USE OF A MOBILE GAS LABORATORY AT MINE FIRES

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ABSTRACT

The N.S.W. Department of Mineral Resources commissioned its first Mobile Gas Laboratory in 1973.Although originally intended for diesel exhaust analysis, it has been progressively made more suitable for mine air analysis. Currently there are two upgraded units in operation.

These laboratories have been used at the scenes of four mine fires, two mine explosions and three recovery operations. The authors' experience jointly covers all of these incidents. In this paper they recount the role of the Mobile Laboratory in each incident - including the difficulties encountered - and trace the development of these units to their present state. Future improvements are foreshadowed, and some comments offered concerning the likely future role of these vehicles in mine emergencies.

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INTRODUCTION

In 1959, the Chief Analyst of the then N.S.W. Department of Mines Chemical Laboratory, Mr. H. Donegan published a paper on Coal Mine Fires, which covered the Aberdare Central Fire in 1944, the Ivanhoe fire in 1952 and the Lithgow and Bellbird fires in 1953. Donegan recognised the fact thatthe direction a fire was taking underground could be reliably observed by following the changes in gas composition. He deplored the fact that gas samples taken during these fires had to be sent to Sydney for analysis and the results, when they became available, were then purely academic. He concluded that "management of a colliery, engaged in fighting a fire, should have scientific assistance, readily available, preferably from a mobile laboratory, properly equipped and staffed with well-trained personnel, from the actual commencement of the fire".

Although for mine air analyses and monitoring, caravan type mobile laboratories have been used by the National Coal Board in Great Britain since the early fifties, Donegan's suggestions were not realised locally until 1974.

THE MOBILE GAS LABORATORY - DIESEL EXHAUST ANALYSER

In 1973 the Department commissioned its first mobile laboratory to enable diesel exhaust analyses to be carried out at N.S.W. collieries or manufacturing plants. A Volkswagen Kombi van was fitted out with analysers to determine the carbon monoxide, carbon dioxide, oxygen, oxides of nitrogen and hydrocarbon content of diesel exhausts. Sulphur and aldehydes could be determined separately, in situ, if required.The integrated system included a sampling pump, flow regulators, flow meters, filters, catch pot and drier. Cylinders of standard gas ensured correct calibration and warm up of each analyser before use and the output indication of each analyser was a meter display with recorder trace option.

During the first year of operation the advantages of this mobile laboratory system, particularly the elimination of sampling errors and the rapid availability of results, coupled with the almost complete lack of downtime due to instrument failure, prompted the Department to investigate the use of this facility to monitor colliery atmospheres in emergency situations.

MOBILE GAS LABORATORY - MINE ATMOSPHERE ANALYSER

Chamberlain et. al., (1970) concluded that carbon monoxide was the most sensitive detector gas for indicating the onset of coal heating and that this indication occurred long before the carbon monoxide - oxygen deficiency ratio became appropriate. He also pointed out that the measurement of hydrogen, ethylene and propylene could be used to indicate the intensity of a fire.

With this information the Mobile Laboratory was modified in the hope of achieving the dual capacity of being able to analyse both diesel exhausts and mine atmospheres. The carbon dioxide and oxygen analysers were considered to be versatile enough to handle both analyses. The carbon monoxide analyser posed a major problem, with its lack of sensitivity, non-linearity and, on its most sensitive range, significant interference from carbon dioxide, methane and water vapour. This necessitated the preparation of interference curves and determination of the detection limits of the analyser.

The range of the total hydrocarbon analyser was increased with the installation of an air-sample splitter system, and a small gas chromatograph was commissioned and installed to enable hydrogen and other hydrocarbons to be determined if required.

The modifications and additions were successfully tested at the Lidcombe laboratory under simulated conditions, and goaf samples were analysed at a number of collieries.

ABERDARE NORTH COLLIERY FIRE

The fire at the Aberdare North Colliery in November 1975 was the first real opportunity to use the Mobile Laboratory under emergency conditions.

A decision was made to seal the entire pit shortly after the Laboratory arrived and, although the Laboratory remained there for three days, no useful results were obtained.

The exercise was however, of significant educational value; it was realised that barometric pressure had a great influence on gas sampling through pipes into sealed areas and samples could only be obtained when the barometer was falling; it was discovered that long sampling lines and non-permeable sampling bags were essential to increase sampling versatility; a power generator was necessary in case power was inaccessible or unavailable; result sheets and tape recorders would facilitate result taking, and an electronic calculator and explosibility or Coward diagrams (Coward, 1928-9) were required to fully assessthe analysed gas mixture.

A trailer mounted power generator was duly commissioned and result taking and result interpretation facilities were introduced. Following the exhaustive testing of available polymer plastics, a large number of saran (polyvinylidene chloride) gas sample bags were purchased, with 100 metres of PVC tubing.

ABERDARE NORTH COLLIERY RECOVERY

In June 1976 the Mobile Laboratory assisted in the recovery of Aberdare North Colliery. This recovery involved sealing off the fire area by sinking bore holes from the surface, to intersect chosen roadways; dry fly ash was then pumped in to effect the seals. The rest of the mine was then ventilated and entry was made in fresh air.

Holes for gas sampling were drilled into the fire side of two of the seals and a third near the supposed site of the initial heating. Continuous gas monitoring was necessary at these three points to ensure that the seals were intact and leak-free during ventilation.

Australian Coal Industry Research Laboratories Ltd., (A.C.I.R.L.) were commissioned to provide this service using fixed gas analysers installed in the Aberdare Central Washery laboratory. Their intention was to use a mains operated pump to fill rubber bladders for analysis and report the results to the mine office by telephone. The Department's role was to use the Mobile Laboratory to confirm the analyses of important samples and act as a reserve facility in case of instrument malfunction.

During the exercise several important advantages of a mobile system over a fixed system of analysers were clearly demonstrated, particularly the capacity of installing the Laboratory at a remote site, using the power generator, and then sampling directly into the analysers. This was exemplified on the second day of continuous monitoring when the oxygen content of the gas from borehole 8, the point close to the supposed original heating, began to increase rapidly. This indicated either a leak in the sampling lines or gate valve at the top of the borehole or a break in one of the underground seals. When the Mobile Laboratory was installed at the borehole itself, and sample gas was continuously pumped through the analysers, the oxygen figure returned to the expected level. This confirmed a leak in the gate valve; the operation of the mine fan had lowered the pressure in the mine and caused outside air to be drawn into the borehole, eventually reaching the end of the sampling line.

At other sampling sites an increasing discrepancy was observed between the oxygen results reported by A.C.I.R.L. and those from the Mobile Laboratory. This was traced to a shortcoming in the pump used by A.C.I.R.L. , as it allowed air to enter the sample train via the pump shaft. The diaphragm pump in the Mobile Laboratory was used to overcome this problem.

The entire exercise proceeded without serious incident and, as previously found, was most educational, confirming that the Mobile Laboratory could perform consistently for long periods of continuous monitoring. However, the need for a spare sample pump and a more sensitive, interference-free carbon monoxide analyser was evident.

APPIN COLLIERY CONVEYOR BELT FIRE

A fire was discovered in the belt drift at Appin Colliery at about 2 am on the 7th November, 1976 and, as part of their new emergency procedure, the Southern Mines Rescue Station requested that the Mobile Gas Laboratory be made available for gas analyses at the colliery.

The Mobile Laboratory remained on site for fifty-eight hours, continuously monitoring the atmosphere at the top of the belt drift for fire products. Sampling was made easier by the reversed ventilation; normally the belt drift at Appin Colliery is an intake, however the heat of the fire caused the air to issue from the top of the drift against the ventilation. Intermittent bag samples were obtained from the drift bottom by rescue personnel, and analysed on their return to the surface.

The real value of immediate gas analysis, in providing information to mines rescue workers and other decision makers as to whether a fire is under control or otherwise, was demonstrated by an incident that occurred on the 8th November. Believing the fire to be out, rescue teams had entered the drift from the top and the bottom with the intention of cutting back the high expansion foam that filled the drift, and extinguishing any remaining smouldering material. The analysers in the Mobile Laboratory suddenly indicated a steady rise in the concentration levels of carbon monoxide, carbon dioxide and methane, with a corresponding fall in oxygen in the atmosphere issuing from the drift. On the strength of these results the rescue teams were immediately withdrawn and by the time the last team member emerged, smoke was visible in the drift atmosphere.

The role played by the Mobile Gas Laboratory at this incident was enthusiastically acknowledged by the Department and it was then decided to completely up-date the present system and duplicate the facility as well. This would ensure that one laboratory would always be on standby in the event of another emergency.

The Department commissioned the second Mobile Laboratory in 1978 and this system was designed to be simple to operate and capable of analysing both diesel exhaust and mine atmospheric samples.

Table 1 details the gas concentration ranges of the analysers, which were installed in a Toyota Hi-Ace LWB 5 door van. This vehicle, because of its mobility, was again preferred to the larger caravan type.

The Horiba AIA-24 carbon monoxide analyser is not affected by methane and contains a second detector to eliminate carbon dioxide and water vapour interference. All analysers were linear with both liquid crystal and recorder output indications.

The sample, zero and calibration gas flows to the analysers were synchronised through precision regulators and flow meters with solenoid valves, and the facility to sample either through tubing or from a gas sample bag was included.

An automatic microprocessor controlled gas chromatograph, with both thermal conductivity and flame ionisation detectors, was installed for hydrogen determination and as a back up unit for the other analysers in case of malfunction or over range.

A recording barometric pressure transducer was included to enable the correct sampling of gases behind seals to be achieved.

To provide a rapid assessment of the

TABLE 1.

GAS	ANALYSER	ANALYTICAL PRINCIPLE	CONCENTRATION RANGES (lowest and highest)
CO	Horiba AIA-24	INFRARED	20 p.p.m. /500 p.p.m.
CO	Horiba AIA-23	INFRARED	2000 p.p.m./ 2%
CH_4	Horiba AIA-23	INFRARED	2% / 20%
CO_2	Horiba AIA-23	INFRARED	10% / 20%
O_2	Taylor-Servomex OA250	PARAMAGNETIC	10% / 100%
NO/NO_2	TECO 44	CHEMILUMINESCENT	10p.p.m. / 10 000 p.p.m.

explosibility potential of a mine atmosphere, a hand-held calculator was programmed, permitting carbon monoxide - oxygen deficiency ratios to be determined and Coward diagrams (Hughes and Raybold, 1960) and the U.S. Bureau of Mines explosibility triangle (Zabetakis et.al., 1959) to be interpreted.

The effect of sampling gases through long lengths of plastic tubing was studied, with particular reference to response time, chromatographic effect, flow rate, pressure drop and static electricity build up. Following extensive testing, three lengths totalling 1 km of 3/8 " o.d. Nylon 11 tubing, with flame arrestors in each junction, were purchased and installed, ready for use, in the power generator trailer.

Field trials indicated that complete accurate analyses could be obtained within thirty minutes from the time power was available to the system, and thereafter bag samples could be analysed and the results processed within five minutes of submission. Analysis time through the 1 km of tubing was approximately thirty minutes, with carbon dioxide suffering a slight chromatographic effect.

WEST WALLSEND NO. 2 COLLIERY EXPLOSION AND FIRE

At about 5 am on 8th January, 1979, a massive explosion devastated the underground workings of the West Wallsend No. 2 Colliery, and caused damage to some surface installations including the housing of the main fan. The new mobile laboratory, with the power generator, travelled to the mine for its first use in a mine incident. It was located at the upcast shaft and prepared for operation while temporary repairs were made to allow the fan to operate. Two sampling lines were sealed into the upcast shaft, and monitoring continued as the fan was put into operation. A.C.I.R.L. had already begun analysing bag samples using equipment which they had installed in the mine offices. Monitoring proceeded during the night, while rescue teams entered the mine to assess damage.

At about 9 am, a light haze became visible at the fan evasee, and the carbon monoxide readings increased suddenly. Within minutes dense black smoke was issuing from the shaft, quickly blocking the nylon sampling lines and delaying the arrival of the gas to the analysers. The increasing heat in the upcast shaft melted the sample lines and sealed them, preventing further gas analysis. By about midday, all entries to the mine had been sealed.

Several difficulties were noted during this operation. The sampling pumps in the Mobile Laboratory tended to overheat in the very high ambient temperatures, and special care was required to keep them from shutting down; the sample drying system was found not to operate well under vacuum; analysis for hydrogen was not possible, as the gas chromatograph in the mobile laboratory had not been fully commissioned. Long sample lines in the upcast shaft were used because the fan was not operating; however after the fan started short lines from near the top of the upcast shaft could have given faster results, and greatly reduced the problem of the obstruction of sample lines by dust (and later smoke). A large capacity filter external to the shaft would have taken care of dust in the sample lines, and could be replaced if it became heavily loaded.

The most important lesson from this incident was the realisation that a chart recorder is far better than a meter for the detection of trends in gas composition, even though the recorder is less precise. Small trends are hidden by the continual fluctuations in gas composition when observed on a digital or panel meter, but can be seen clearly on a chart recorder.

Following this incident, the gas chromatograph was more thoroughly commissioned, the sampling pumps were re-oriented to provide better cooling, the drying system was revised, and new fittings and filters obtained for the sampling lines. New sample result sheets were designed, simplifying the recording of results and the assessment of explosibility of gas mixtures.

BURWOOD COLLIERY FIRE

On the 14th January, 1979 a fire at Burwood Colliery necessitated the sealing of the entire underground workings.

The Mobile Gas Laboratory was dispatched to the colliery and continuous gas analysis of the atmosphere in the fan evasee was maintained for sixty hours.

The results from this exercise again showed that meaningful results were obtained only when the barometric pressure decreases. Management and rescue personnel at the mine were reassured in the knowledge that the atmosphere issuing from the fan evasee during and after the sealing operation was not capable of forming an explosive mixture when mixed with air.

BURWOOD COLLIERY RECOVERY

On the 20th February, 1979, the Mobile Laboratory was again made available to the Manager of the Burwood Colliery to monitor gases from a borehole that had been sunk into the area of the supposed initial heating.

The main purpose of the exercise was to observe the possible migration of gases in the fire area over a known period of time. During the first hour of testing the main power transformer for the Laboratory's analysers failed; fortunately power was still available to the sampling pump and gas chromatograph. The chromatograph was programmed for automatic sampling and analysis and, without the aid of other analysers, provided half-hourly analyses for hydrogen, methane, oxygen, carbon monoxide and carbon dioxide for the duration of the exercise.

The value of the power generator, and of the gas chromatograph as a back up analyser, was amply demonstrated during this exercise.

WEST WALLSEND RECOVERY

The initial recovery work at West Wallsend No. 2 extended over several months and involved several visits by the Mobile Laboratory. The atmosphere in the sealed mine contained about 90% methane and was beyond the range of the methane analyser but could be analysed on the gas chromatograph.

Re-ventilation of the mine was effected on 25th June 1979. The Mobile Laboratory monitored continuously for almost five days, being powered for the first twenty-one hours by the power generator. The equipment performed faultlessly, and the recovery proceeded smoothly, with gas analyses being telephoned regularly to the manager's office.

APPIN COLLIERY EXPLOSION

Following an explosion at Appin Colliery on the 24th July 1979, the Southern Mines Rescue Station requested the services of the Mobile Gas Laboratory to assist in gas analyses during the rescue operation and temporary ventilation restoration.

The role of the Mobile Laboratory was to monitor the return gases issuing from the main fan evasee, to supplement the results being obtained from three underground points by the Colliery's Corex Tube Bundle System.

Although the gases analysed at the return shaft were more dilute than those obtained by the tube bundle system, changes in concentration were detected by the Mobile Laboratory some forty minutes before they were reported by the Colliery's analysers. This was because of the long sample transit time in the tubes. The Mobile Laboratory also offered a wider range of analyses than could be obtained from the colliery system, and bag samples taken at specific underground locations could be analysed and immediately assessed.

LAMBTON COLLIERY FIRE

Analysis of return air from extensive and largely inaccessible discontinued workings at Lambton Colliery indicated the probable existence of a self-heating. The Mobile Laboratory was summoned on 7th December 1979 and provided continuous analysis for sixty-seven hours, during which time the problem was investigated and the area was sealed. The actual site of the heating was not found. No significant problems were encountered in the operation of the Mobile Laboratory. One unusual feature of this monitoring period was the unattended operation of the Mobile Laboratory overnight. The analysers, chart recorders and automatic chromatograph provided a permanent record of gas concentrations available for evaluation the next morning.

RECENT IMPROVEMENTS

Since the last incident involving the Mobile Gas Laboratory, a number of improvements into certain performance aspects have been effected. These include:

(1) The complete updating of the original Mobile Gas Laboratory to a system equivalent to Unit 2, including again the transfer of equipment and instruments to a Toyota Hi-Ace Van.

(2) Compilation of detailed operating instructions for each Mobile Laboratory including details of result interpretation, a check list of equipment and spares required for a particular emergency, and telephone numbers of mobile laboratory operators, appropriate colliery and mines rescue personnel and mines inspectors.

(3) The installation of a fixed communication system in each Mobile Laboratory compatible with the frequencies used by all of the state's four mines rescue stations. Portable units will alow communication between the laboratory operator and decision makers at future incidents.

(4) The complete automation of the microprocessor controlled, Baseline, Series 1030 gas chromatograph, with all gas analyses being related to atmospheric oxygen as the only standard.

(5) The design and implementation ofa new concept in the explosibility assessment of mine atmospheres, to replace the existing Coward diagram and the U.S. Bureau of Mines triangles. This will greatly assist in the rapid determination of the explosibility potential of an atmosphere and enable a continuous trend to be followed on one diagram (Ellicott, 1981).

FUTURE IMPROVEMENTS

The operation of a Mobile Gas Laboratory at a mine incident may be divided into five aspects: preliminary information, sampling, analysis, result output, and communication of results.

Preliminary information will require compilation of detailed maps giving the precise location of every colliery in the state, the siting of available gas sampling points, power connections and their type, and detail of the normal carbon monoxide and methane concentrations in each colliery's return air.

In analysis, and in the communication of results, the mobile laboratory is considered to be almost fully developed in its present form.

Some changes may be introduced by the use of computer control of the analysers. This would allow advances in the processing and recording of results, with automatic alarms if preset limits are exceeded or if particular trends are detected(e.g. increasing carbon monoxide). This would improve the ability of the mobile laboratory to operate unattended; however the benefits of such changes must be balanced against the versatility, simplicity and reliability of a manually operated system.

Sampling remains the greatest difficulty in the use of the Mobile Gas Laboratory. Rescue personnel, having come to depend on gas analysis for their safety, are now equipped to relay bag samples of gas to the surface for analysis. It is possible that all collieries will be requested to install on the upcast shaft a fitting to be designed and supplied by the Department, to permit immediate sampling of the return air.

At mines which have a tube bundle system, suitable connection points on the sample tubes would permit the mobile laboratory to sample from individual locations in the mine. As the Mobile Laboratory has greater capability, both in terms of the number of gases for which it can analyse and the concentration ranges it can cover, it could be used to increase the versatility of mine monitoring systems.

CALL-OUT PROCEDURE

The Mobile Gas Laboratory is made available free of charge for emergency use, on the request of an inspector of collieries. In practice, a call for assistance may be relayed through a rescue station; the Southern Mines Rescue Station has information which allows it to contact an operator at any time.

Where use of the unit is required for a planned operation - such as a mine recovery - a charge is made for the time of the personnel involved.

SUMMARY

It is now well recognised that the interpretation of the state of a mine fire can be made easier through the results of immediate gas analysis. This interpretation provides information essential to mines rescue personnel and other decision makers, regarding the withdrawal or continuance of rescue men in a rescue and recovery operation before an explosion develops, whetherthe fire fighting techniques are effective, whether the fire is under control, and in ensuring the safety of the workmen during and after sealing operations.

The Mobile Gas Laboratory with its ability to provide rapid, frequent and reliable analyses and interpretation of gas samples has effectively demonstrated its value to the coal mining industry during recent emergency operations. The main problem is the effective sampling of gases underground.Continuous monitoring is alsways preferable to bag sampling, although this is not always possible. Trends can be best discerned from continuous monitoring using a recorder trace rather than instantaneous numerical values.

The laboratory is seen as complementary to tube bundle and other colliery gas monitoring systems through its mobility, independence and gas analysing versatility, and should maintain a permanent place in coal mining's future.

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DISCUSSION

W. ROBERTSON (Corex Laboratories, National Coal Board, U.K.): The layout of Unit 2 as a mobile laboratory is very impressive and especially the amount of equipment in it. The optical benches are very large and occupy a lot of, what would appear to be valuable space in a very limited area. There obviously is a cogent reason for choosing the Horiba analyser and perhaps the reasons for choosing the Horiba could be stated. The comparison given between the speed at which the mobile laboratory can give results and the speed of a mine air monitoring system appears to be slightly unfair since a tube could quite easily have been taken from the return shaft and coupled into the existing Corex system and would have given the same answers with the same delay time.

C. ELLIS (New South Wales Department of Mineral Resources): When the Government buys anything of course it is done by tender. The sorts of things sought in analysers were known. There are alternative configurations of the Horiba analyser; one where it is contained in one unit and the other where the optical bench is separate from the electronic unit. It was felt that the space that would be occupied by the optical bench was not terribly important and so that configuration seemed suitable. The other thing sought was freedom from interference and the Horiba met this; and then, there is the other business of money which comes into it, and it seemed to be the appropriate analyser to buy at the time. Its performance hasn't been disappointing either.

P. MacKENZIE-WOOD (New South Wales Department of Mineral Resources): It has a very fast warm-up time as well - something less than a quarter of an hour, and that was considered very important.

C. ELLIS: Possibly that was unfair in comparing the response time of analysers but in the situation that existed at the time it was possible to report increasing carbon monoxide and methane concentrations, as stated, well ahead of the monitoring system at the mine. That may be unfair; the Corex system at the time was not fully commissioned, and for sure there have been some quite significant changes made to it, and it was caught during the commissioning when that incident occurred. But that was as the situation existed. The mobile laboratory was able to assist the Company by providing earlier indications of trends.

P. GOLLEDGE (Queensland Department of Mines): As the justifications for using bag samples, permeability figures for certain gases were quoted. Hydrogen was not included; are the bags satisfactory with hydrogen?

P. MacKENZIE-WOOD: Hydrogen was not included because that gas wasn't included in the particular publication referred to. Tests were done on hydrogen and it was found saran bags again were very good, although any difference between say saran and tedlar could not be distinguished. They were certainly better than the rubber bladders that the Department was trying to get the industry to replace.

D. ROWLANDS (University of Queensland): What was the all-up cost of the latest version of the mobile laboratory? Secondly with regard to the chart recorder, although the value of chart recorders is accepted perhaps the trend being sought would have been picked up by a moving average type figure.

P. MacKENZIE-WOOD: The cost of the Unit 2 at that time was about $47,000 plus the vehicle.

The figure would be something towards $60,000 now to replace that unit. That $47,000 didn't include quite a few of the accessories, including the standard gas cylinders, the power generator and the radios, so the real cost would be say $60-$70,000. Costs of course, are tax free.

C. ELLIS: On the detection of trends; an averaging type of arrangement would certainly be the way to detect changes in trend and allow alarms to be indicated when trends were detected. The difficulty that arises with anything like that was mentioned briefly in the paper. If something different is needed part way through a run - if a span check is wanted, or a bag sample is to be fed through, that is, something that is different - whatever monitoring system is there that is overlooking the output has to be overridden. Some of the versatility that exists at the moment may be lost. Whilst monitoring continuously if somebody brings a bag sample that they want analysed, there is no problem in switching over and doing that. If the system is automated it may become much more complicated to do that kind of thing.