AVAILABLE DEFENCES AGAINST OUTBURSTS IN THE UNITED KINGDOM IN 1980

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ABSTRACT

The paper considers the nature of outbursts of coal and firedamp as they occur. It follows the development of methods of working used to try and induce outbursts safely under controlled conditions and details the life support systems used to provide maximum protection to persons who may be affected by spontaneous outbursts.

THE NATURE OF OUTBURSTS IN THE UNITED KINGDOM

Only some areas in the coalfields of the United Kingdom are affected by outbursts of coal and firedamp. The main area affected is the western end of the Anthracite coalfield in West Wales. In this area 206 outbursts have been recorded resulting in the loss of 28 lives.

Anthracite is a high rank coal produced by the geological effects of age, depth and dynamic metamorphism. Outbursts have been experienced over a wide area of the anthracite field but have been most frequent, and most severe, in the areas where carbon content is at its highest and where the coal measures have been subjected to the highest degree of faulting and overthrusting. Most outbursts are associated with geological abnormalities and the coal ejected during outbursts is usually of a soft and powdery nature.

The stresses which are present due to geological thrusting before an outburst occurs are compounded by the stresses that are produced by mining excavations and the interaction of the inherent and induced stresses forms part of the triggering mechanism of an outburst. Therefore strata control is an important feature in the outburst phenomena.

Outbursts of coal and firedamp have also occurred in certain parts of the Scottish coalfield but these have a different cause (THOMAS 1976). These occur when headings or workings enter areas of burnt coal associated with igneous Whin Dyke intrusions. The altered coal is ejected violently accompanied by large volumes of methane. This type of outburst is less frequent and less violent in nature than the anthracite outbursts but the defences used are similar but less comprehensive.

A typical outburst in the anthracite area of West Wales follows a period of difficulty with strata control and is usually preceded by a characteristic warning noise associated with the release of energy, known locally as 'pouncing' and is compared with the noise of a two-stroke engine. Simultaneously, or immediately afterwards, firedamp is released from the seam together with ejected coal, usually finely powdered, and accompanied with varying degrees of violence. Outbursts have been known to produce up to 110,000 m^3 of firedamp and up to 1,000 tonnes of fine coal. The nature of the coal produced in outbursts often requires its removal in sealed bags.

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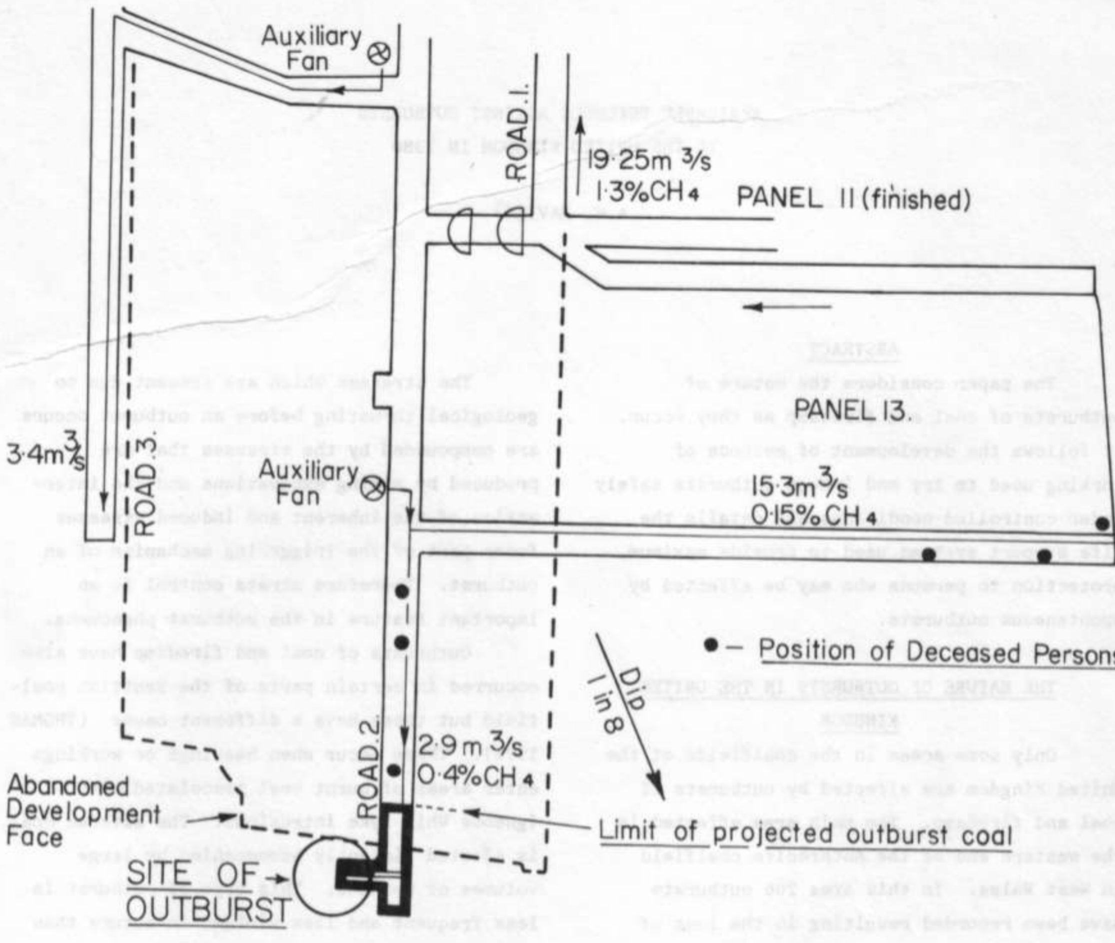

Fig. 1 - The Cynheidre Outburst of 1971. Plan of the parts affected.

The cavities found after outbursts are comparatively small and cannot be related to the volumes of coal and gas produced.

The dangers to persons in an outburst situation are threefold. Persons in the immediate vicinity can be knocked down by the violence of the material ejected and can be engulfed by the fine powdery coal. Persons who may have escaped the ejected coal can be overcome due to oxygen deficiency when the large volumes of firedamp overtake them. Thirdly the explosive fringe of gas which is pushed ahead of the plug of firedamp can be ignited if there is an incendive source and can cause an explosion.

The worst outburst in anthracite coal occurred at Cynheidre Mine in West Wales in 1971 and resulted in the death of six persons. Sixty nine others suffered varying degrees of asphyxia (MARSHALL 1971). A thick seam of anthracite was being worked which had an analysis of 90% carbon and 6% volatiles. Figure 1 shows the layout of the part of the mine affected. A longwall panel, No. 13, was being worked successfully by mechanical means and was producing a gross output of 12,200 tonnes per week.

A cross-cut development drivage was being driven on the intake and dip side of the longwall face to further the development of the seam. The cross-cut drivage was in the abutment pressure zone of a previously abandoned longwall development face which had advanced to the dip. This cross-cut had been advanced 15 m when the outburst occurred. Three men were cleaning up loose coal in the heading in preparation for setting an arched support when the outburst overwhelmed the forcing ventilation system which delivered 3 m^3/s to the face of the heading. The men escaped the ejected coal but were overcome by the oxygen deficiency and died as they tried to escape up the heading. The plug of rich firedamp passed out of the heading and along the intake panel of 13 longwall face where 25 persons were rendered unconscious. Three of them did not recover and a further 44 persons were affected at positions further outbye in the ventilating circuit. Four hundred tonnes of fine outburst coal had been ejected in the cross-cut heading and temperatures of up to 60°C were found in this material. About 60,000 m^3 of firedamp was released in the first seven hours of the outburst.

The report on the causes of and circumstances attending the Cynheidre Outburst made by Mr J S Marshall, who was then HM Divisional Inspector of Mines and Quarries, South Wales, contained far reaching recommendations. These recommendations were subsequently put into effect under the guidance of the Joint Advisory Committee on Outburst of Coal and Firedamp which exists in West Wales under the Chairmanship of HM Inspectorate of Mines and Quarries and contains representatives of management, industrial scientists, rescue specialists and the three Unions in the mining industry. As a result the defences available against outbursts were considerably strengthened (DAVIES and JENKINS 1978).

DEALING WITH THE OUTBURST PHENOMENON

Outbursts in the anthracite field increased in frequency as the workings exceeded some 200 m in depth early in the century. It was realised at an early stage that shotfiring often acted as a trigger to start an outburst and this lead to shotfiring being used as a defence against outbursts. It was also realised, following serious incidents, that the use of percussive tools, such as pneumatic picks, in coal getting could trigger an outburst. The importance of the methods of work that were used became evident as they produced different patterns of strata pressures and these were related to the induction of outbursts. The importance of ventilation layout became increasingly clear as the effects of plugs of firedamp travelling the workings were observed.

The defences against outbursts developed along two lines. The first aspect was to develop methods of work that would lead to outbursts being induced under controlled conditions when the minimum number of persons would be at risk. Various forms of shotfiring became the first defence against outbursts, together with other controls over the choice of methods of work and ventilation practice. These special methods of work will be described later.

The intention was that as many outbursts as possible would be induced under controlled and known conditions using shotfiring methods as a trigger. It was always realised however, that even with the most effective induction techniques, spontaneous outbursts could and would still occur. The proportion of outbursts that had been induced rather than those that have occurred spontaneously has improved over the years, but the historical position is shown in the following table:- (WILLIAMS and MORRIS 1972).

OUTBURSTS IN WEST WALES 1961 - 1980

TOTAL	TYPE		LOCUS	
	SPONTANEOUS	INDUCED	LONGWALL	NARROW WORK
100	28	72	39	61

It can be seen that 61% of all outbursts in this period occurred in narrow headings and the remainder on longwall faces. Seventy two percent were induced but 28 were spontaneous, representing a high risk to those employed and calling for the highest degree of protection for those persons who were exposed to the hazard.

To protect against the hazard from spontaneous outbursts life support systems were required. The first requirement was for a high quality communication system incorporating outburst alarms that could be operated and transmitted automatically when a spontaneous outburst was developing. The other requirement was for the provision of breathing stations or self contained breathing apparatus for use in the circumstances of a spontaneous outburst and for the protection of persons involved in inducer shotfiring.

These defences have been written into Codes of Precautions from time to time and the latest consolidation and revision of the Code was in 1974 (National Coal Board 1974). The continuing development of defences against outbursts has already outstripped the latest edition of the Code and already there are important precautions which are not included in the latest edition.

Considerable efforts continue to be made by industrial scientists and academic and research institutions in the United Kingdom to try and obtain a better understanding of the nature and mechanism of outbursts but these are not dealt with in this paper. The main defensive mechanism against outbursts remains the attempt to induce outbursts under controlled conditions by shotfiring and reduce the incidence of spontaneous outbursts. No alternative triggering mechanism, other than shotfiring, has so far been found.

DEFENCES AVAILABLE BY CONTROL OF METHODS OF WORK

Sequence of Seam Extraction and Advantages of Longwall Working. Figures already quoted show that narrow working in coal seams presents the greatest hazard. Outburst Codes therefore provide that production must be from longwall faces. If a series of seams are to be extracted the seams least liable to outburst should be worked first to allow as much methane to be released from the strata as possible before the difficult outburst prone seams are worked. Headings can only be driven in order to open up longwall faces. Longwall faces do present an outburst hazard particularly at the corners. The more acute the corner the greater is the likelihood of an outburst if geological overthrusts are encountered, and corners should be kept to right angles. One of the advantages of longwall working is that means of escape is easier and a good travelling way should be maintained along the longwall face. Ventilation is less likely to be overcome by an outburst on the longwall face than in a heading. If headings are required on the intake end of longwall faces for any reason, then work should not be allowed on the longwall face at the same time.

Percussive machines are only allowed for drilling stone in rippings. Pneumatic picks for coal getting are prohibited. All mineral getting must be by shotfiring in headings and this precludes the use of heading machines such as Dosco Roadheaders or Dintheaders. Longwall faces can be mechanised but machines such as shearers cannot be allowed to cut into the rib at longwall face ends as this action is likely to induce an outburst. All longwall face ends must be subject to shotfiring as a precautionary measure and the power loader can only be used to clean up and fill the coal loosened by shotfiring.

In all headings the method of work described must be designed so that a complete cycle of work can be completed within a shift. This requirement of the Outburst Code is designed to secure the best roof control. If a heading is left excavated but unsupported, roof control will deteriorate and this could be the first step leading to an outburst.

A further requirement in headings is that a stone ripping should be taken with a seam in development headings. The only headings allowed to be driven in coal only are those being driven to open the longwall face itself. It is considered that these headings have to follow the seam roof as it would be difficult to start a longwall face with powered supports if the heading had been formed with a roof ripping. The advantage of taking a stone ripping are two fold. The effect of some of the shotholes being positioned in stone is that the total round can carry a higher explosive charge and the shock effect on firing is larger and more likely to induce an incipient outburst. The other advantage is that roof control is improved. Headings in coal, especially if the coal becomes weak and friable as is usually the case in outburst prone conditions, tend to run forward with loss of roof control. The carrying of a roof ripping is very effective in counteracting this tendency.

Despite the precautions described roof control can be lost in headings. Outburst conditions are often accompanied by very friable and weak coal which spalls away from the face and sides of a heading and defies support. The result is that the face and/or sides run forward leaving a large area of roof and sides unsupported beyond the last permanent support, and throwing forward and increasing the forward abutment pressures. Often a geological disturbance will accompany this condition and the roof of the heading will rise in the direction of advance and become friable and start falling. The coal may become so soft that drilling is not possible and inducer shotfiring cannot be done. The coal can be filled out by shovel without any blasting or digging. These are highly dangerous and difficult conditions and signal the imminence of an outburst. The development of these conditions is shown in Figure 2. It is most important that these conditions be recognised before they erupt in an outburst and to try and ensure this the manager of Cynheidre Mine is required to report to the Joint Advisory Committee if any round of shots fired in a heading produces a face advance of 50% more than that intended by the round. When this condition arises in a heading the only option open may be the shoring up of the face of the suspect heading and in-filling with cement/vermiculite/bentonite mixtures as shown in Stage 3 of Figure 2. This can be a slow process but where it has been applied outbursts have been avoided and inducer firing has been possible in the in-fill material which forms the face of the treated headings.

Headings driven in stone are not considered to be an outburst risk but if a heading is about to enter a coal seam the outburst risk can be at its highest. To protect against the possibility of a stone heading entering a coal seam inadvertently, the Outburst Code requires advance boring to be done to ensure that a warning is given of the nearness of a coal seam. When the position of a seam is known the shotfiring pattern must

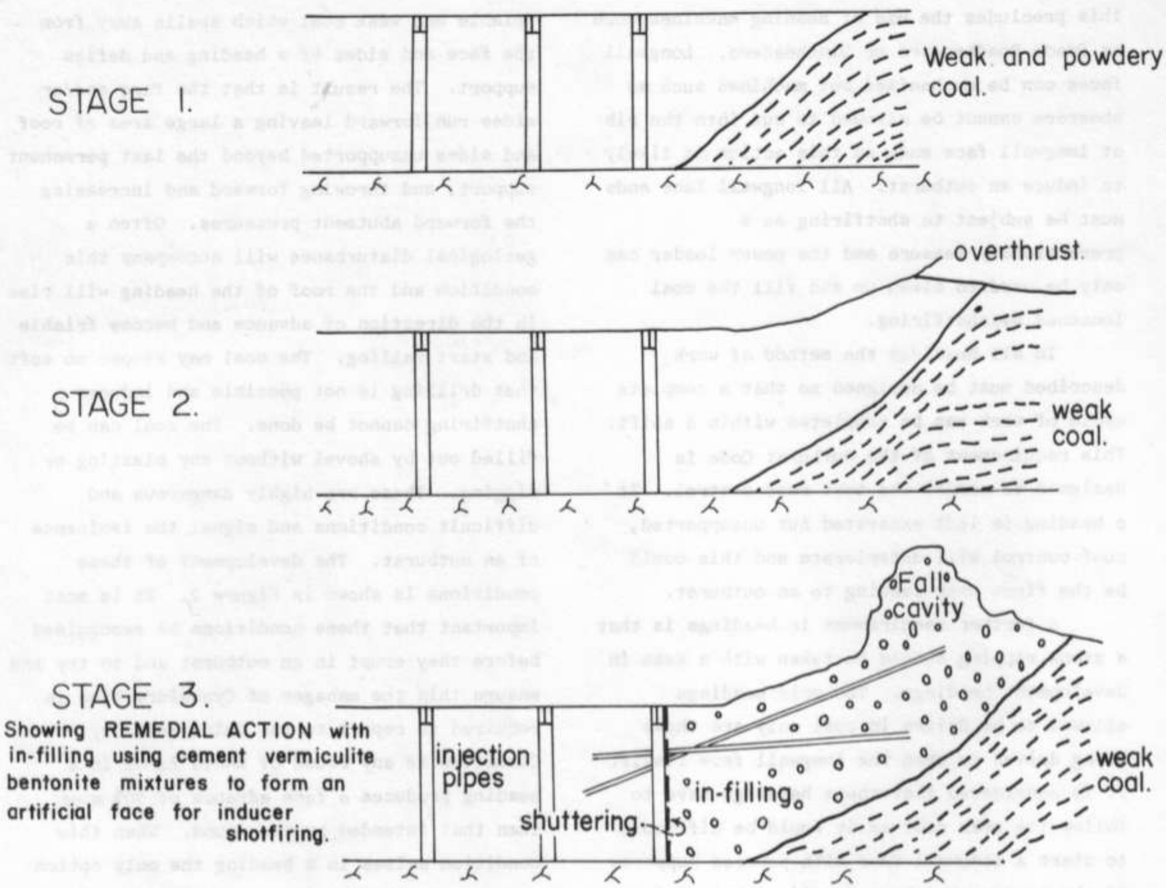

Fig. 2 - Stages in the Development of Outburst Prone Conditions

be designed to break into the seam over the full face of the heading if possible. Experience has shown that outbursts often occur as a seam is being entered and if a thin skin of stone separates a heading face from an outburst prone seam the condition can be dangerous. Similar precautions are prescribed when shafts being sunk are approaching coal seams.

DEFENCES AVAILABLE BY SHOTFIRING TECHNIQUES

As stated shotfiring remains the main defence against spontaneous outbursts and the aim of shotfiring techniques is to induce as many outbursts as possible under controlled conditions. All mineral must be got by shot-firing but the conditions prescribed for shotfiring vary in accordance with the degree of hazard. The most onerous shotfiring requirements apply to headings in coal, and headings approaching coal seams are treated in the same way. The other important hazard exists at the corner of longwall faces and shotfiring must be done between each production shift at these locations. In certain conditions, when an outburst risk is indicated on the general length of a longwall face, shotfiring is prescribed. These circumstances will be described separately.

Inducer Firing in Headings

All headings must be got by full round firing and no persons are allowed on the return side of the heading being fired. This means that all the returns must be clear to the surface and a controller on the surface ensures that this condition is satisfied before firing is allowed.

The number engaging in shotfiring in a heading is limited to three and the shotfiring station must be at least 200 m from the face and on the intake side of the forcing auxiliary fan outside the heading. The shotfiring station must be equipped with a telephone, a loudspeaker communication unit, an airline breathing station and a notice designating the station. The post-firing examination is made 20 minutes after firing and the persons making it must examine for firedamp at 50 m intervals as they enter the heading. The result of the post firing examination is communicated to the surface controller before any persons are allowed to enter the return roadways that could be affected.

Normally P4/5 explosives and Carrick delay detonators are used for inducer firing but in some harder rock conditions P3 explosives have been used.

Precautionary Firing at Longwall Face Ends

A shotfirer was killed when shotfiring at a longwall face end when he was engulfed by an outburst. A similar situation resulted in the death of an official at a mine in Colorado in 1977 but in that case a shearer was cutting into the longwall face end. Precautionary firing was established in the Code of Practice with a view to inducing outbursts that may be incipient at longwall face corners at a time when persons are not exposed to risk.

This practice is now combined with the work of preparing machine stables on power loaded faces, but if machine stables are not maintained, precautionary firing still has to be done systematically. The shotfiring must take place over a distance of 2.5 m. The depth of machine stables, where they are used, is not allowed to exceed 2 m plus the depth of one round of shots, otherwise they would have the same risks as headings. Precautionary firing must be practised even though the face may be equipped with a shearer that can load to the face end.

The layout of precautionary firing on a longwall face is shown in Figure 3. The firing is done between production shifts. Persons are withdrawn from the return side of the round being fired for the length of the district return as far as the next split, but not to the surface. The shotfiring station must be 200m on the intake side of the place being fired and the firing station is equipped with a loud-speaker communication unit and an airline breathing apparatus.

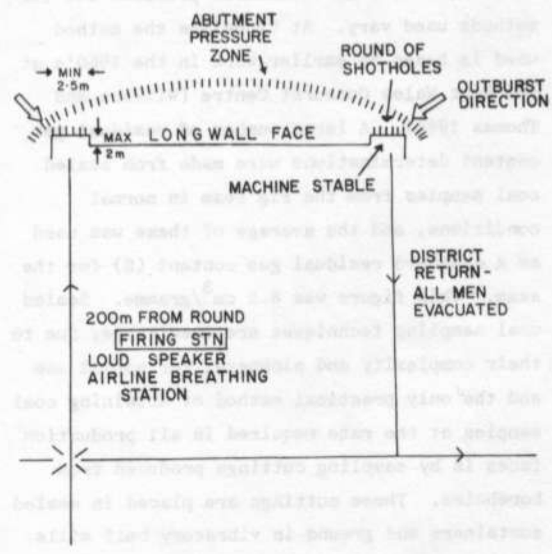

Fig. 3 - Layout for Precautionary Firing

Present proposals are to fire precautionary rounds together with the ripping at that end of the face. The full shotfiring precautions associated with firing in headings would be adopted with all returns empty of men to the surface and the operation would be controlled by the surface controller.

Volley Firing on Longwall Faces

If the nature of the coal at any part of the longwall face indicates that there may be an outburst risk the face is shotfired for a length extending to 10 m on each side of the affected area. Desorption ratios are calculated systematically on longwall faces and if these exceed 4 this is considered to indicate an outburst risk and the details are reported immediately to the manager of the mine for action to be taken. This type of firing is usually done using instantaneous detonators to maximise the shock to the strata as coal preparation is not a consideration. All returns are empty of men to the surface and the other precautions are similar to heading firing.

Desorption ratios have been used in most countries which have outburst problems but the methods used vary. At Cynheidre the method used is based on earlier work in the 1960's at the West Wales Outburst Centre (Withers and Thomas 1966). A large number of residual gas content determinations were made from sealed coal samples from the Big Seam in normal conditions, and the average of these was used as a standard residual gas content (S) for the seam. This figure was 8.5 cm^3/gramme. Sealed coal sampling techniques are unsuitable, due to their complexity and slowness, for normal use and the only practical method of obtaining coal samples at the rate required in all production faces is by sampling cuttings produced from boreholes. These cuttings are placed in sealed containers and ground in vibratory ball mills at the Outburst Centre. The gas released gives a desorption value (U) in cm^3/gramme. The desorption ratio is given by:-

$$\frac{S}{U} \quad \text{or} \quad \frac{8.5\ cm^3/\text{gramme}}{U\ cm^3/\text{gramme}}$$

Boreholes are maintained 12 m in advance of the face line at the face ends and in the middle of longwall faces and the holes are sampled at 3 m intervals. Experience has shown that if the ratio exceeds 4 there is a liability to outbursts and the Code requires the manager of the mine to institute volley firing on that part of the face.

DEFENCES AVAILABLE BY SELECTION OF VENTILATION METHODS

Longwall faces must have unit ventilation. Any outburst occurring on the face should then have the effects confined to that unit and the return from the unit.

Auxiliary fans used to ventilate headings could easily be overwhelmed if used in the exhaust mode on the return side of a heading. Forcing ventilation is therefore prescribed in the Outburst Code for all headings.

The return air from each heading is not allowed to pass to another face or another heading. Three of the persons killed in the 1971 disaster were on the longwall face when the products of the outburst passed from the development heading which was on the intake side of the face. Many more could have died if the oxygen deficiency had persisted for a few minutes longer.

When the rule in the last paragraph is applied a severe restriction is placed on the way development can be done at the mine. It is often necessary to drive a pair of development headings together, and to avoid passing return air from the first heading to the second, steel ventilation tubes have been used to conduct the return air from the first development heading direct into the main return. Reverse ventilation doors or dams have been used in

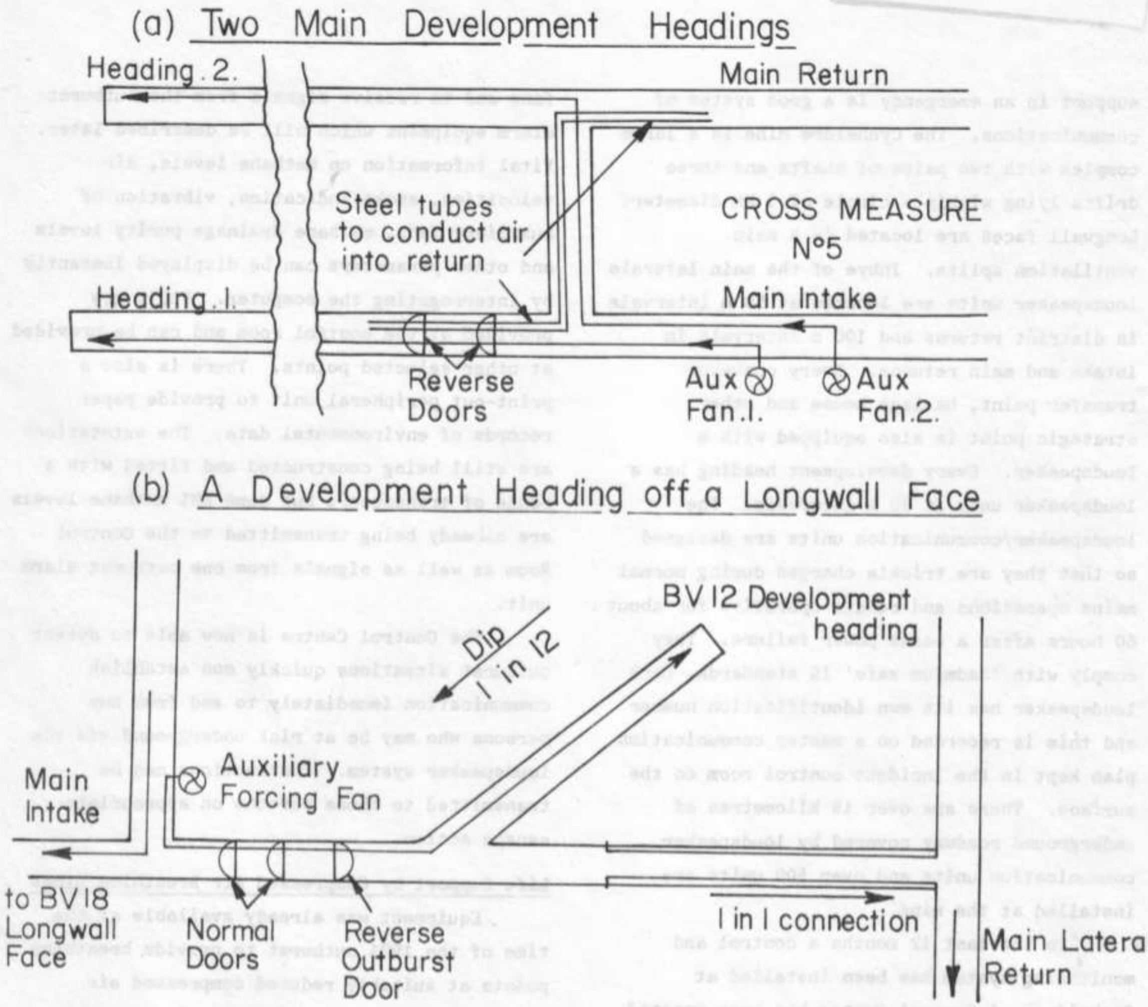

Fig. 4 - Examples of Unit Ventilation of Headings and Use of Reverse Doors

headings and roadways with a view to providing a restriction for the development of an outburst and forcing the firedamp produced into the return. This arrangement is illustrated in Figure 4(a).

Where there is a possibility of the products of an outburst induced by a round of shots fouling the intake of another nearby ventilation split, reverse ventilation doors have also been used to protect that split. Men may still be employed in the other split during shotfiring although the return from the heading will have been evacuated to the surface. An example of the way a reverse door was used to protect an adjacent intake split is shown in Figure 4(b).

The Outburst Code requires electricity to be switched off before shotfiring operations take place to reduce the possibility of an ignition source being present should explosive mixtures of gas be released by the shotfiring.

LIFE SUPPORT IN THE EVENT OF A SPONTANEOUS OUTBURST

Communications

The first requirement for effective life support in an emergency is a good system of communications. The Cynheidre Mine is a large complex with two pairs of shafts and three drifts lying within a circle of 5 km diameter. Longwall faces are located in 4 main ventilation splits. Inbye of the main laterals loudspeaker units are located at 50 m intervals in district returns and 100 m intervals in intake and main returns. Every conveyor transfer point, haulage house and other strategic point is also equipped with a loudspeaker. Every development heading has a loudspeaker unit at 50 m intervals. The loudspeaker/communication units are designed so that they are trickle charged during normal mains operations and remain operative for about 60 hours after a mains power failure. They comply with 'cadmium safe' IS standards. Each loudspeaker has its own identification number and this is recorded on a master communication plan kept in the incident control room on the surface. There are over 19 kilometres of underground roadway covered by loudspeaker communication units and over 500 units are installed at the mine.

In the last 12 months a control and monitoring system has been installed at Cynheidre. A Control Centre has been erected near the main shafts. The open-speech loudspeaker systems described in the last paragraph are all channelled to the Control Centre. The Centre also houses the exclusive mine telephone system, which is also to 'cadmium safe' IS standards, and is coupled to the GPO network.

The Control Centre also houses a Minic 'Type M' on-line computer supplied by Messrs Transmitton Limited. The central computer is connected to underground monitoring outstations by 4-core cables and information is transferred by the TM 101 Data Transmission System which is a digital time-division multiplex arrangement. The Computer is to be used exclusively for monitoring of the environment and auxiliary fans and to receive signals from the outburst alarm equipment which will be described later. Vital information on methane levels, air velocities, smoke indication, vibration of auxiliary fans, methane drainage purity levels and other parameters can be displayed instantly by interrogating the computer. VDU's are provided at the control room and can be provided at other selected points. There is also a print-out peripheral unit to provide paper records of environmental data. The outstations are still being constructed and fitted with a range of transducers but some BM1 methane levels are already being transmitted to the Control Room as well as signals from one outburst alarm unit.

The Control Centre is now able to detect outburst situations quickly and establish communication immediately to and from any persons who may be at risk underground via the loudspeaker system. Instructions can be transmitted to those persons on appropriate escape action.

<u>Life Support by Compressed Air Breathing Lines</u>

Equipment was already available at the time of the 1971 outburst to provide breathing points at suitably reduced compressed air pressures and provide filtered air from the colliery compressed air mains. Compressed air mains were laid in most roadways at Cynheidre Mine and were fed from surface compressors.

Equipment modified to suit Cynheidre conditions was obtained and installed. The units consist of reducing and filtration units which are connected by hoses to banks of 4 or 8 breathing points, each containing a valve which is operated when a short hose is pulled out of a retaining box. The air is played into a safety helmet and the person breathes from the helmet. The quality of the air is checked weekly by sampling.

The use of compressed air breathing lines is controlled by the Code of Precautions 1974.

Breathing stations must be provided at 50 m intervals in headings and return gates of longwall faces and at 100 m intervals in intake gates of longwall faces. They are also provided at places where persons normally work in main returns and at shotfiring stations. Breathing stations are equipped with reflective indicators showing their positions and with loudspeaker communications.

The possible difficulty of finding a breathing station in the dusty environmental conditions following an outburst has been recognised and efforts are being directed to providing a distinct audible signal through the loudspeaker at each breathing station to indicate its position in situations of low visibility.

Life Support by Individually Carried Escape Breathing Apparatus

Following the 1971 disaster it was recommended that an individually carried escape breathing apparatus should be developed suitable for escape conditions. The original intention was that the apparatus should be an oxygen self-contained and rechargeable set which would be of the order of size of the present self-rescuer. An escape set was developed over the ensuing years but its size was much larger than hoped for because the oxygen demands of a fit person escaping in a state of panic from an outburst are very large - larger than the demands of a trained rescue brigadesman engaged in rescue duties.

A search was made for readily available escape sets while a custom designed set was being developed. The Russian Sh S7 sets and the German Auer SSR16BB sets were available and supplies were secured. These were introduced for workmen employed in headings, who were at greatest risk, under Special Regulations issued by HM Inspectorate of Mines and Quarries. The method of use was to store them for one month intervals at the entrance to headings and remove them to the surface for immersion tests once per month. Each man entering the heading would take one with him and hang it on a peg board about 30 m from the face. A man at the face on hearing the signs of an outburst would turn and run. His thoughts would be more orderly by the time he passed the peg board at 30 m and he was trained to grab his escape set and put it on either when running or pausing to do so. Both the Russian and the German sets were Chemical Oxygen sets.

Chemical Oxygen sets have severe limitations in the escape situation. They are sealed sets and due to the cost and availability no live training could be given. Men were trained on dummy sets only and could not be given the feel of the apparatus when breathing oxygen. Chemical sets cannot respond to high oxygen demand by the wearer. Training tried to instil in the men the need to walk rather than run, but in the real panic situation the wearer could make excessive demands on the sets and find himself in difficulties. Chemical sets have very high inhalation temperatures. Training tried to prepare the wearers for this sensation but it could not be demonstrated due to lack of live training. Chemical sets are hermetically sealed and maintenance and examination procedures have to be confined to immersion tests.

Efforts to design and produce a self-contained oxygen rechargeable escape set continued from 1971 to 1977 and eventually a design was agreed and production models made by a Swedish firm. The Aga set now carried by all men employed in headings at Cynheidre provides all the oxygen required in the escape situation. The set weighs 5.9 Kg and has a minimum duration of 30 minutes. It is in effect a minature self-contained breathing apparatus with a demand valve which ensures adequate oxygen supply in the special circumstances of escape duty. The sets are used in a similar

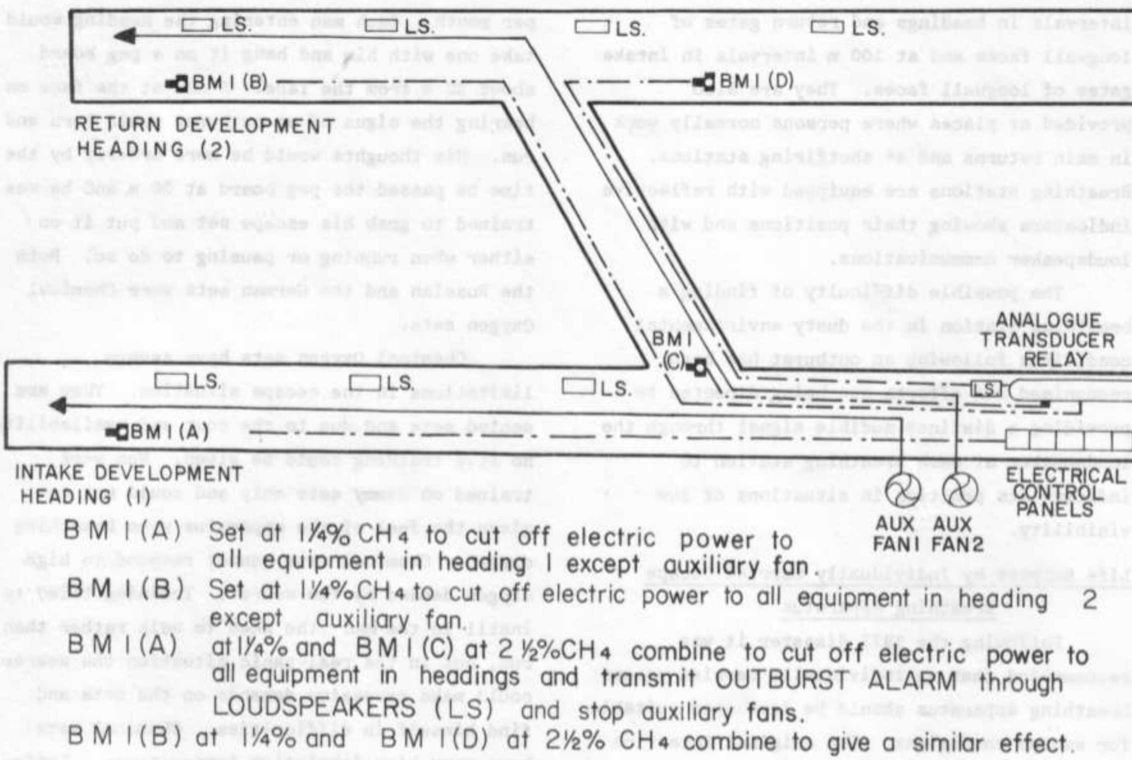

Fig. 5 - Use of Four BM1 Instruments and Analogue Transducer Relay to Give Outburst Alarm for Two Development Headings

way to that described for Chemical sets and are examined and maintained at monthly intervals by the National Coal Board Rescue Service. Some 600 men at Cynheidre have been trained in their use and they have been in regular use for over a year. They provide a second line of defence for men employed in the higher risk areas of headings, and have none of the disadvantages of Chemical Oxygen sets.

The Automatic Outburst Alarm

Continuous monitoring methanometers (BM1) had been used in increasing numbers at Cynheidre since 1973. Whenever electricity is used in headings a detector head from a BM1 is located over the item of electrical equipment which is furthest inbye and so arranged to cut off power if the methane level reaches 1¼%.

In 1976 equipment became available that could be combined with two BM1 instruments to provide an outburst alarm. This item was an Analogue Transducer Relay Unit which was extended by the addition of an electronic trigger switch which receives signals from the two BM1's.

The arrangement of 4 BM1 units to cover two headings was developed and installed by the Electrical Engineer at Cynheidre Mine and is illustrated in Figure 5. The BM1's situated in the headings are set at 1¼% methane and a signal from them will isolate all power to the heading affected, but will leave the auxiliary fan running. The BM1 bleep, which is broadcast through the loudspeaker system, will change from the 15 sec interval (healthy state) to a 1 second interval. The sensing heads of the second BM1's are located in the main air current outside the headings and are set to give a signal at 2.5% methane. If this percentage of methane arrives in the general body outside the heading, then it is certain that an outburst is happening or is imminent, and when the signal is fed to the Analogue Transducer Relay Unit the auxiliary fans are stopped so that the methane produced in the heading is not pushed out to the return faster than it would arrive naturally, and all power is shut off. This gives the men in the return more time to make their escape.

At the same time a distinctive outburst alarm is broadcast over the loudspeaker systems, which remain powered by a separate IS battery source. The men have been trained by means of a tape recorder to recognise the outburst alarm and resort to life support equipment promptly. The outburst alarm is generated by a 12 volt supply to a tone generator whose output signal is fed to an amplifying unit and broadcasts a superimposed note over the one second bleep of the BM1. This superimposition of a continuous tone of one frequency over an intermittent tone of another frequency produces a distinctive and strident warbling sound.

This outburst alarm equipment developed at Cynheidre Mine was subsequently certified intrinsically safe and is now manufactured commercially. The signals can now be transmitted to the surface Control Centre via the outstations linked to the central computer. The outburst alarm is received at the Control Centre as it is given underground and control of the emergency situation can be assumed by the Control Centre immediately.

Defences against outbursts have been progressively developed since the phenonenon was first noted at the beginning of the century. The disaster of 1971 gave added urgency to the development of these defences. Indications of some success in the United Kingdom are that no spontaneous outbursts occurred during 1979 and no lives have been lost in outbursts since 1971.

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REFERENCES

THOMAS, M.G., 1977: Health and Safety, Mines and Quarries, 1976, Scottish District para 83. London HMSO ISBN 0 11 8820052.

MARSHALL, J.S., 1971: Department of Trade and Industry. Outburst of Coal and Firedamp at Cynheidre/Pentremawr Colliery, Carmarthen. Report on ... 1971 London HMSO 22 pages Cmnd 4804.

DAVIES, A.W. and JENKINS, C.B., 1978: Precautions against Outbursts. The Mining Engineer Vol. 138 No. 205.

WILLIAMS, R. and MORRIS, I.H., 1972: Emissions and Outbursts in Coal Mining. Symposium Paper No. 11. Symposium on Environmental Engineering in Coal Mining, Harrogate. October-November 1972 London IME pp 101 - 116.

NATIONAL COAL BOARD, 1974: Cynheidre Mine. Outburst of Coal and Firedamp. Code of Precautions 1974. The Board 32 pages.

WITHERS, A.G. and THOMAS, D.A., 1967: An Account of Current Investigations into the Problem of Outbursts of Coal and Gas in the West Wales Anthracite Area. The Mining Engineer No. 79, 126 April 493 - 509.