PREVENTION AND SUPPRESSION OF GAS EXPLOSIONS IN MINES

By

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ABSTRACT

Since 1958 there have been 16 major coal mine explosions in the U.S. claiming 323 lives. Whilst the exact cause of a number of these incidents has not been determined, the majority has involved gas ignitions in one way or another. In addition there have been fatal gas explosions in salt mines and vapor explosions in oil mines. Furthermore, many of the oil shale mines in the U.S. have proven to be gassy giving cause for concern. Compounding these problems is the fact that frictional ignition of methane in coal mines has dramatically increased over the past several years; over 100 such ignitions were reported in 1979. While no fatalities have been attributed to frictional ignition in the U.S. since early 1978, a recent mine explosion in Nova Scotia which resulted in 11 fatalities was attributed to a frictional face ignition.

Research being conducted at the Bureau of Mines is aimed at the prevention and suppression of gas explosions. Emphasis is placed on new coal cutter bits for reducing ignition frequency, machine-mounted water sprays for preventing frictional face ignitions and automatic devices for quenching incipient ignitions and fully developed gas explosions.

INTRODUCTION

Steady improvements in the health and safety of coal miners have been made over the last half century. This is nowhere better exemplified than in the dramatic reduction in the loss of life due to mine explosions; there has been a steady decline in explosion fatalities since the turn of the century. Nonetheless, major mine explosions still occur at fairly regular intervals. Since 1958 in the United States, 19 such incidents claimed 335 lives and resulted in untold property damage. Most of these explosions resulted from the accidental ignition of methane. Most of them also involved coal dust which contributed in some degree - usually major - to the violence of the explosion.

It would be gratifying if the downward trend in explosion fatalities were to continue but a recent upturn in the frequency of frictional face ignitions caused by mining machines in the United States is a matter of great concern. The purpose of this paper is to discuss the magnitude of the problem of frictional face ignitions and some of the research being conducted at the U.S. Bureau of Mines in an effort to alleviate this problem.

BACKGROUND ON FRICTIONAL IGNITION

The increased use of mechanical mining equipment coupled with the exploration of gassier coal seams has led to a reported increase in the annual frequency of methane ignitions by friction in underground coal mines. This can be seen in Table 1 which gives ignition statistics for the years 1971 - 1979.

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Table 1
Annual frequency of underground
frictional ignitions

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Continuous Miner	30	20	22	44	50	57	37	36	74
Shearer	0	0	0	0	0	4	7	2	13
Roof Bolter	0	1	1	0	2	3	2	8	10
Cutting Machine	3	1	0	1	1	1	0	0	0
Roof Fall	1	2	0	0	1	2	0	0	0
Hand Pick	0	0	0	0	0	0	0	1	0
TOTAL	34	24	23	45	54	67	46	47	97

The increase from 47 ignitions in 1978 to 97 in 1979 is especially alarming. It will be noted that most of the ignitions involve the cutting bits of mining machines. An analysis of 223 frictional ignitions attributed to continuous miners over the period 1971-1976 indicated that 64% were caused by bits striking roof rock and 22% were the result of bits striking inclusions within the coal seam; the remaining 14% were attributed to bits striking the mine bottom (1). The high incidence of ignitions from cutter bits hitting roof rock is probably incidental but suggests the possibility of methane layering; others have suggested that the flammable mixtures result primarily from the dilution of essentially pure methane by ventilating air at the face (2).

Current mine safety standards aimed at the prevention of frictional face ignitions in U.S. mines are based primarily on assuring adequate face ventilation and early detection of the buildup of hazardous methane concentrations. U.S. regulations (3) require the quantity of air reaching each working face to be at least 86 m3 / min machine-mounted methane monitors that give audible or visual warning when the methane concentration reaches 1.0 to 1.5 % and automatically deenergize the machine when the concentration reaches 2.0 % are also required. These measures have certainly contributed to minimizing the consequences of frictional face ignitions and there has not been a fatal mine accident attributed to this cause since 1970 when a miner was asphyxiated as a result of a frictional face ignition. The last major mine disaster (5 or more fatalities) attributed to a frictional face ignition was in 1963 at the Carbon Fuel No. 2 Mine in Helper, Utah. However, a more recent mine explosion in Nova Scotia which resulted in 11 fatalities was attributed to a frictional ignition (4). Over the period 1971-1979, there were 30 injuries attributed to frictional ignitions in the U.S. and in some cases, as reported in Reference 1, methane flames were observed to travel 15 m or more from the point of ignition at the face. This reference also presents an interesting positive correlation between the extent of flame propagation and the proximity of the ventilation duct which illustrates the effectiveness of ventilation in minimizing the extent of flame propagation. Nonetheless, in view of the increased frequency of frictional face ignitions associated with modern mining machines, other remedial measures must be explored. The various approaches to this problem have been outlined in Courtney's recent article (2). These were broken down into four broad areas: preventing the formation of flammable mixtures (through improved ventilation), preventing the ignition of the flammable mixtures, ignition quenching and face inerting. This paper concentrates on the two areas of ignition prevention and suppression.

MEASURES TO CONTROL FRICTIONAL IGNITION

There has been a large amount of research on the subject of frictional ignition in general and the frictional ignition of methane by mining machines in particular; several excellent survey papers on the subject have been published (1, 2, 5, 6, 7). The important findings regarding the face ignition problem in coal mines can be summarized as follows:

1. Most ignitions are caused by cutter bits striking rock in mines; siliceous or quartz bearing sandstones present the greatest hazard followed by pyrite inclusions.
2. The ignitions invariably start in methane-air mixtures not coal dust.
3. The principal source of ignition is hot or molten material on the rock not hot bits or sparks. (There is not total agreement on this point).
4. All bit materials can cause ignition but some materials are more incendive than others.
5. The tendency for ignition to occur greatly increases with bit wear.
6. Reduced cutting speed appears to reduce the tendency for ignition to occur.
7. Directed water sprays are effective in reducing the probability of ignition.

Items 2, 5 and 6 suggest practical ways of reducing the frequency or severity of ignition, i.e. improved ventilation, a rigid bit inspection program with frequent bit changes, freeing frozen (rotating) bits, and reducing cutter speed. Items 4 and 7 suggest ways for further improvements, namely, improved cutter bits and the use of water sprays; these are currently being investigated with emphasis on the use of water sprays.

IMPROVED CUTTER BITS

Observations on the relative incendivity of the various metals used in the construction of coal cutting bits indicate that there is some room for improvement in the design of bits to reduce their tendency to ignite methane. For example, Blickensderfer's early work (8) showed that the steel used in the construction of bit shanks was significantly more incendive than the tungsten carbide cutting tip. More recent work conducted under a Bureau research contract (9) has served to reinforce this conclusion.

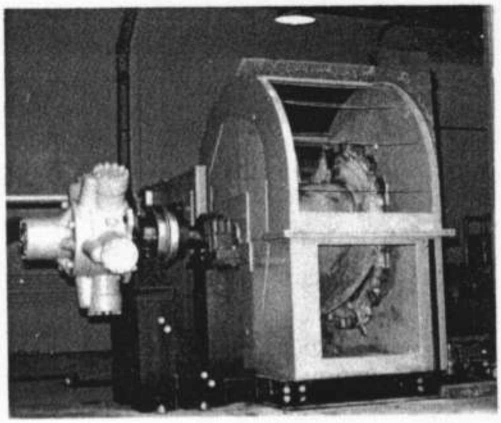


Fig. 1 - Equipment used in frictional ignition studies.

The equipment used in these studies is shown in Fig. 1. It consists of a full-scale Joy shearer drum driven by a 120 kW hydraulic motor. The drum is 1.37 m in diameter (bit tip to tip) and is equipped with cutting bits which make a series of long slanted cuts (45 cm max. length) into a large sandstone block which is driven across the rotating drum. The entire unit is enclosed in an air tight chamber and the number of cuts (strikes) required to ignite a 7% methane air mixture is measured.

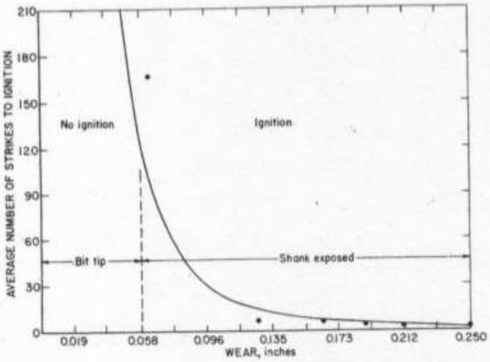


Fig. 2 - Effect of bit wear on ease of ignition

Figure 2 shows some recent data obtained with a single chisel bit cutting into sandstone; drum speed was 47 rpm with a corresponding bit speed of 200 m/s and the depth of cut was adjusted to 5 mm. The figure shows the number of strikes, averaged over a number of trials, required to produce ignition as a function of bit wear. It will be noted that there is a dramatic decrease in this number at a bit wear value corresponding closely to the first exposure of the steel shank to the cutting action. This suggests that any modification in bit design that would prevent early exposure of the shank material would serve to moderate the tendency for bits to cause ignitions.

This possibility is being explored using the two bit designs shown in Fig. 3.

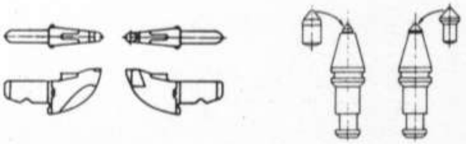


Fig. 3 - Bit designs to reduce shank exposure

The chief feature of both designs is a modification in tip geometry to prevent early exposure of the shank during the cutting cycle. The plumb-bob design has recently been evaluated in laboratory studies using the modified bits mounted on the Joy shearer drum of Fig. 1. For this purpose both conventional and modified plumb-bob bits were mounted on the drum at diametrically opposed locations and tested against a sandstone block. Early wear characteristics of the two bits are shown in Fig. 4.

As can be seen, the modified "mushroom" design offers some protection against early shank exposure. A new chisel bit design based on the Fig. 3 is currently being evaluated in the same manner and in-mine wear tests for both bit designs are scheduled for the near future.

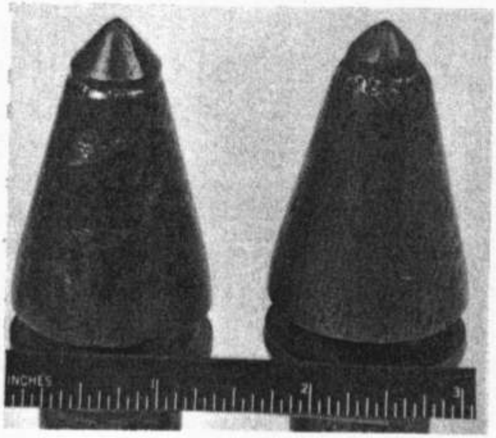


Fig. 4 - Early wear characteristics of new and old bit designs

Another possibility for reducing cutter bit incendivity lies in the development of improved bit materials. Blickensderfer's work has shown that copper-nickel bonded titanium boride is less incendive than tungsten carbide and that modest reductions in the incendivity of shank steels are also possible (10).

WATER SPRAYS

Perhaps the most promising method for reducing or eliminating frictional face ignitions lies in the use of machine-mounted water sprays. There is ample laboratory evidence to support this claim. The early work of Kocherga (11) indicated that water sprays with flow rates of approximately 2.0 l/min were effective in eliminating frictional ignitions during the cutting of sandstone or pyrites. With pyrites the direction of spraying was not important but best results were obtained with the sprays directed behind the pick. The direction of spraying was very important when cutting sandstone: four ignitions were obtained in six experiments lasting 127 seconds with sprays directed in front of the cutting bit while no ignitions were observed in 153 experiments, which lasted 6330 seconds with water sprayed behind the cutting bit.

Powell and Billinge (6) obtained similar results in laboratory studies with bits forced against the face of a rotating sandstone slab at cutting speeds of 1.5 and 4.5 m/sec. They found that a water spray delivering 2.7 l/min was very effective in reducing the probability of ignition - 0-27% with water sprays compared to 83-100% without sprays; the sprays were only effective when directed behind the pick.

The most impressive demonstration of the effectiveness of water sprays in eliminating frictional ignition was performed by A. Lobejko (12) at the Central Mining Institute's Barbara Mine. He used a full-scale KR-1 cutter drum (1.25 m diameter) laced with 30 NK-h radial picks with a conical spray nozzle behind each pick. In experiments with 2 m long cuts into sandstone at depths ranging from 1.5 to 4.5 cm with bit speeds of 3.8 m/sec, 16 ignitions were observed in 16 trials without water; with a total water flow of 82 l/min (2.5 l/min per pick), no ignitions were observed in 51 trials.

Similar experiments are now underway in the U.S. using the Joy test rig described earlier. Preliminary test results indicated that the optimum location of the water spray was behind the pick in agreement with European studies. A photograph showing the operation of an experimental nozzle is shown in Fig. 5 and some recent results illustrating the effectiveness of back-mounted sprays are presented in Table 2. These results were obtained with a single chisel bit impacting sandstone at a velocity of 3.4 m/sec and a depth of cut of 6.4 mm. With water flow rates of the order of 2 to 2.5 l/min, back sprays were found to be extremely effective in eliminating frictional ignition.

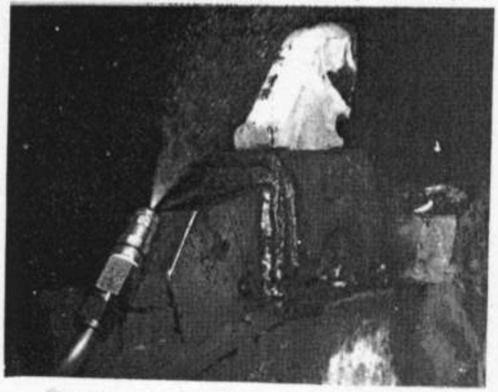


Fig. 5 - Experimental back spray

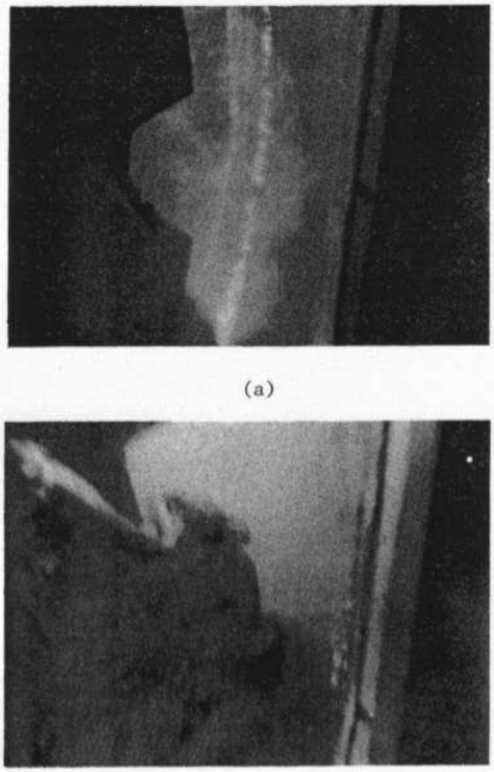
Table 2

Ignition tests with chisel bit impacting sandstone

Type of test	Water pressure atm.	Water flow rate, ℓ/min	No. of impacts	Result
Dry	---	---	14	Ignition
Dry	---	---	57	Ignition
Dry	---	---	2	Ignition
Dry	---	---	2	Ignition
Dry	---	---	5	Ignition
Wet	6.2	2.3	178	No ignition
Wet	6.2	2.3	97	No ignition
Wet	6.2	2.3	114	No ignition
Wet	4.8	2.0	102	No ignition
Wet	4.8	2.0	131	No ignition
Wet	4.8	2.0	109	No ignition

Views from a high-speed motion picture sequence of two test runs, one without a water spray and one with, are shown in Fig. 6a and b. Bit speed was 3.4 m/sec and the depth of cut in sandstone was adjusted to 5 mm. Without water (Fig. 6a) the bit leaves a long luminescent streak of hot molten sandstone in its wake.

While it is not obvious from this photograph, a methane ignition occurred during this pass which was the second in the test run. An examination of the original film of this event failed to show the exact location of the ignition but it appeared to originate on the sandstone surface at a point some 10 to 15 cm behind the bit. It is likely that most ignitions occurred in this way since the hot spots on the sandstone are stationary and are therefore much more effective in heating local volumes of methane to the ignition point than say a moving source such as a hot bit or hot particle dislodged from the contact point. This hypothesis is compatible


(a)

(b)

Fig. 6 - Effect of back mounted water spray: (a) without spray; (b) with spray

with the results of Fig. 6b which show that the principal effect of the back spray is to cool the sandstone as evidenced by the total disappearance of the incandescent streak except for a very small region near the contact point which is hidden from the spray. (The spray nozzle extends diagonally downward from the upper left corner of the photograph.) The water flow rate in this case was about 2 l/min.

The current efforts on water spray are aimed at optimizing spray nozzle type, location and water flow rate. Future plans call for laboratory and in-mine tests with a fully laced Joy shearer drum equipped with back-mounted water sprays. This project is scheduled for completion in late 1981. Engineering studies are also being planned to equip a ripper-type continuous mining machine with back sprays for controlling frictional ignition. The basic problem of plumbing water into the ripper head remains to be solved and may require some extensive redesign of the cutting head assembly.

An interesting alternative to the use of external water sprays for reducing frictional ignition has been developed by French researchers (13). They found that bits with internal passages for water injection originally designed for improved bit wear (14) and dust suppression are also effective in reducing the occurrence of ignition. It is not clear whether the mechanism for inhibiting ignition is associated with bit cooling or cooling of the rock surface in the vicinity of the cut. This technique may be advantageous, especially if it prolongs bit life but maintaining the integrity of bit seals in a mining environment might be a problem.

IGNITION QUENCHING DEVICES

Along with improved cutter bits and back-mounted water sprays, a third method for controlling frictional face ignitions is ignition quenching. This method depends on the early detection of the methane flame at the face and the dispersal of a suitable extinguishing agent in time to quench the developing flame. Kawenski (15) et al, demonstrated the feasibility of the approach as early as 1969. They used an ultraviolet flame detector to activate an explosive device which released a powdered inhibitor from a tubular container. The detector was capable of sensing a methane-air flame within 20 ms after ignition when it had grown to a diameter of about 10 cm. Quenching tests in a 7.5 m long entry having a cross section of 2 by 3 m indicated that 3 kg of potassium bicarbonate was adequate to quench an ignition in 9.5% methane-air when the dispersion system was located 1.2 m from the ignition source. Although the results of the early research were encouraging, some practical problems were evident with the proposed device. For example, dust, oil, or grease accumulations on the detector window greatly attenuated the radiation incident on the flame detector. In addition, the explosive train used to open the tube and disperse the dust generated an unacceptably high level of noise. Further work was then concentrated on improved flame detectors and inhibitors and alternative methods of dispersing the inhibitors.

The response of the ultraviolet detector was tuned to cover a narrower radiation band which was reduced the possibility of false alarms and a system was devised to continuously wash the quartz lens of the detector with a moving film of water. This eliminated the problem of dirt and grease buildup in the lens. The revised system functioned satisfactorily in in-mine proof tests.

In order to reduce the noise level associated with the explosive activated unit a system which utilized pressurized nitrogen for dispersing dry powder extinguishers was developed. A typical disperser consisted of a 1.2 m long steel pipe, 15 cm in diameter containing a 5 kg charge of extinguishant. It was equipped with a diverging nozzle and a scored metal diaphragm which was ruptured by a No. 6 electric detonator. The cannon was normally pressurized to 40 atm with nitrogen for dispersing the dry powder; the cannon met the requirements of a 140 db "C" peak sound pressure level.

This device was evaluated against methane-air-coal dust ignitions with four different mining machines in simulated mine tests (16). To insure adequate coverage of the face, the ultraviolet detectors and extinguisher units which contained ABC powder were mounted on the top and near the middle level of the mining machine. Table 3 summarizes the minimum number of cannons and detectors required to consistently quench ignitions with the detectors and extinguishers 3 to 5 metres from the face.

Table 3

Extinguisher and detector requirements for four mining machines

Machine	No. of detector units	No. of cannon units	Amount of agent lb
Joy ICM ripper	4	5	46.7
Lee Norse 33y-oscillating head	4	6	59.0
Modified 33y full face drum	4	6	59.0
Joy 2BT twin borer	5	9	66.1

A suppression system based on Halon 1301 was also examined in detail because of the demonstrated effectiveness of Halon 1301 as a flame inhibitor and because of the availability of a commercial dispersion system (Fenwal) that appeared suitable for the purpose (17). The Fenwal device consists of a spherical bottle that is equipped with a dispersion nozzle and an explosive activated release device. Vaporizable extinguishing agents like Halon 1301 provide vapor pressures of about 14 kg/cm^2 which is adequate for most applications.

Early tests with the Fenwal system indicated that the discharge was characterized by a pattern of lobes between which flame could conceivably propagate. Therefore an improved hollow cone nozzle was developed to provide a mine uniform spatial distribution of extinguishant. The effectiveness of the Halon extinguisher was demonstrated in quenching methane-air ignitions in a section of the Bruceton Experimental Mine. With the extinguisher mounted 1.2 m from the face, fire balls up to 1.2 m in diameter could be quenched with about 12 kg of Halon 1301. A film clip of a successful extinguishment is shown in Fig. 7.

In an attempt to improve the spatial and temporal distribution of the agents, hybrid systems consisting of a mixture of Halon 1301 and a dry powder such as Purple-K ($KHCO_3$) were also explored and found to be very effective (17).

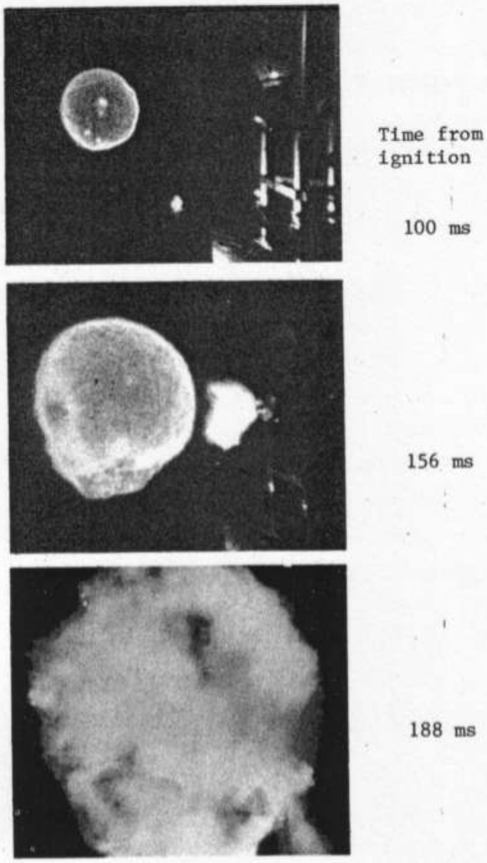


Fig. 7 - Suppression of methane-air ignition with Halon quenching device.

For example, results in a 2m diameter gallery showed that a mixture of 2 kg of Halon 1301 and 2 kg of Purple K was effective in quenching methane-air ignitions whereas 10 kg of Purple K or 4 kg of Halon 1301 were not effective when used alone.

The hybrid system was further evaluated in ignition quenching tests with a full-scale mockup of an experimental tunnel boring machine (17). For this purpose eight Fenwal units and ultraviolet flame detectors were evenly spaced around the periphery of the cutting wheel which was 5 m in diameter. The extinguishers were equipped with a spiral nozzle and each contained 5 kg Halon 1301 and 5 kg Purple K. Test results indicated that the 8 units were adequate for extinguishing 8% methane-air mixtures; for 9% mixtures an additional extinguisher was necessary particularly if the ignition occurred near the top of the cutting wheel.

Although the dry powder suppression system demonstrated on the continuous miners was a technical success, the system was deemed impractical for mine applications due to the number and size of the extinguishers required for ignition suppression. The same applies to the Halon system demonstrated on the tunnel boring machine with additional reservations associated with the toxicity of the decomposition products of Halon For these reasons recent Bureau work on ignition suppression is aimed at reexamining the potential use of water as a suppressing agent. Since water is universally used for dust suppression on mining machines, a source of water is readily available and the integration of a water suppression system into existing machine designs might be simpler than the retrofitting of a dry powder of vaporizable liquid system.

Earlier Bureau work has shown that cold water is only partially effective in quenching incipient flames (18). However, effectiveness of water can be improved by elevating its temperature. This was demonstrated in the laboratory experiments of Sapko, et al (19). More recent experiments using a Fenwal suppression system have shown that incipient flames can be quenched at close distances providing the water is heated to 100°C or higher. Results of experiments with cold and hot water are summarized in Table 4.

Table 4

Summary of suppression tests using cold and hot water

Water weight kg	Temperature °C	Distance m	Result
13.6	20	3	No suppression
13.6	20	6.4	Partial suppression
13.6	20	10.1	Full suppression
10.0	99	1.2	No suppression
10.0	116	1.2	Full suppression
10.0	152	1.2	Full suppression

These tests were conducted in a 2 m diameter gallery which was 28 m long; the first 6 m length was confined by a thin polyethylene sheet and filled with a 7.5% methane-air mixture which was ignited at the closed end. A single water filled Fenwal bottle pressurized to 15-20 atm with nitrogen was mounted along the axis of the gallery at varying distances from the face. Water discharge was affected by the initiation of a No. 6 electric detonator in proximity to a scored metal diaphragm at a time when the methane fireballs had grown to a diameter of 1/2 to 1 metre. As will be noted, cold water sprays were not effective at distances of 3.0 m from the face, only partially effective at 6.4 m and fully effective at 10.1 metres. This was attributed to the effect of turbulent wind ahead of the flame in breaking the water spray into finer drops (18). However, water heated to temperatures above 100°C was effective at distances as close as 1.2 m. It would thus appear that a practical machine-mounted system utilizing hot water as the quenching agent could be evolved. Current research efforts in this area are aimed at reducing this concept to practice.

CONCLUSIONS

It was shown that the incidence of frictional face ignitions associated with mining machines are on the rise in the U.S. Unless more effective preventative measures are taken, it is anticipated that this trend will continue, perhaps with disastrous results. Practical measures such as improved ventilation, rigorous bit maintenance programs, and reduced cutter head speed have been suggested and will serve to partially alleviate this problem. However, more direct and positive ways of preventing face ignitions or suppressing them in their incipient stage will be required to completely eliminate the hazard of face ignitions. While a large amount of research effort has been expended on positive prevention and suppression techniques, to the best of our knowledge none of these techniques are being applied in production mining. At present the most promising approaches to this problem appear to be: (1) improved cutter-bit designs and materials; (2) machine-mounted water sprays; and (3) machine-mounted quenching devices. Recent results with new bit designs appear to hold some immediate promise but new nonincendive bit and shank materials appear to be further downstream. Back-mounted water sprays show excellent promise in laboratory studies but whether they work in an in-mine environment remains to be seen. Machine-mounted quenching systems have been demonstrated to be effective in suppressing face ignitions in a variety of configurations. However, none have been designed that are simple and rugged enough to meet the requirements for in-mine use. Hot water systems may be more amenable to these design requirements than others.

Work on all three of these approaches is expected to continue at the Bureau with short-term emphasis on machine-mounted water sprays.

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DISCUSSION

W. ROACH (Consultant, Brisbane): It was stated better suppression is obtained with hot water. What are the mechanics or the chemistry of that statement?

R. WATSON (United States Bureau of Mines): It doesn't involve the chemistry all that much. It just involves the better spatial distribution. Finer droplets and water vapour are better able to inert the area in the immediate vicinity of the fireball than the large drops obtained with cold water sprays. So it is a matter of really distributing the material properly and has little to do with the chemistry of the material itself.

P. GOLLEDGE (Queensland Department of Mines): Regarding the U.S.B.M. flame detectors, at one time it is understood that there were problems trying to get the detector to work when there was dust and grease and water around. Has that problem been solved?

R. WATSON: Yes, the early versions of the detector did suffer from that deficiency. The newer models have been equipped with a water flushing system that works over the face of the unit and has eliminated the dust problem.

P. GOLLEDGE: Referring to the pressure of water when cutting through sandstone some work in the Federal Republic of Germany suggested that with 72% silica in the rock much higher water pressures were needed in order to get a suppression of the arc of sparking. What was the percentage of quartz in the sandstone used in the U.S.B.M. tests? Was it the same or less?

R. WATSON: The systems presented were optimised on the basis of a single type of sandstone and the requirements may be different for different stones. The laboratory demonstration with the fully laced drum is aimed at looking at another problem. It is necessary to ensure when cutting coal composites with sandstone inclusions that the water sprays themselves are not blocked by the cutting action.

O. KREILIS (Southern Engineering Services): Returning to the point about the hot water, isn't it the action that when the hot water comes out of the nozzle it is virtually at flash point, and the surrounding air and dust is really being trapped into the steam path which gives a better result.

R. WATSON: Basically that is it.

O. KREILIS: If the temperature of the water is 99° and it is passed through a nozzle and expanded, flashing off occurs.

R. WATSON: That is correct.

R. CYBULSKA (Experimental Mine Barbara, Poland): Further to the explanation about the hot water, when considering water as an extinguisher mostly two physical properties are considered - the latent heat of evaporation and the specific heat but mostly the steam is forgotten. When there is for instance 30 per cent steam so the lowering oxygen content must be considered. This is an important factor.

R. WATSON: Yes, that is correct.

R. CYBULSKA: Because this water evaporates easier when it is hotter so the oxygen reduction is greater.

R. WATSON: There is better physical distribution of the quenching agent, but it is correct to look at it as removal of the oxygen, that view is quite valid.

J. CANNELIS (Fire Fighting Enterprises (Aust) Ltd.): Are Fenwall explosion suppression systems used in the mines at all in the United States?

R. WATSON: Fenwall would probably be extremely happy to supply systems for in-mine use but the truth of the matter is that there has been little luck in talking mine operators into using such systems.

T. CALLCOTT (B.H.P. Central Research Laboratories): In Table 1 referring to frictional fires, three instances of roof falls were mentioned. Is there any information of those events of 1975 and 1976?

R. WATSON: No, there are really not any details there except that they apparently did involve rock on rock impact. These were taken from the accident reports, providing statistics but no details of those incidents.

W. GLYNN (The Bellambi Coal Co. Ltd.): Mention was made of applying the water behind the pick, purely on the score of causing ignitions to be reduced. Now what effect, if any, would applying the water behind the pick have on dust suppression? In this country most times the water is used for dust suppression and not for frictional heatings.

R. WATSON: Several years ago this problem was examined not from the frictional ignition viewpoint, but from the optimisation of water sprays on mining equipment for dust reduction. Water sprays were mounted ahead of the pick, behind the pick and in other locations. The results of this research hinted strongly that the reduction of respirable dust did not depend heavily on pick position. However, there were certain locations that were far easier to implement and maintain than others so these were chosen instead of the rear-mounted water sprays.

M. CARR (New South Wales Department of Mineral Resources): In the paper the quantity specified for continuous miner operations says 86 m^3/min which approximates 1.4 m^3/sec in local jargon. Yes 86 m^3/min was the quantity specified as laid down in the legislation in the States in the paper. This would be regarded as being a low quantity in Australia. Is this quantity responsible in any way for the large number of ignitions which are occurring because 1.18 m^3/sec (2500 cfm) at the face where a continuous miner is operating, if there is any make of methane, is hardly sufficient to dilute it and render it harmless. What is the American standard?

R. WATSON: 1.4 m^3/sec (3000 cfm).

M. CARR: Is this in any way responsible for the high gas?

R. WATSON: There are arguments both ways. There are some people in the United States that claim that ventilation itself increases the frequency of ignitions. This is for the simple reason that what is being diluted is pure methane down to the upper explosion limit. So that can be argued from both directions.

J. CARVER (Retired H.M. Chief Inspector of Mines and Quarries, U.K.): With regard to the minimum quantity of 1.4 m^3/sec (3000 cfm)of air, in the United Kingdom the specification of minimum quantities was ceased. It was ceased because, on balance, what is specified as a minimum tends to be regarded as a maximum. When Mr. Carr asked if this is responsible for some of the ignitions he had a valid point. It is sufficient to place the obligation on management, according to their own conditions, to adequately and continuously ventilate working places.

R. WATSON: Those comments are certainly appreciated.

D.R. HUMPHREYS (Australian Coal Industry Research Laboratories Ltd.): Why is methane ignition initiated some inches behind the cutting tip rather than say at the front of the tip or immediately behind the tip?

R. WATSON: Golledge in Paper 2 indicated that there is a temperature-time effect in the ignition of methane. It is necessary to have an object at a certain temperature and have methane exposed to it for a certain amount of time. This means that things like flying sparks or moving bits are not particularly effective in igniting methane for the simple reason that they are not exposed to a given volume of methane for sufficient time to heat the methane to its ignition point. However, the hot streak is stationary in relation to its immediate methane environment and therefore is a much more effective ignition source.

R. LAMA (Commonwealth Scientific Industrial Research Organisation): Has an investigation been made of the location of these sprays with respect to the rate of rotation of the drums. Very close to the drum there is a certain amount of movement of the methane and air and perhaps it might be related to its speed and a fixed distance of the sprays from the back of the drum can be kept.

R. WATSON: That is an extremely interesting point; the answer to the question however, is no, the effect of drum rotation on the spray parameters has not been examined. It is a point that probably should be taken up Thank you for mentioning it.