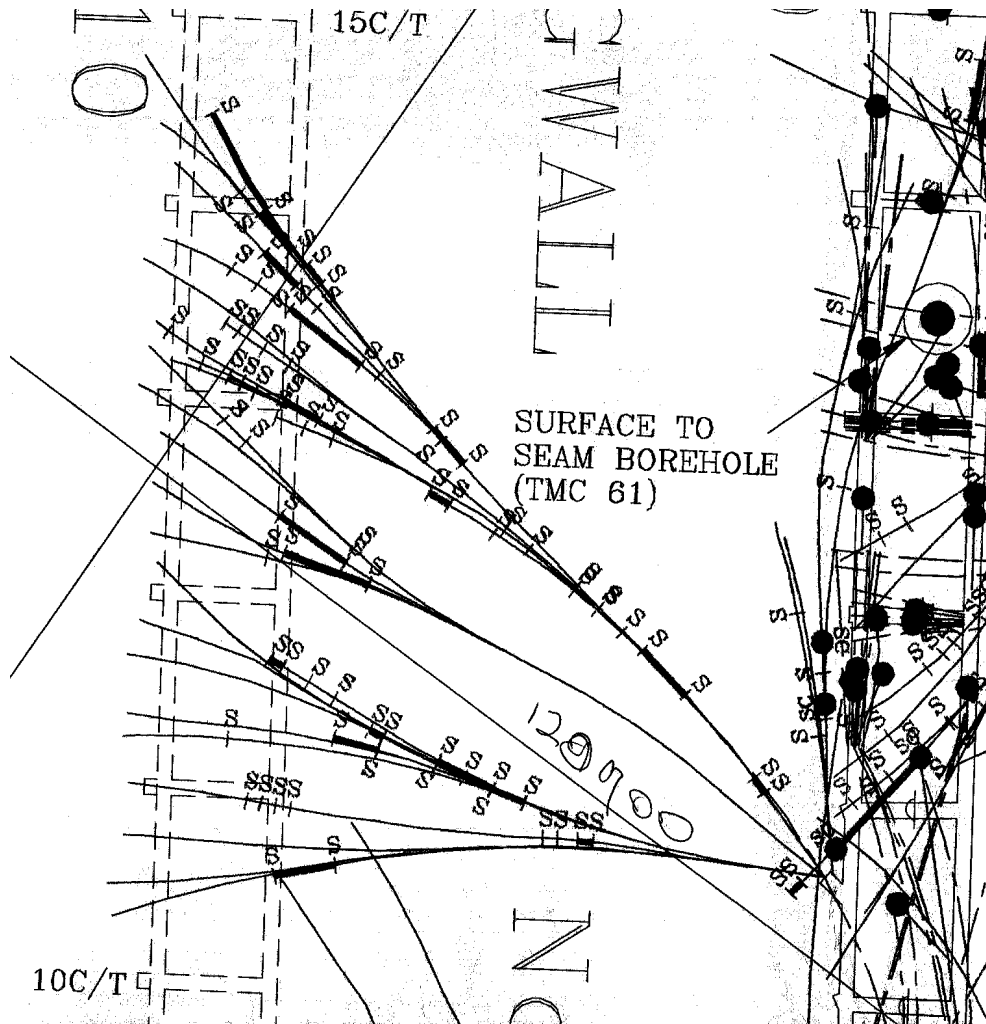
Actual back analysis of gas drainage effectiveness was not carried out in the project. Of the two trial sites, Tahmoor Colliery was the only one where the coal being mined had been predrained. Although system up time was relatively low (compared to Dartbrook Mine), such an analysis (arguably) should have been carried out.

It is by no means automatic, that the required effect in gas reduction is achieved in undertaking gas drainage drilling. Routine monitoring of borehole gas flows is becoming more widely accepted across the industry. Analysis of gas drainage effectiveness using gas flow data is simplest from short, parallel spaced boreholes. With the advent of directional drilling, many mines (including Tahmoor Colliery) take advantage of improved drilling efficiencies by drilling multiple branched boreholes. This approach is fine where the borehole/s stay open and are up dip and self draining (which is the case at Tahmoor Colliery). Down dip boreholes requiring dewatering tube add a further degree of uncertainty, as do longer, uncased boreholes.

The two main methods of assessing drainage effectiveness for practical day by day use, are calculating remaining gas using gas flow data, and taking in-seam cores for gas content testing. With branched boreholes, gas flow data provide particularly rough estimates of gas drained, given the normal assumptions of uniform gas flow per unit hole length and varying hole spacing due to branching. In-seam cores are normally taken at a coarse frequency (eg 100 m) compared to the borehole spacing employed (eg 20 m). In partially

drained coal, there will be a relatively high variability in remaining gas content. In well drained or undrained coal, the variability will be relatively small.

Fig. 8.1 In-Seam Pre Drainage Drilling 510 Panel Over Area Monitored



Continuous return gas monitoring has the potential to provide a much clearer picture of the drainage response. The following procedure is suggested:

1. On the mine plan, mark the position of mining for each shift (figure 8.2).
2. In each box, record the normalised value for gas make or gas quantity.

{Because gas make varies with production for the same level of gassiness, raw gas make figures cannot be used. Gas data for production levels below 100 tonnes per shift should not be used}.

The normalised value is the offset from the line of best fit, either positive or negative. All values can be made positive by subtracting the lowest negative value.

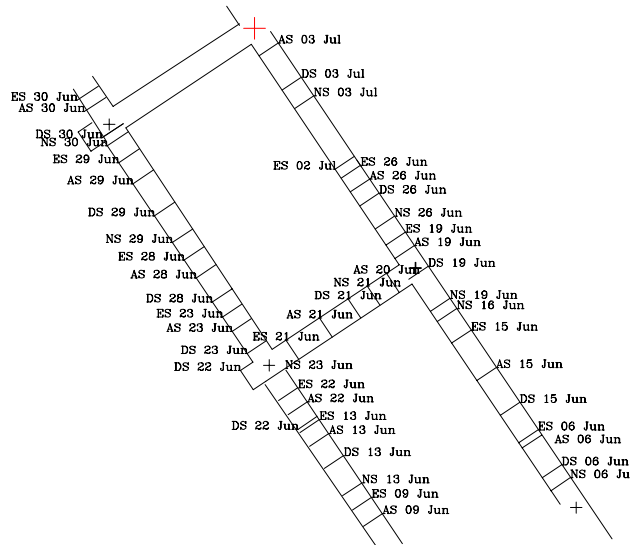
Annotate these values onto the mining plan. Use a colour scheme for groups of values.

3. Overlay the drilling plan (figure 8.1) on the mining plan (figure 8.2).

4. Observe any pattern in gas emission that corresponds to the drilling pattern. A well drained area should not show any correspondence. Areas of widest spacing should be examined to define the zone of influence of the bore hole.

Poor gas drainage results from inadequate drainage time for the spacing employed, borehole collapse and water accumulation. Seemingly sporadic areas of poor drainage that are unrelated to hole position may reflect borehole blockage or water accumulation.

Fig. 8.2 Annotation of Shift Metres Mined on the Mine Plan



5. The original return gas monitoring data should be rechecked where there are drainage anomalies. (Is the anomaly real or due to the return airway monitoring?) Do any gas content core results make sense with the pattern of gas emission.
6. If the zone of influence of the gas drainage as defined by the return gas monitoring can be related to the drilling pattern, a table and graph of distance from the borehole and normalised gas monitoring value should be drawn up. These values should be related to gas content. {A higher frequency of gas content cores should be taken over the area of analysis}.
7. Gas reservoir simulation modeling (eg SIMED II) can be done to match the measured response in the first instance, and go on to define more appropriate hole spacings as a function of drainage time.

This type of analysis would be carried out say once in the life of a gate road development to fine tune the drilling and drainage approach. Its value lies in more closely tying the drilling pattern (spacing) to the inherent conditions of gas content and permeability. The result is less wasted drilling metres (where gas drainage is an over kill), and avoidance of gas related hold ups during mining.

This approach remains to be tested.

9. Extent to Which Objectives Have Been Achieved

9.1. The Prime Aim

The prime aim, “to create a **turn key, prototype**, stand alone, real time, gas monitoring system capable of providing quantitative assessments of gassiness levels on at least a shift by shift basis and enabling unusual gas emission patterns to be readily flagged”, has been essentially achieved.

The “turn key” aspect of the project has been an overriding consideration. By “turn key”, we mean a system that is has been thought through, is well documented in its application and is robust.

The gas monitoring system (hardware and CITECT software), is a fully functional monitoring system in its own right. It has a number of features not found in other systems currently operating in Australian underground coal mines:

- High gas analyser accuracy coupled with short response time. *{Current systems are either short response time and less accurate (gas detector based systems), or high accuracy but delayed response (tube bundle)}*.
- High sampling frequency (down to 2 seconds).
- High level of flexibility in setting sample rates and moving averages, with the user able to change settings in the PLC via the CITECT software interface.
- Complete automatic calibration of the gas analysers. *{The underground located gas analysers at Tahmoor Colliery were initially calibrated from GeoGAS’s Wollongong office via remote control}*.
- A high level of PLC controlled condition monitoring to ensure that the system is working.

The decision to use CITECT software was made to create a fully functional, WINDOWS based, operator interface, complete with trending, alarms and user access rights. CITECT is an Australian made and supported product, that is becoming widespread throughout the industry. Both Tahmoor Colliery and Dartbrook Mine use CITECT.

CITECT is good for data logging and trending (real time functions), but less amenable to intensive data processing. The GeoGAS Return Gas Monitoring System (RGMS) software was written from the ground up to undertake the necessary calculations and establish a process for operators to follow to arrive at meaningful results. The RGMS software is a fully functional PASCAL language (Borland Delphi 2.0), 32 bit WINDOWS program (with all the familiar WINDOWS features).

Because it is a separate program to CITECT, it has the ability to process data derived from any SCADA package - not just CITECT.

The system achieved shift by shift assessment of gas emission. It was built with the capability to undertake intra shift analysis, by inclusion of the belt weigher output. The belt weigher worked long enough at Tahmoor Colliery to establish that this aspect works. We were not able to get the belt weigher to work consistently as part of the trials. The system hardware and the CITECT software take full account of the belt weigher output. Additional programming of the RGMS data processing software is required to include belt weigher output. Other algorithms will need to be developed in this software to use belt weigher output for intra shift assessments.

9.2. Subsidiary Aims

The aim of “defining and documenting the process of using this data to back analyse gas drainage effectiveness” has been achieved, but without physically undertaking an actual analysis.

The aim to “assess the potential for using the technique to quantitatively define seam gassiness on a sub shift period basis” was not addressed due to inability to obtain belt weigher data.

The aim of “defining indices relating the gas emission response (rate of emission, peak emission rate, quantity, composition) to outburst proneness in terms significant to outbursting” has been reasonably achieved. The detailed reporting process as defined in the RGMS data processing software, guides the user toward arriving at a decision concerning the level of gassiness of the coal being mined and implications from a gas emission and outburst view point.

The system is put forward as an additional barrier to outburst prevention. Until more use is made of the technique, it is not seen as a replacement for existing barriers. It does have these additional applications:

- In mines (South Coast NSW) where an increase in gas content threshold has been argued on the basis of the GeoGAS Desorption Rate Index test, the Return Gas Monitoring System should make it easier for approval to be given.
- In mines (mainly Queensland) where gas content thresholds are approaching potential outbursting limits, and where thicker seams and greater inherent variability in gas content occurs, the Return Gas Monitoring System would be a sensitive identifier of the onset “gas dynamic incidents”, ie sudden gas releases that are not in themselves outbursts, but are definite warning signs.

A small outburst at South Bulli Colliery triggered a real life need for this type of monitoring. Day by day updates on the levels of gassiness during mining were forwarded to

the mine. Data files were accessed via MODEM, processed, and a report faxed back to the mine.

A significant benefit beyond the scope of the project is the ability to use this data to more accurately model gas emission on development for design of ventilation and as necessary, gas drainage and gas capture control measures.

10. System Limitations and Improvements Required

Although the system is deemed “turn key”, a number of limitations were identified, as follows:

Combinations of high rib emission rates and high air quantities result in lower levels of accuracy. At Dartbrook the majority of gas (80%) was generated outbye the face (This is a condition unlikely to be found at other coal mines). Drilling to reduce this emission added to noise levels. None-the-less, reasonable results were obtained. As the mine develops and gas drainage effectiveness improves, the system should become more sensitive to changes in the face.

Consideration can be given to periodically moving the system up so that it remains within 1 kilometer of the face. This will reduce some of the return emission, but do nothing for intake emission.

Improvements are required in air velocity measurement. Air velocity measurement is the largest single source of error in the system. Apart from the calculated error, the measurements are quite unsteady, resulting in a lot of noise in the calculated gas quantities.

If intake air to the panel being monitored has an appreciable quantity of seam gas contamination, changes in air quantity to the panel result in changes to the overall gas quantity in the panel. Periodic monitoring of the intake gas concentration would overcome this problem. The PLC could switch sample lines to monitor the intake at a low frequency (say for 1 minute every hour). The PLC could be programmed to only do the switching when the return gas levels are below mining levels to avoid loss of useful data.

A much lower cost CH₄ only system can be configured for mines subject to CH₄ only.

11. Technology Transfer Activities

The following activities were undertaken:

- A paper entitled “Application of hole flow measurement and return gas monitoring to validation of low gas mining conditions” was presented at the “International symposium-cum workshop on high gas emissions and outbursts in underground coal mines” - March 1995, Wollongong.
- Inclusion of a leaflet on the ACARP/GeoGAS system as part of GeoGAS’s brochure.
- Photographs and explanations as part of corporate displays at the 1995 Wollongong conference, the Mining Expo in Singleton in 1996 and the Mining Expo in Mackay in 1997.
- Direct contact with mining personnel in relation to this project (Tahmoor Colliery, Dartbrook Mine, South Bulli Colliery, North Goonyella Mine) and with the DMR.
- Presentation during the July 97 “Hanes/ACARP” drillers seminar.

It would be useful to present the results at suitable industry forums. It may be appropriate for ACARP to convene a seminar in NSW and one in Queensland for presentation of the results.

12. Acknowledgements

Considerable credit goes to Quality Data Australia Pty. Ltd. (Glen Jones, John Parker) who assisted in/guided design of the system and who completely assembled the product, included writing of CITECT and PLC code. They produced a product that exceeded expectations, delivered on time and within budget.

The authors express their gratitude for the assistance and resources enthusiastically given by Tahmoor Colliery and Dartbrook Mine. Both collieries made direct financial contributions to the project. The help and interest shown by Graham Pryor, John Perfect, Gary Dunn and Bob Case from Tahmoor Colliery and Roy Moreby, Richard Holland, John Hayward, Wayne Jacques, Tony Willmott and Gary Barrowcliffe from Dartbrook Mine is particularly acknowledged.

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