

SOURCES AND EXTENT OF MINE ATMOSPHERE CONTAMINANTS

by

A.J. Hargraves¹ABSTRACT

Seam gases are the most important atmosphere contaminants in Australian collieries, their importance increasing with depth; CO₂ as well as CH₄ may be important in intruded environments. The generally high rank of the coal, with low moisture content, makes for abnormal dust production. The other contaminants are introduced and subject to better control, including products of spontaneous combustion. Due to market situations the generally lower rank and higher sulphur coals more prone to self heating are mined less. Future mining at greater depths should see greater problems with atmosphere contaminants.

INTRODUCTION

The need for ventilation arises from the additions to (or abstractions from) mine air which render it less fit for human breathing or which introduce other atmospheric hazards to the mine environment. Thus it is logical to divide atmospheric additions into those with physiological effects and those with environmental effects. Whilst it is intended to confine detailed discussion to contaminants of mine air it is acknowledged particularly that heat additions to or abstractions from mine air can have working comfort effects and that under cold conditions particularly, high ventilation

velocities have great influence on comfort. Most Australian collieries, being close to sea level and in tropical or mild temperate latitudes mainly experience mild to warm surface atmospheric conditions. At present maximum working depths air temperature rises due to auto-compression in downcasts is less than 4°C. Although it is known that the Old Balmain Colliery, Sydney, at nearly 1000m depth suffered from high ventilation temperatures, other ventilation details of Balmain ventilation are sparse. The relatively shallow depths to which mining is carried out in Australia, together with not abnormally steep geothermic gradients result in mine ventilation temperatures generally well below 26°C. Past experiences with high wet bulb temperatures giving rise to shortened working shifts were virtually confined to tropical locations and during the wet season in shallow hand-worked mines with many working places. In temperate locations, unless effective temperatures exceed 26.1°C, normal working conditions exist. At the opposite extreme, except in some mine access situations in lower latitudes in winter, cold is not a problem and extreme cold conditions such as those experienced in collieries in some mountainous areas overseas just do not exist.

Having made mention of these other mine atmosphere environmental factors, the subject of atmospheric contaminants will be treated on the basis of source and extent and of physiological or environmental importance only, the health aspects will be covered in a separate detailed paper. An excellent summary of coal mine gases

¹Visiting Professor, Department of Civil and Mining Engineering, The University of Wollongong.

is provided in the Joint Coal Board Chart of Mine Gases. As seam gases are the major source of atmospheric contamination some general statement on seam gases appears pertinent.

SEAM GASES GENERALLY

The traditional gas of coal mines is "firedamp", an inflammable gas or gas mixture, largely methane. "Methane" is emitted continually from exposed virgin coal and it progressively bleeds away from pillars and detached coal.

Methane (CH_4) is the principal migratory product of the progressive metamorphism of solid coal due to temperature and pressure in the buried underground environment. The chemical changes in the metamorphism of coal are shown in Fig. 1 (after Hargraves 1962). Although, in the total metamorphic process, the other chemically produced migratory products, CO_2 and H_2O appear to be as important as CH_4 , by the time coal has been metamorphosed to black coal, especially to high bituminous rank, the production of H_2O and CO_2 is insignificant compared with the production of CH_4 . With no underground lignite mines still operating, all present underground coal mining in Australia is of black coal of rank well into the CH_4 producing stage of metamorphism.

The methane content of high rank bituminous coal, say the Bulli Seam with composition 22-27% V.M afd is around 15m^3 /tonne in the deeper mines. Gases are held in coal by processes more complex than simple compression into the pores of the coal. Only a small fraction of the actually sorbed gas could be compressed into the pores at the gas pressures which have been measured - over 4MPa - and, anomalously the coals with lower porosities (and generally higher rank) appear to have generally higher sorptive capacities.

The sorptive capacities of coals cc/gram relative to gas pressure are depend-

ent upon temperature (sorption falls as temperature rises) (Fig. 2, derived from Ettinger, 1969) and are therefore expressed as sorption isotherms, the curve of sorption relative to pressure at constant temperature. As indicated above, sorption varies with rank, increasing with increasing rank at least to semi-anthracitic stage (Fig. 2). (Conversely permeability decreases as rank increases.) Important to Australia is the variation of sorption with gas composition, CO_2 having two to three times the sorption in coal that of CH_4 (Hargraves 1958). What is not yet so well known is the extent of reduction of sorption with stress, and its corollary, the local increase of gas pressure in a seam where it undergoes locally an increase in stress although some data is available on this (Hargraves 1966). Increased hydrostatic stress reduces the permeability of coal to the passage

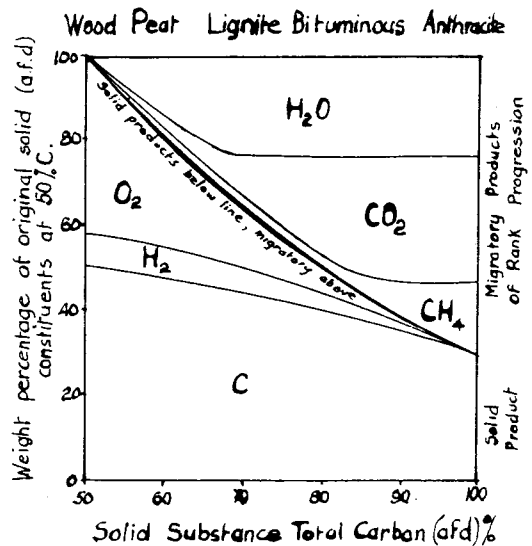


Fig. 1-Metamorphism to coal and migratory products

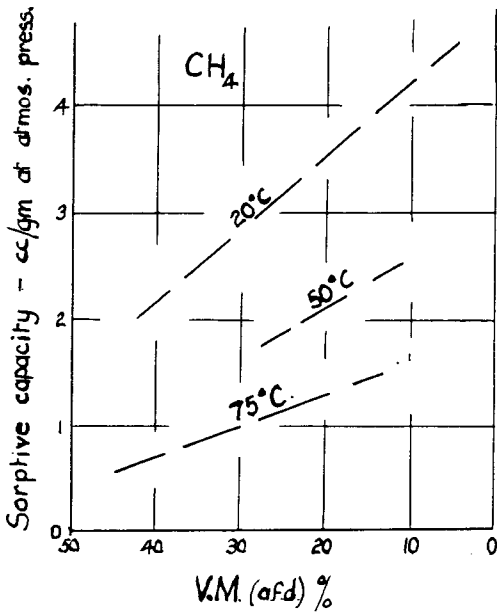


Fig. 2-Sorptive capacity relative to rank

of gas (Fig. 3, Bartosiewicz 1983)*. All of these influencing factors, plus time, as included in rates of advance of places and as applying after exposure of coal, make the process of development of gas pressure gradients and the issue of gas from exposed coal and the diminishing rate of drainage of gas from detached coal, whether in pillars or broken free, a most complicated and largely empirically treated situation. However, in the one colliery and seam, with reasonably repetitive geometry, it is possible to reach some degree of predictability of gassiness.

Australia is one of the few coal mining countries where CH_4 is not the sole major component of deep seam gas, but CO_2 may be quite important in some areas in concentrations

rising to almost 100% CO_2 (Hargraves 1963a). In both the Sydney and Bowen Basins the proximity of igneous intrusion, including intrusion of the seam has established the relationship between intrusion and the occurrence of CO_2 in

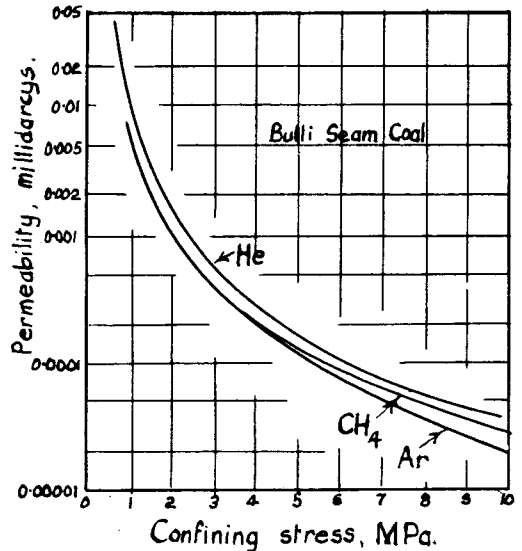


Fig. 3-Influence of hydrostatic stress on permeability of coal

deep seam gas such that the CO_2 has been regarded as of pneumatolytic origin (Hargraves 1963a) substantiated by isotopic analysis by Smith and Gould (1980). With the higher sorptive capacity of coals for CO_2 than CH_4 , the prospects of gassiness of coal related to depth can be seen in Fig. 4, for CH_4 in Fig. 4a (Hargraves 1962 after Lidine 1949) and for CO_2 in Fig. 4b. By comparison to CH_4 and CO_2 all other gases have little significance as components of deep level seam gas.

In deeper mines with gas stored in coal under relatively high pressure, the escaping and expanding gas, on release, is cooler than the strata which it leaves and usually is cooler than ventilation air. This is particularly so with noisy-rapid-release of gas.

Notwithstanding the occurrence in some seams from time to time of blowers of gas or of outbursts of coal and gas from the working

*H. Bartosiewicz, CSIRO Division of Geomechanics, Victoria - private communication.

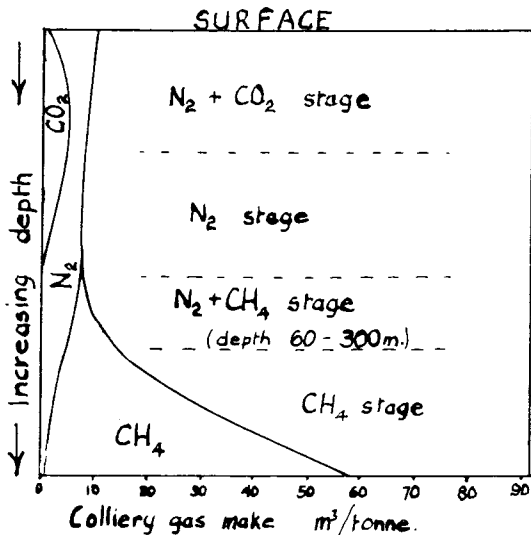
seam, it is probable that there is no significant difference in the original gas content of the coal of that seam in the area of the blower or outburst of coal and gas than elsewhere. Likewise, despite the surges of gas which they produce, the average output of gas from the

coal including the blower or outburst would not be greater than the average gas output without such incident. No comment will be made at this stage on apparent seam gas composition changes with violent emissions, as have sometimes been reported.

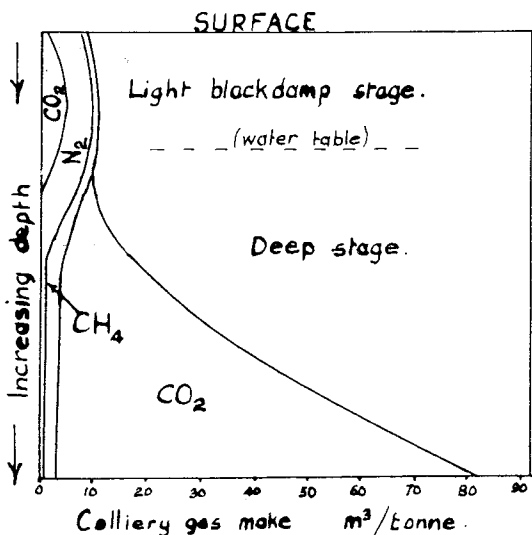
One general fact applies equally, although not quantitatively to CH_4 as to other seam gases - that exposed virgin ribs will continue to emit seam gas forever in quantity diminishing to some constant value, modified by any subsequent adjoining work in virgin coal. Likewise formed pillars of coal will emit from all rib-sides gas in generally diminishing quantity until the eventual "winding" (bringing the gas content of the coal to equilibrium with atmospheric pressure) of the pillar coal.

Likewise coal in areas of adjoining seams relieved by extraction of larger areas of coal in the working seam will release gas in the direction of the working seam according to the extent of relaxation of the adjoining seam and the changed permeability of the intervening strata due to the same relaxation influence of extraction. This flow will diminish with time and should eventually reach virtually zero. However the perimeter of relaxation in the adjoining seam will act like a partially exposed rib around an extraction in a working seam, and after initial greater flows should eventually asymptote to a constant value, this gas also reaching the working seam through intervening relaxed strata due to the extraction of the working seam. Two aspects qualify this situation - if caving above an extraction caves or exposes a seam, the gas content of such detached or exposed coal will naturally eventually come to equilibrium with atmospheric pressure, and if the strata below the extraction breaks intermittently instead of progressively with extraction advance, then blowers of gas may be experienced, as on recent Appin longwalls rather than smooth or smoothly changing gas flow rates.

All seam gases are mixtures, although



(a) CH_4 - after Lidine.



(b) CO_2

Fig. 4-Total gas make, m^3 /tonne mined, relative to depth

usually predominantly CH_4 , and in the case of Australia possibly predominantly CO_2 with all mixture possibilities. Hence all density possibilities exist also, from 0.55 to 1.53 relative to air. The possibilities of layering at roof or floor have been mentioned. Mixed gases never unmix due to density differences of the components. The ease of dispersal and diffusion of gases in air is greatest where the density of (mixed) gas is closest to that of air, and diffusion into air of mixed gas is in the same proportion as the gases of the mixture (Hargraves 1963b).

There are methods for assessing the gassiness of coal, both desorbable - which is the basic interest of the mining engineer - and total, involving crushing and evacuation of coal samples. The United States Bureau of Mines method was described by McCulloch and Diamond (1976). Armed with such an assessment of gassiness of virgin coal the forecasting of seam gases issuing into mine ventilation becomes more basic. It must be remembered that coal clears the mine portals with some gas still included such as a remaining 1 to 2 m^3 of CH_4 /tonne at a deep Bulli seam mine in the Illawarra measures of the Sydney Basin. An example of such a prediction in the UK was given by Dunmore (1981).

SEAM GASES PARTICULARLY

Methane.

CH_4 occurs in virgin coal at the sorptive capacity of that coal at that depth and under the stress conditions prevailing. A figure of about 15 m^3 of CH_4 per tonne of coal is typical for deep Australian coking coals. The presence of the CH_4 in the coal is due to its retention during the prolonged metamorphic process from vegetable matter to anthracite according to back pressure along escape paths from the seam to the surface, deduced to be about hydrostatic pressure from the water table to the seam. Accompanying the CH_4 may be small

percentages of C_2H_6 and traces of other higher hydrocarbons (6% C_2H_6 in some exceptional cases). The seam gas CH_4 intercepted by workings in the seam is diverted from its upward escape path to the surface, and gas pressure gradients are created from the virgin seam at virgin seam gas pressure to atmospheric pressure at the coal exposures in the mine openings. Figure 4(a), presents an idea of the quantity of CH_4 seam gas in coal relative to depth (Hargraves 1962). Apart from creating O_2 deficiency as an atmospheric contaminant CH_4 becomes an environment safety hazard at about 5%, equivalent to air with 19.8% O_2 .

Because of its tendency to layer in high concentrations at the roof in places of sluggish ventilation and in rising places because of its low density (0.55 relative to air) miners can suffer from O_2 deficiency in rises and in near roofs, perhaps collapsing, to revive when falling into pure or less contaminated air below.

Nitrogen.

N_2 occurs in small quantity in normal CH_4 seam gas. Its presence may be due to retention of relatively small quantities of N_2 from changes in the original protein contents in the vegetable matter forming the seam. The source of N_2 in seam gas in shallow workings - above the water table - is due to surface - meteoric - water with air entrained passing through the soil and surface rocks down towards the seam. Migrating through coal, this entrained air provided O_2 to oxidise the coal to CO_2 , leaving the N_2 virtually unchanged. Thus shallow level, light "blackdamps" comprising mostly N_2 with CO_2 are frequently the seam gases of shallow workings. Being close to the surface, with little or no hydrostatic head of pressure the quantities of gas are small, although the N_2 content of the gas is high. Figure 4 illustrates the occurrence and quantity of shallow level "blackdamp", largely N_2 (Hargraves 1962).

Sometimes, in deducing seam gas

composition by deducting N_2 on the basis of sample O_2 content and the factor X3.73, there appear to be considerable amounts of N_2 in the deep level seam gas, sometimes tens of percent. Often this apparent high N_2 is considered to be exaggerated due to removal of some O_2 in oxidation within the sample container during long storage before analysis.

As N_2 is physiologically inert and virtually chemically inert its presence in air over normal proportions has the sole effect of decreasing proportionate O_2 content.

Carbon Dioxide.

Occurs in shallow level coal, with N_2 , as a light blackdamp. As it is derived from oxidation of coal by air, shallow level CO_2 is accompanied by a predominance of N_2 . As stated above, the quantities are not large, as Figure 4 shows. Because of the higher solubility of CO_2 in water its presence in shallow level seam gases may be further reduced.

Much more important as affecting ventilation is CO_2 in seam gas in deeper level workings. This may contain a small proportion of CO_2 residual from the early metamorphism of the coal, but is almost entirely gas introduced from outside the seam by pneumatolytic gases associated with adjacent intrusion, as described above. Because of the higher sorptive capacity of coal for CO_2 than CH_4 the expected gassiness of a CO_2 seam gas area will be greater than the equivalent of CH_4 , as Figure 4 shows.

The occurrence of predominantly CO_2 seam gas replacing the more normal CH_4 occurs in discrete areas of the Bowen and Sydney Basins (Hargraves 1963b, 1962) and subsequent developments have disclosed further areas (Hargraves 1983) and no doubt future developments will disclose more.

Because of its density (1.53 relative to air) and its consequent tendency to layer

in high concentrations at the floor in places of less brisk ventilation and in dipping places, miners can suffer from oxygen deficiency, perhaps stumbling or collapsing, and falling into even higher concentrations at the floor. Such were the conditions at the two instantaneous outburst disasters in 1954, with CO_2 overwhelming ventilation for the time being (Hargraves 1958). CO_2 smarts the nostrils and the eyes and in concentrations over 5% causes uncontrolled fast and deep breathing although at 5% CO_2 the O_2 content of air, 19.8%, would be well within the life support range.

Hydrogen.

H_2 , is sometimes reported as a constituent of seam gas. This identification, which is usually in small quantity is rather doubted, as being due to sample contamination or some other extraneous cause.

Carbon Monoxide.

CO , likewise is sometimes reported in small quantities in seam gas. Again, CO as a seam gas is rather doubted, to be explained by partial oxidation of coal dust collected in the sample, or by some other similar cause.

Hydrogen Sulphide.

H_2S sometimes occurs in seam gas, usually in high-sulphur coals, usually at shallow levels and in the vicinity of faults, although there are exceptions. The source of H_2S is seen as the decomposition of sulphides by acidic ground waters and perhaps by introduction during intrusion - in other words a pneumatolytic gas. Fortunately occurrences are rare, but not unknown in both the Bowen and Sydney Basins, and compositions in seam gas have been of the order of 1%. In one instance in the lower rank, high sulphur Greta Seam, Sydney Basin, a seam gas predrainage scheme was installed especially to combat an H_2S problem (Hargraves 1982). In other mines ventilation only was used to cope

with the H₂S problem, but sicknesses due to over exposure have occurred.

Helium.

He was found in Metropolitan Colliery seam gas, both Bulli and Balgownie seams, (Brigden, personal communication 1960) and at that time was attributed to a pneumatolytic origin, because of its association with CO₂ seam gas. However, subsequent analyses of essentially CH₄ seam gas also in the Bulli seam disclosed He also indicating that its occurrence is more widespread. It occurs in more than trace proportions, sometimes hundreds of parts per million.

OTHER CONSIDERATIONS OF CONTAMINATION

Oxygen.

Fresh air contains 20.93% of oxygen (O₂) by volume, hence healthy mine atmospheres contain not much less oxygen than this figure. As coal of whatever rank tends to oxidise in air, the lower the coal rank generally the faster the oxidation; no free oxygen should occur in a coal in-situ. Any O₂ reported in seam gas analysis is likely to be from air entrained with the sample. Rather, coal surfaces no longer protected from air when seam gas emission ceases may be subject to oxidation, effecting a partial removal of O₂ from the air.

The only real source of O₂ underground is from battery charging stations which are generally in separate small circuits close to main intakes and returns. Some ozone (O₃) may be formed - converted from O₂ of air - in the vicinity of electrical equipment. Air discharges from compressed air machines, air movers etc., add incidental normal oxygen content air to working places.

Hence mine air should contain a maximum

of 20.93% O₂ and this figure may be reduced by about 0.21% for every 1% of diluent gas. With diluents CH₄ and CO₂ lying within statutory limits in working places, air should contain at least 20.5% O₂. More readily oxidisable lower rank coals may cause some further O₂ reduction.

Hydrogen.

H₂ has its main source underground from battery charging stations, normally separately ventilated. In examples of spontaneous combustion, treated in detail elsewhere, H₂ may occur also.

Spontaneous combustion and fire produces various other gases, the most important being CO because it is the mainly used indicator of occurrence and progress, to some extent CO₂, and also H₂O because of visual uses in detection. Aromatic hydrocarbons may be produced, and, dependent on the sulphur content of the coal, H₂S and Oxides of sulphur may be emitted. Fire and smoke is a final stage of Spontaneous Combustion of coal. In fires of most other materials in coal mines smoke is an important product, and gases dependent on the nature of the combustible.

Diesel Engines.

Although the use of the many diesel engines in Australian underground coal mines is closely controlled, including limiting sulphur content of fuels to minimise output of oxides of sulphur, and checking throttle openings (derating) to minimise output of carbon monoxide and carbon, nevertheless these and other gases do appear in the exhausts, and are partly controlled in the exhaust conditioning. Conditioners particularly remove soluble products and hence emissions to atmosphere are richer in less soluble N₂, presenting a small source of N₂ contamination. The volume of diesel exhausts to atmosphere is from 5.4 to 72 m³/KWH decreasing with speed and load. Typical average contaminant emissions in raw diesel exhaust are:

A. BRIGDEN, Gas Chemist, Department of Mines Laboratories, Sydney.

CO 0.8 to 2.2 gram/KWH

Hydrocarbons 0.13 to 0.8 gram/KWH

Oxides of N₂ 4.4 to 10.0 gram/KWH

Oxides of N₂ are highly soluble and CO may be catalytically converted to CO₂.

Eccleston et al (1981) provided typical figures of contaminant improvement, from which Table 1 was derived. No dramatic improvement appeared with oxides of N₂.

Other observations from the work of Eccleston et al (1981) are that:-

Concentration of Hydrocarbons does not change much with speed and load

Concentration of CO increases with speed and load

Concentration of CO₂ increases with speed and load

Concentration of Oxides of N₂ increases with speed and load

Concentration of Oxides of S increases with speed and load

Thus, an engine under high loads and exhausting, say 10m³/KWH could produce a conditioned exhaust comprising say 100 to 350ppm CO, 300 to 500ppm Oxides of N₂ and 50ppm of Oxides of Sulphur. Eccleston et al (1981) tested only direct injection engines; indications are that indirect injection engines could have provided better figures.

Dust is the most frequent contaminant

after seam gas. It is accepted that dust production is an inherent part of winning coal, primarily coal dust from the picking, drilling, shotfiring and machining of coal and of inducing coal to break under strata pressure. Dust is raised as it is produced, unless it can be suppressed at origin and dust is raised in the loading of coal heaps. Rock dust is also raised in some of these processes and in the caving of roof on extraction of coal - most noticeable in the advancing of longwall, etc., supports because of the proximity of the operator. As well as the relationship of dust in atmospheres to health, in extreme circumstances it also affects underground visibility, most apparent during the operations of stonedusting. The cure of dust problems at source has been attempted by water infusion of solid coal, both virgin coal and pillars, but with mixed success, (Commonwealth Coal Commission, 1946, Hargraves 1983). The places in which infusion was tried, in high rank Bulli Seam coal of low permeability and low maximum inherent moisture capability accepted negligible water into virgin coal (where water was infused to try to change the gas condition of the coal as much as to reduce dustiness) even at high pressures whilst in pillar coal more success but not great success was achieved. It appears that infusion, like suppression with water sprays, etc., is most

TABLE 1
CONTAMINANT REMOVAL BY SCRUBBER AND CATALYST

| Contaminant | From engine p.p.m. | From scrubber and catalyst p.p.m. |
|--------------------------|----------------------|-----------------------------------|
| Hydrocarbons | 58 | 32 |
| CO | 133 | 61 |
| Oxides of N ₂ | 1003 | 1026 |
| Oxides of S | 48 | 30 |
| Formaldehydes | 1 | 0.9 |
| and | | |
| Carbon particulates | 91 mg/m ³ | 66 mg/m ³ |

effective in those coals which need dust suppression less, lower rank coals with higher inherent moisture contents. The cure in deep environments with higher rank coals, whilst using the sharpest tools for machining to minimise coal dust production, still lies with laying by water sprays, etc., and diluting by ventilation and keeping operators upstream of dust producing areas as much as possible.

Australia has its own particular contaminants. In the bushfire season at times miners have been alarmed by the smell of bushfire smoke underground.

In one memorable attempt to establish the time for air to pass from the working face through tortuous returns to a proposed monitoring point way outbye close to an intake a mercaptan stench was used. Inadvertent spillage of some mercaptan near the working face resulted in a strike.

IDENTIFICATION AND ASSESSMENT OF CONTAMINANTS

It is not the purpose of this paper to outline the procedures and equipment available for the monitoring of contaminants, but, having listed the major contaminants, to acknowledge that monitoring is generally available. The earliest needs for monitoring concerned the purity of air and the earliest detection of spontaneous combustion. Now, no mine manager would be content without the fullest monitoring of as many contaminants as possible, at as many points as practically required and displayed in a control room, if not partly in his own office.

CONCLUSION

Present underground coal mining in Australia, concentrating on higher rank coals at moderate depths, probably experiences drier and potentially dustier environmental conditions than the average world situation. The high rank also leads to a gassier environment,

accentuated by the number of mines which suffer CO₂ seam gas. Historically the dust situation has been controlled adequately, as evidenced by an enviable pneumoconiosis record over the past 40 years. The prospect of deeper and gassier mining appears to be under control with recent CH₄ drainage installations in two mines, and extensive experimental work, including in CO₂ environments, being carried out in other mines.

REFERENCES

- Commonwealth Coal Commission, 1946. Abatement of coal dust in pillar workings by means of water infusion at low pressure. Govt. Printer, Sydney, 22pp.
- Dunmore, R., 1981. Prediction of gas emission from longwall faces. *The Mining Engineer*, London, February, pp.565-572.
- Eccleston, B.H., Seizinger, D.E., and Clingenpeel, J.M., 1981. Diesel exhaust emissions from engines for use in underground mines. Bartlesville Energy Technology Center, Bartlesville, Oklahoma - U.S. Dept. of Energy, DOE/BETC/RI-80/6, April, pp.42.
- Ettinger, I.L., 1969. Sorption conditions of working coal seams and their part in the process of gas emission into coal mines. Based on doctoral thesis in technical science in Division 311 - Underground development and exploitation of coal, metallic and non-metallic deposits - The Institute of Physical Sciences in the name of O.U. Schmidt. Moscow 36pp.
- Hargraves, A.J., 1958. Instantaneous outbursts of coal and gas. *Proc.Aust.Inst.Min.Metall.*, No.186, June, pp.21-72. (Summarised and translated into Spanish in AHMSA AVANTE, Nov./Dec., 1972. Jan./Feb., 1973, Monclova, Mexico).
- Hargraves, A.J., 1962. Gas in face coal. *Proc. Aust.Inst.Min.Metall.*, No.203, Sept., pp.7-43.
- Hargraves, A.J., 1963a. Some variations in the Bulli Seam. *Proc. Aust.Inst. Min. Metall.*, No. 208, Dec., pp.251-283.

- Hargraves, A.J., 1963b. Instantaneous outbursts of coal and gas. Ph.D. Thesis, The University of Sydney.
- Hargraves, A.J., 1966. Occurrence investigation and control of instantaneous outbursts in Australian mines, Proc. Int. Cong. on Instantaneous Outbursts, Leipzig, Oct.
- Hargraves, A.J., 1982. Background to seam gas drainage in Australia. Keynote Address. Symposium - Seam Gas Drainage with particular reference to the working seam. Ill. Branch, Aus.I.M.M., Wollongong, May.
Published in summary in Aus.I.M.M. Bulletin Nos. 466 and 467 Aug./Sept.
- Hargraves, A.J., 1983. Instantaneous outbursts of coal and gas - a review. Proc. Australas. Int.Min. Metall. No.285, March, p.1-37.
- Lidine, G.D., 1949. Factors determining tenor in firedamp in USSR Collieries. Tome 1. Trans. USSR Acad. Sc.
- McCulloch, C.M., and Diamond, W.P., 1976. Inexpensive method helps predict methane content of coal beds. Coal Age. June, pp.102-106.
- Smith, J.W., and Gould, K.W., 1980. An isotopic study of the role of carbon dioxide in outbursts in coal mines. J. Geochem., 14.27-32.

DISCUSSION

M. CARR (Department of Industrial Relations): The paper went to some length, but perhaps not enough, speaking about these figures from the Bureau of Mines gas analyses. Recent information received from the Department of Mines Chemical Laboratory is that oxides of nitrogen are not soluble; the paper says oxides of nitrogen are highly soluble. What is the position with oxides of nitrogen in regard to their solubility or otherwise?

A.J. HARGRAVES (Hargraves Mining Engineering Pty. Ltd): Certainly the N_2O_5 and the N_2O_3 as forming nitric and nitrous acids must be very soluble but the comparative solubilities of the N_2O and NO are not known - possibly N_2O_4 is highly soluble also. Perhaps Mr. Barnes can comment.

M.J. BARNES (Coke Ovens Laboratory, Australian Iron and Steel): The various oxides of nitrogen are referred to in the literature. However specific values are only given for N_2O (130 cc/100 cc H_2O @ $0^\circ C$ - 59 cc/100 cc H_2O @ $25^\circ C$) and NO (7.4 cc/100 cc @ $0^\circ C$). The only statement about NO_2 , N_2O_3 and N_2O_5 is that they are soluble.

If the dramatic reduction in solubility of N_2O over a temperature increase from $0^\circ C$ to $25^\circ C$ is of any indication, one might expect the other solubilities to similarly drop. Hot exhaust gases forcing through a hot water scrubber would tend to carry oxides of nitrogen to the atmosphere.

A.J. HARGRAVES: Table 1 is not a transcription from the Bureau of Mines paper but is derived from their paper. It would appear with the oxides of nitrogen having passed through the scrubber that they were not taken out by the scrubber fluids which would be a minimal

solubility, which does not seem right.

B. HAM (M.I.M. Holdings Ltd.): At Collinsville there is a somewhat morbid interest in this H_2S problem. In fact it appears to be raising its ugly head one more time and so it is of interest. More elaborate details on that work done up in the Cessnock area in the Greta Seam, would be useful, some of the circumstances and the approaches used in seam gas drainage and how it relates to either the current ideas of gas drainage practice that are really being applied to outburst areas.

A.J. HARGRAVES: That work by Stewart (1966) is documented well. There are two particularly good figures in his paper, which were reproduced in the 1982 Seam Gas Drainage Symposium (Hargraves 1982). The situation was that a lower portion of the Greta Seam was being mined and there was a dirt band either in or close to the roof and that it was necessary not only to release the H_2S from the coal ahead of the development but also above the working roofline and the holes were drilled ahead and angled upwards through the dirt band into the top of the seam; maybe the top of the seam had more sulphur than the rest because Greta Seam tops are invariably brassy. It was a very simple installation, the gas was exhausted through infusion type mechanical seals in the holes through galvanised pipes to an exhaust pump close to the return and discharged into the return. The return probably was a shaft with an exhaust fan on the top, part of the main ventilation, not a separate installation. No figures are available off hand but Stewart's paper is commended to you.

C. JEGER (Cerchar Laboratories, C. de F. Verneuil, France): Talking about He as a

precursor of outbursts, in France the concentration of He was measured in firedamp flowing from a borehole drilled in front of a heading as a possible precursor. First it was checked whether this concentration was sufficiently stable at the same place and not too much depending on the duration of drilling of the borehole and on the time elapsed from the end of drilling to the taking of the sample. Unfortunately it was observed that the concentrations of He in several samples were very different depending upon this time. The concentrations of He in the issuing gas decreased in a few minutes after drilling and did not become stable after a longer time. So He concentration cannot be a reliable measurement. Please comment on that.

A.J. HARGRAVES: No studies have been done here in regard to changing composition of He with time. Barnes has mentioned examples of analysis only. Talking about other gases than He, Australia has very many instances, as does France, where CO_2 and CH_4 occur together as they issue from the coal. It has been found here, and no doubt this would be found in France also, that with the passage of time the composition of the mixed gas changes. To what extent this is due to different molecular sizes or viscosities or differing relative chemical

reactivity of the component gases with the coal is not known. There are a number of factors and certainly the composition does change with time and this has been documented in a number of instances commencing in 1963 (Hargraves, 1963b) and it's one aspect of seam gas emissions still under examination.

Taking this matter a little further, not only does the chemical composition of the gas change with the passage of time but the isotopic composition of the carbon in the respective gases changes with time. There are a lot of unknowns about seam gas emission and it is useful that Barnes, deeply involved in seam gas analysis in the Illawarra, is geared to measure He whenever he wishes. It would be useful to pursue these matters in collaboration, but in the meantime the figures of "partitioning" of mixed gases in seam gas emission, apparently with the coal somewhat as a chromatographic column holding some gases back will be forwarded to Dr. Jeger. It appears that He has its own pattern of composition change in mixed gas issuing.

REFERENCE

Stewart, I. McC., 1966. "Gas emission into mine workings" Paper No. 46, Symposium on "Seam Gases in Coal Mines", Dept. of Mining Engineering, Uni of Sydney, March, pp. 4a/1-11.