INCENDIVE SPARKING ASSOCIATED WITH SHEARER MACHINES

By
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INTRODUCTION

Methane is present in varying degrees in nearly all underground coal mining operations. At mixtures with air near 5-15% it is explosive and consequently since it is not usual for these levels of contamination to be reached in the general body of a mine ventilation system it is not unusual to experience it in specific places. On longwall faces the most used power loader is the shearer machine and because of its general shape, situation and operation it is likely that all the factors which are required to cause a frictional ignition can be present. This paper makes a general appreciation of the causes of these ignitions and methods which are and have been used to control these situations on and around these machines.

CUTTING MEDIUMS

The minerals which are likely to be encountered in coal mining which can produce temperatures high enough to cause ignitions when hit by machine picks are quartz, pyrites.

Quartz is generally present in most coal measures and its grain size and quantity vary. Depending upon these factors the material is usually categorised into three parts:-

Rock containing over 50% quartz -
High Incendive Temperature Potential (I.T.P.)
Rock containing 30 to 50% quartz -
Intermediate Incendive Temperature Potential
Rock containing under 30% quartz -
Low Incendive Temperature Potential.

Generally the stronger the rock and higher the quartz content the greater will be the chances of producing incendive temperatures when cutting. High I.T.P. can be found in sandstones usually containing 50 to 75% and exceptional quartz contents of over 90% can be found in ganister and orthoquartzites; also irregular bands of quartzlager with contents of around 80% have been found in coal seams.

Siltstones usually have quartz contents of 20-50% with an intermediate (I.T.P.) and mudstones with less than 20% would be rated as low (I.T.P.).

Pyrites, usually found in and close to coal seams in the form of ironstone with pyrites, highly pyritic dirt bands, and massive pyrites will possibly have an intermediate I.T.P. and the worst situation likely to be encountered might be a combination of pyritic rock and high quartz content rock such as pyritic sandstone. Cutting coal seldom if ever results in frictional ignitions of gas, but it also follows that coal seams with these elements in or around them will present a likely situation of incendive sparking. Where methane is also present it is possible that if precautions are not taken then frictional ignitions will follow during the course of mining coal and if these are not controlled there may be a possibility of causing a dust explosion also. Three basic approaches are taken to stop this happening and they are:-

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1. Preventative
   Ensure that there is the least chance possible of causing an ignition.
2. Suppression
   The application of water, critical positions and the effect of quantity.
3. Ventilation
   Diluting the air to a level where ignitions will not occur.

CUTTINGS

Cutter pick and the design of the tips will have varying effects on the incidence of incendive sparking, as also will the speed at which they are used and the angle of application at which they are set. The incidence of sparking will increase considerably with cutter tools which are blunt, regardless of their design. Wedge type picks commonly used on radial picks and forward attack picks are less prone to causing sparking than are point attack picks, and possibly it is because they retain their 'sharp' profile longer that this is the case. It is the wear flat area on top of the pick which affects the width of the hop strip which is trailed off behind the pick and point attack picks are likely to produce this earlier in their life than are the wedge type.

Cutting at all times should be done with the carbide tip and not the parent metal of the body, and on many point attack picks, it is impossible to avoid a situation where the body of the pick is not in contact with the material being cut (Fig. 1). Back clearance should be in the order of 12^{o} for point attack, but can be down to 5^{o} for wedge type tips. Point attack picks with slug inserts are particularly bad in that the carbide tip covers only a small contact area with the rock.

The effect of cutting speed is that the higher the speed, the less is the time required to reach the critical temperature which can cause ignitions and whereas it is not possible to give accurate ratios of the relativity of cutting speeds to the incidence of ignition, laboratory tests have shown figures where in sandstone, the time to reach a 50% probability of ignition is over four times as long at a cutting speed of 137 m/min as it is at 274 m/min.

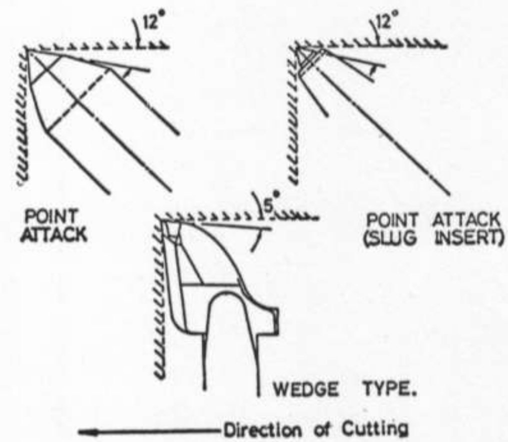

Fig. 1. Clearances with various pick types

Another advantage of reducing the shaft speeds is the benefit which can be obtained relative to the control of dust with a possible consequence of a lowering of the dust levels in the general air body. Modern trends on shearer machines are to move to slower shaft speeds, but because of the higher torque values which are inevitable when doing this, machine bodies, extended arms and planetary gear cases have to be larger with the attendant problems of increased difficulty with coal loading. Ventilation of the surrounding area later referred to, also becomes more difficult.

APPLICATION OF WATER

There are two reasons for using water within the cutting zone apart from dust control and the main one is to quench hot material left by the cutting picks, the second, particularly when cutting rock is to cool the carbide tip.

At temperatures around and above 600°C, the strength of both steel and carbide start to fall off quite abruptly, consequently it follows that tip blunting and abrasion will progress at an increased rate in these circumstances. The application of water to picks is not new in that it has been an accepted practice for some years now to flush the face of the picks with water to reduce the dust makes. It is also quite possible that in cooling the picks this has had some effect upon the life of the carbide tip. However it is also known from laboratory tests that when incendive sparking is caused that the hottest spot does not appear at the tip itself, but on the cut off particles which are left in the cutting track of the tool and that any ignition can take place some distance behind the pick. Findings to date show that water ejected up the front of the pick has little effect on cooling the hot spot, but tests have also shown that water which is ejected behind the pick can be effective in both reducing the incidence of ignitions and also keeping the pick cool.

Since the disposition of picks on a Spiral Vane Drum is such that they are placed behind each other and on the vanes slightly to one side, it might be thought that water which was sprayed upon the cutting face of one pick may have a quenching action on any hot spot left by the preceding pick. This is not the case even in the ring of back face picks where the space between picks is often at a minimum distance. Experiments to determine the effect of droplet size have shown that water sprays are more efficient than water jets and that the finer the spray the more efficient the quenching action, although the optimum droplet size is not yet known. In the test siutation where water was supplied to the back of the pick in the form of a jet at normal face working flow pressures of say 552 KPa, with a consumption of 13.6 l/min the probability of ignition was twice that of a solid cone spray taking only 2.5 l/min, but the flow pressure of the latter was increased to 5.52 MPa, which would bring with it the attendant problems on the coal face of making this pressure available.

Fig. 2 shows a radial type pick with a typical water jet positioned behind the body of the pick and arranged to flush the body of the pick. Water applied in this manner will have a degree of success and it is also this application

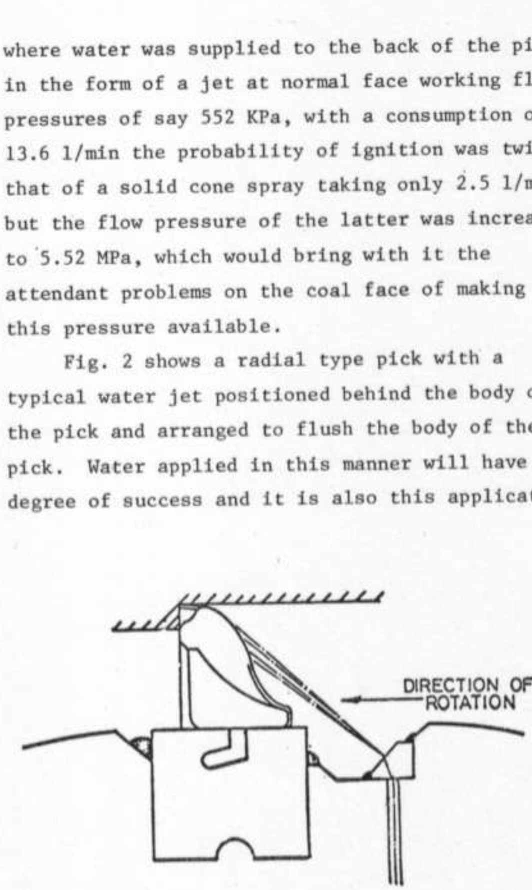

Fig. 2. Body flushing with jet at rear of pick

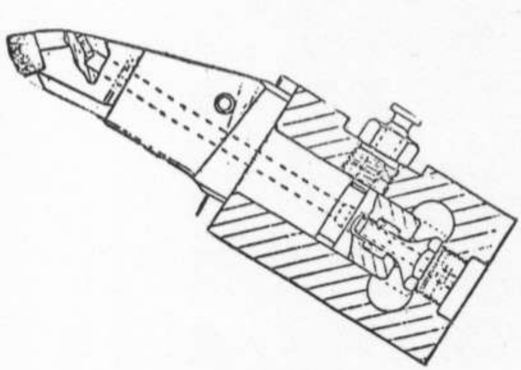

Fig. 3. Water flushing through pick body

to which spraying rather than flushing has shown to be better. Currently trials are in operation with which water is being passed through the body of the pick and Fig. 3 illustrates a pick of this nature. These trials are in their infancy but initial results would appear to be very good. It is however too early to make comment on the reliability of this tool and holder. Radial picks used in a similar way were effective in the early part of the pick box life, but as soon as wear was experienced between the pick and pick box there were problems in maintenance of the water seal.

VENTILATION OF THE CUTTING DRUM

This approach, to dilute the methane within the immediate area around the drum can be an effective method of avoiding incendive conditions. Many shearer machines now have hollow shafts of a size which can be effectively used to pass air and water. Since it is usually necessary to feed the cutting drums with water in order to control dust, considerable development work has been applied to obtaining the maximum performance from both the dust control aspect and the ventilation requirement. Normal water pressures on the coal face are unlikely to be adequate to operate the ventilation (or venturi) systems effectively, and it will be necessary to make a supply available; this is usually done by means of a pump in the heading and an independent feed to the venturi jet. Trials are currently taking place in the U.K. with a pump box built into the shearer machine to boost the pressure at the machine and to obviate the need for a separate hose feed on the face, however it is too early yet to comment on any findings from this, but obviously if it is successful then the application of venturi systems will become much more readily acceptable and the possibility of high pressure spraying becomes more feasible also.

Many shearer machines are now produced as standard with hollow shafts and the shaft bore diameters are extremely important in the effect they have upon the quantity of air which can be passed. A typical example of volumes of air which can be anticipated can be seen from Table 1, however it is generally considered that bores of 70 mm internal diameter and under are not large enough for any effective form of ventilation. One attendant problem which may be encountered when operating these systems is that because of the amount of air which is being passed and its velocity it is not unusual to experience an embarrassing increase in the level of dust make from the cutting head. One method of counteracting this situation which is quite effective is to increase the size of the venturi jet and pass a greater quantity of water through the hollow shaft. As can be seen from Table 2 there is an optimum size of jet to give a maximum air flow and by exceeding this the volume of air is then reduced. In practice it has generally been found that a compromise

Table 1

Minimum quantities of air relative to water pressure and bore size in m^3/min

Shaft bore with 22 mm P.F.F. Feedpipe	Water pressures		
	2.5 MPa	5 MPa	10 MPa
65 - 70 mm	3.82	5.80	8.66
70 - 75 mm	4.53	6.79	10.21
75 - 80 mm	5.24	7.95	11.89
80 - 85 mm	6.08	9.14	13.67
85 - 90 mm	6.93	10.39	15.59
90 - 95 mm	7.75	11.69	17.60
95 -100 mm	8.60	12.90	19.27
100 -110 mm	9.31	13.98	20.97
110 -120 mm	10.75	16.19	24.25

situation can be met without increasing the volume of high pressure water to an unreasonable level but it is usually necessary to set up each system on the machine in-situ. In order to be able to do this it is important that the equipment which is in use can be monitored quickly and easily while actual coal cutting is taking place. Fig. 4 shows a sectionalised view of a typical hollow shaft ventilator with pick face flushing water supply. Also shown is an integral pressure tapping which enables airflow measurements to be taken on the face. Because of the bulky nature of the standard venturimeter which would be embarrassing underground it is usual to use a pre-calibrated short measuring system. Table 1 can also be used as a guide to the minimum quantities of air which are recommended relative to water pressure and shaft bore in U.K. mines, but it is not intended to recommend airflows for various situations, as the required operational level should be decided on the basis of coal face conditions, e.g., rate of gas emission. However the quantities given in Table 1 are based on figures which have been achieved and are by no means unreasonable to obtain.

VENTILATION OF THE SURROUND AREA OF THE DRUM

Tests undertaken by the National Coal Board at two sites have shown that although the hollow shaft ventilator is capable of diluting the methane within the body of and around the cutting head, there is also an area around the shearer which will have low air velocity regions outside the cutting zone and this can encourage the accumulation of explosive concentrations of methane. The directions of machine travel to the ventilation when using a single ended full section extraction unit showed that with the drum leading against the airflow there was some considerable area between the machine body and the coal face which extended away from the machine where air velocity dropped to below 30.5 m/min. Fig. 5 (a) shows this situation and the shaded area indicates region around the machine where the airflow is likely to fall below 30.5 m/min when the main body has a mean speed of 76.3 m/min. The shaded area can be reduced by increasing the mean speed and a comparison can be seen when the mean speed is increased to 305 m/min. Fig. 5 (c) shows a similar situation but in this case the direction of the air has been reversed. It can be seen

Table 2

Shaft bore: 89 mm

Test conducted with Easifit jets

Water pressure MPa	Nozzle 1		Nozzle 2		Nozzle 3	
	Water flow l/min	Air flow m^3/min	Water flow l/min	Air flow m^3/min	Water flow l/min	Air flow m^3/min
1	7.3	4.13	10.4	5.32	15.9	5.32
2	10.1	5.86	14.1	7.70	21.8	7.58
3	12.3	7.27	16.8	9.56	26.9	9.42
5	15.9	9.56	21.8	12.54	32.3	12.54
7	18.8	11.40	25.4	15.22	40.0	15.22
9	21.8	13.92	28.7	17.49	45.2	17.43

Jets used: 1. Easifit 2.4 mm dia., 2. Easifit 2.8 mm dia., 3. Easifit 3.2 mm dia.

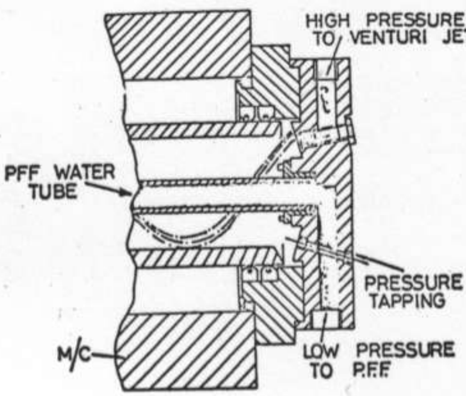

Fig. 4. Goaf side section of hollow shaft ventilator

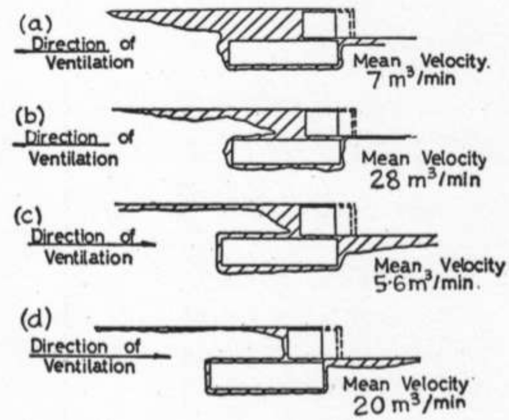

Fig. 5. Low air velocity regions around shearer machine

that the area of low velocity air (below 30.5 l/min) is reduced and in this case little advantage was to be gained by increasing the air flow above 213.5 l/min. In situations where a cowl was being used it was beneficial not to seal the cowl up to the roof but to have a 76 mm gap at the top and this allowed some air to flow across this region.

Water powered airmovers which were capable of being operated from the normal water pressure on the machine can further be employed at strategic positions on the machine to ventilate low velocity zones. However because the volume of air which they pass is relative to water pressure it is necessary to compensate by increasing the sizes. 152 mm diameter is normal or they can take the form of rectangular shapes and the use of suitable jets is not unusual. It would be expected to pass up to 153 l/m through such a unit at around 689.5 KPa but also because of their size they become susceptible to damage in operation particularly in thinner seams.

CONCLUSIONS

1. Realise the potential hazard which is on the coal face.
2. Take steps to reduce this hazard by choosing and using cutting tools in a way which is likely to cause the least incendive sparking.
3. Apply water in a manner which will minimise the chances of frictional ignitions.
4. Ventilate the cutting drum area through the hollow shaft.
5. Take full advantage of the face ventilation to disperse methane around the shearer machine.
6. Use outboard arms on the shearer machines as these allow the face ventilation to pass closer to the cutting zone.
7. Take advantage of air movers mounted in strategic places on the machine if necessary.
8. When using cowls ensure there is a gap between the top of the cowl and the roof.

DISCUSSION

R. WATSON (United States Bureau of Mines): Is there any effort in the U.K. or elsewhere to adapt the water-spray technique to continuous mining machines as opposed to shearers?

T. BINGHAM (Green & Bingham, United Kingdom): None is known. Certainly if any of the continuous miner machine manufacturers will adapt their machine designs to a form where water can be passed through the shafts, and not many yet do this, then this will open up the possibility of both considering incendive sparking suppression in this way and also of adapting water in a much more efficient way to control dust too. To date nobody is known in this field who is considering or who has a machine doing this. It would be interesting to know if anyone is. It is something that these people ought to get a hold of and this has been pressed for a while.

T. ROBSON (Jeffrey Mining): Jeffreys do have face flooding in the States. It has been discussed just recently with a company down here.

T. BINGHAM: That news is surprising and not common knowledge. No details of this interesting development have yet been received from Columbus or Johannesburg.

T. ROBSON: The information only came to hand last week. Coming back to cutting pick tip speeds. The Company is now asking for 2.286 m/second. It is possible to come down to 1.96 m/second.

T. BINGHAM: This is very interesting and it is something which has been pressed for quite a long time. It will open up quite a much wider field here both on incendive sparking suppression and also on dust too. It is very pleasing to hear it is going ahead.

G. GRANT: (Coal Development Services Pty. Ltd.): In relation to cutter drum peripheral speeds it is surprising that mention was not made of drum speeds in the conclusions. Research available both from overseas and in this country suggests that to remove the risk of frictional ignitions there should be a peripheral drum speed of around 60 m/minute. It would be interesting to hear whether research in the U.K. is directed towards cutter drum speed reduction or whether most of the work being done is in relation to water at the pick point and hollow shaft venturis.

T. BINGHAM: Yes, it is generally thought that to avoid frictional ignitions a reduction to speeds around about 60 m/min peripheral is necessary. But this cannot be foreseen happening on shearer machines. To come down to that speed, it is going to so affect the design of the spiral vane discs that the loading of coal would be affected. There would need to be too many vanes and too many picks. There should be no departure from the concept of mining coal and that is that. However these problems which are dangers should never be forgotten. Accepting this, the first job here is to mine coal. To think about going down to 60 m/min peripheral on drums of possibly a metre and a half for example or 2 m is quite impractical. Too many picks would be needed.

Not very much research is going on now concerning pick face flushing or if it is in the UK it is not known. Research on dust control is taking other forms now, not necessarily that particular one. Just what other development is being done at the moment with regard to what is called pick body flushing is unknown also. Mention was made about the size of water droplets. Many are possibly aware of the work which has been and is being done here with steam on dust suppression; that is quite effective on suppressing ignitions too.

It has never really got off the ground because of the problems of generating steam underground.

R. STROH (Anglo American Corporation of South Africa): Has any consideration been given to using the available water energy to drive a small turbine. The recovered energy could then be used to drive fans. It is accepted that a fan on the miner is probably more susceptible to damage. But if it is possible to recover energy more efficiently through a water turbine and to couple this directly to a fan on the head of the miner, it then can be used to disperse some of the gas which might accumulate behind the shearer. In fact small turbines are being used or considered for use on refrigeration systems in the gold mines in South Africa.

T. BINGHAM: In short, no. No current work on water turbines of this nature is known. Maybe someone else has some knowledge of it.

R. WATSON: Regarding the effect of drum speed on frictional ignition, some of the recent work done under contract of Bituminous Coal Research indicates (of course) that as the drum speed is reduced so significantly is the probability of ignition reduced. Ignitions have occurred at drum speeds significantly below 60 m/min, as low as 16 m/min. These peripheral speeds would be below values that would be practical for cutting the coal so that is not really the total solution to the problem.

R. PARKIN (Western Collieries, W.A.): Regarding the relationship between peripheral speed and incendive sparking, if the peripheral speed is reduced then obviously you increase the horse power and obviously the size of the machine to produce the same work output. First of all has any more work been done between the bayonet type pick and the point attack pick in the realms of incendive sparking, taking into account the hardness of the coal and secondly has any more development been done with regard to extractive techniques around the shearer drum itself.

T. BINGHAM: The two types of pick, the bayonet and the point attack are also known as the radial attack and the point attack. In comparison to those two particular picks consider the fitting into both those two types of picks the forward attack and the radial exactly the same tip. Mount the pick and sharpen it in exactly the same way - very reasonably expecting to have exactly the same results in any consequence of incendive sparking which may come there. The one from which changed results would be expected is the point attack. Two examples were given. The one with the slug insert where the parent metal of the point attack pick was not covered by carbide would certainly increase the chances of incendive sparking. Again that same situation can be improved by having a carbide tip mounted in such a way which covers the whole of the end of the tip of the pick but this then runs into the possibility of the frictional ignition caused by wear. (In this respect a worn pick is considered to be worn when it has 3 mm of flat on the top of it.) Consider what a pick looks like when it is taken out of a shearing machine. 3 mm of flat on top. The clearance angles are 5^{o} generally for a wedge type tip and 12^{o} for a point attack type tip. It is generally thought that why a wedge type pick has less chance of incendive sparking is because it holds its wear characteristics a little longer than the point attack does and possibly because of the clearance angle which is necessary to have to cut properly. This should not be confused with the general life of picks, particularly on continuous miners, road headers and this sort of thing, where the short point attack pick can in many instances give longer life than a radial pick in hard cutting.

D. ASHBRIDGE (B.H.P. Collieries, Newcastle): This paper has more or less generalised on problems associated with shearers. At the present time greater interest is being shown in problems associated with thinner seams. In order to maintain high production in thin seams, manufacturers are now moving the shearers in-web. Obviously with in-web shearers, ventilation becomes even more of a problem. Please comment specifically regarding in-web shearers.

T. BINGHAM: That is correct. Certainly the incidence of ignitions on longwall faces is much higher with in-web machines. There is no doubt about this at all. The majority of ignitions are coming from in-web shearers. Speaking generally, without any specific results, with regard to ventilation around the machines the incidence of hollow shaft ventilators applied to the in-web shearer machines is much higher in the U.K. than it is generally with other machines. There is one manufacturer of an in-web machine and there are problems with putting it into gassy conditions. It doesn't have a hollow shaft and the arms have to be ventilated over the top. Particularly in the smaller seams, this means taking some room with the added problems of loading coal. Good machines, they cut coal well but it is more difficult to ventilate the machine and this may affect the performance of this machine. Certainly in-web shearers are likely to present more of a problem in this field.

D. WHITEHOUSE (The Shell Company of Australia Limited): Regarding the low velocity areas that exist around shearers(as defined by the tests that were talked about in the paper) it would seem that in having a low velocity area of this sort there is a higher risk of ignition in that area because of the probability of a higher concentration of gas. There are a number of recorded incidents also where, within the loading cowl, because of almost lack of air movement and high concentrations of gas there have in fact been ignitions take place in this area. Is the best solution to this problem to get rid of the loading cowl and use the conveyor structure, in particular a well designed ramp plate system and a well designed pushing system to do the job of loading coal rather than a cowl? This appears to form a trap in which methane is likely to be held.

T. BINGHAM: That is an interesting comment as well as being quite correct. Unfortunately it isn't always possible to efficiently load the coal from shearing machines, either with single ended machines or double ended machines in a way which is satisfactory. This is of course the reason why the cowl is put on. It should also be realised that when the cowl is put on it does have another advantage too and that is that it traps quite a lot of dust and usually better dust control figures are obtained with a cowl fitted than without. But certainly this does make a zone of low velocity air around this area. It is generally recommended that the cowl should not be fitted up to the roof. This allows some air to go through. But, yes, there is a hazard there; yes, it would be most desirable to get rid of it if coal can be cut and loaded efficiently on the conveyor but unfortunately it can't always be done.

J. CARTHEW (B.H.P. Steel Division Collieries): Some work has been done in Germany in recent times using very high pressure water behind ploughs in the first instance with the objective of hydraulic assistance to cutting. Are there any views on its applicability to shearing machines and its effect, if any, on incendive sparking.

T. BINGHAM: That is an interesting development are there any other details?

J. CARTHEW: Yes, but very little detail. Some experimental work has been done using both GHH and Westfalia ploughs with very high pressure water, possibly 600 bar or of that order. 600 to 800 bar pressure has demonstrably increased the clearance rate of coal from the plough. This information is now nearly 12 months old and some more information should now be available.