

SAFETY IN MINES RESEARCH ADVISORY COMMITTEE

SIMRAC

Final Project Report

Title: TO ESTABLISH THE CURRENT STATUS OF RESEARCH,
DEVELOPMENT AND OPERATIONAL EXPERIENCE OF WET HEAD
CUTTING DRUMS FOR THE PREVENTION OF FRICTIONAL
IGNITIONS

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Executive Summary

Research has shown that one of the most effective methods of preventing the frictional ignition of methane/air mixtures at the coal face is to spray water directly behind the cutting picks and parallel to their direction of travel. However, not all mining machines have water available on the cutting drums and this research report discusses the current status of wet-heads.

The research has shown that, while longwall shearers and roadheading machines have had the option of wet-heads available for at least a decade, it is only in the last few years that a similar feature has become viable on continuous miners.

The report concludes that continuous miners with wet-heads are now commercially available, either as new machines or as a wet-head retrofitted to existing machines. Furthermore, the criteria for designing spray systems to provide protection against frictional ignitions have proved satisfactory when used on shearer drums and are equally applicable to continuous miners.

There is world-wide interest in wet-head continuous miners not only for frictional ignition protection but also because of the opportunity they afford to reduce respirable dust concentrations. While it is recommended that no further research on frictional ignition suppression is undertaken, it should be recognised that wet-head continuous miners will have a major impact on dust control strategies and that this should be taken into account when evaluating future research needs.

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- Consol, Inc
- D.M.T.
- Eickhoff
- Hydra Tools International (Pty) Ltd
- Joy Manufacturing
- Powercoal Pty Ltd.
- USBM/NIOSH

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Two other individuals, Dr D.P. Creedy of Wardell Armstrong, U.K. and Mr D.R. Hardman, University of the Witwatersrand also provided valuable assistance in tracking down literature on this topic.

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Introduction

The occurrence of explosions in South African coal mines, together with the consequent loss of life and injuries has been well documented (Phillips and Brandt, 1995). Since the first recorded explosion in 1891, 350 incidents have caused the death of some 1100 coal miners, while a further 560 have been injured.

Although it would appear that the risk of explosions has been a long-term problem, without significant improvement, there have been vast changes in the number of men employed underground, the annual tonnage produced and the mining methods used. Improvements in safety measures have reduced some risks, while other problems have arisen as a result of the deployment of new technology. In particular there has been a steady increase in the number of frictional ignitions following the introduction of continuous miners in the early 1970's and an equally noticeable decrease in the percentage of incidents caused by blasting. A study of the sources of ignitions in South African collieries (Phillips, 1995) has provided the data reproduced in Table 1.1, which shows that, in the period 1984-93, 68% of all incidents, for which the cause was determined, were the result of frictional ignitions.

The conclusion that friction at cutter picks is the major sources of ignitions is further re-inforced by the finding that 80% of incidents occur at the working face and that 66% of all incidents are at the face of bord and pillar operations.

During 1995 a SIMRAC project was undertaken to identify methods to reduce the risk of explosions and fires caused by frictional ignition hazards (COL 226). The final report (Phillips, 1996) showed that the situation in South Africa is no different to that in the United States, the United Kingdom or Australia. As an example, the data given in Table 1.2 shows that in New South Wales a total of 23 ignitions of methane occurred in the period 1 July 1987 to 31 December 1993.

**Table 1.1 Sources of ignition in South African collieries
for the period 1984-93**

SOURCE OF IGNITION	IGNITIONS	EXPLOSIONS	TOTAL	% TOTAL
FRictionAL				
CM Picks	8	3	11	44
CC Picks	2	0	2	8
Shearer Picks	1	0	1	4
Stone on Stone	3	0	3	12
TOTAL	14	3	17	68
FLAME/HEATED SURFACE				
Blasting	0	2	2	8
Spontaneous Combustion	0	1	1	4
Heated Surfaces	1	0	1	4
TOTAL	1	3	4	16
ELECTRIC				
Electric Sparks	1	2	3	12
Lightning Stray Currents	0	1	1	4
TOTAL	1	3	4	16
OVERALL TOTAL	16	9	25	100

The data for New South Wales shows that all types of frictional ignition account for 20 of the 23 ignitions and that friction generated during the cutting action of machines operating at the face dominate the statistics with 16 out of 23 ignitions or 70% of incidents.

The SIMRAC project (COL 226) involved reviewing the enormous quantity of literature that has resulted from nearly a century of research into the phenomenon of frictional ignition of methane. Three distinct mechanisms were identified involving metal on metal, rock on rock and cutting tool on rock ignitions. Of these cutter tool ignitions were regarded as the most important in coal mining. By comparing the results of the international literature survey with a review of whether machines currently used in South Africa comply with known principles for reducing frictional ignition risks, it was possible to produce recommendations for improving the situation.

Table 1.2 Reportable ignitions of methane gas in NSW underground coal mines 1/7/87 to 31/12/93

TYPE OF INCIDENT	NUMBER
Continuous Miner Drum Picks	12
Continuous Miner Shovel	1
Continuous Miner Cable	1
Longwall Shearer Drum Picks	4
Rock Fall In Goaf	1
Cutting and Welding Operations	1
Roof Drilling/Bolting Operations	2
Filling Abandoned Shaft	1
TOTAL	23

The main results of the very considerable body of research that has been devoted to cutter pick ignitions indicated four very important conclusions:

- 1) For a frictional ignition to occur cutter picks must come into contact with strata containing either quartz or iron pyrites. Quartzitic rock must contain at least 30% of fairly coarse quartz grains before the risk of ignition becomes significant. It is, therefore, possible to use petrographic and other analytical techniques to undertake a risk assessment of any site where a machine is to be deployed.

- 2) The sources of frictional ignitions are not sparks but smears of melted quartz that are left on the rock surface as a result of rubbing friction. The risk of frictional ignition rises rapidly when worn tools, which need higher cutting forces and more energy of cutting, are used. It follows from this that one of the most effective precautions against frictional ignitions caused by shearers, continuous miners and coal cutters is to maintain picks in good condition and to change them before they wear excessively.

- 3) Research has shown conclusively that reducing pick speed reduces the risk of frictional ignitions because the length of hot spot also decreases. Because the performance of longwall shearers tends to be limited by the rotational power available to the drums rather than the haulage force, it has been possible to

reduce drum rotational speeds significant, with some machines operating at 19 rpm. The consequent reduction in pick speed has very probably had a major impact on the frequency of frictional ignitions caused by shearers. Continuous miners, on the other hand, tend to be limited by the thrust generated between their tracks and the floor. Experience with modern, heavy continuous miners has shown that rotational speed can be reduced, certainly to 37 rpm, with no adverse effect on production and improved dust readings. However, with a 1 m diameter drum this would still produce pick speeds of nearly 2 m/s, i.e. well above the 1 to 1,5 m/s at which the frictional ignition risk starts to diminish. At the present time, there appears no prospect of continuous miners being manufactured with the required rotational speeds of below 20 rpm.

- 4) The most effective means of preventing frictional ignitions during cutting is to spray water directly behind the pick, parallel to its direction of travel. This quenches the hot spot within the lag time for methane ignition, provided such important criteria as quantity, droplet size and to a much lesser extent minimum water velocity are met. Research has produced proven designs of suppression systems to be used in conjunction with all common types of pick. For many years cutting drums on longwall shearers and some roadheaders have been equipped with phased water supplies, to supply nozzles in front of and behind individual picks. However, wet heads are not yet in general use for continuous miners because of technical problems associated with large-diameter rotary water seals.

The report of Project Col 226 made a total of six recommendations, two of which are the subject of further SIMRAC sponsored research. In addition to work currently being conducted by CSIR - Miningtek to produce training aids for the prevention of frictional ignitions, the recommendation that "interested parties" monitor the progress of the development of wet-head cutter drums for continuous miners has resulted in the present project.

2. The history of wet-head continuous miners

Wet-head continuous miners i.e. with water available on the rotating cutter head, were first manufactured in the 1970's and tested as part of a research programme to reduce respirable dust levels. The work was sponsored by the United States Bureau of Mines and largely undertaken by that agency. Joy, Jeffrey and Lee-Norse continuous miners, Jeffrey and Wilcox auger continuous miners and longwall shearers were all subjected to underground trials in the period 1974-76 (Strebig,1975). Although it was recognised that water supplied directly behind the picks could significantly reduce the risk of frictional ignitions, the main thrust of the programme was concerned with dust reduction.

In general, these early tests showed reductions in dust levels from as much as 56% to as low as 13%, with one machine actually showing an increased dust make. The tests also identified two problems with wet-head drilling: -

- a) the seals then available were unreliable and resulted in considerable leakage,
- b) the nozzles were prone to blockage because of the quality of mine water, lack of adequate filtration and because rust and metal particles inside the continuous mines contaminated the water, even after it had been filtered.

By the end of the 1970's it was generally accepted that the attempt to produce wet-head continuous miners had failed and that until better seals became available and a proper water supply could be ensured no real progress could be expected. A 1980 report on the wet-head miner states "Unfortunately, proper water supply is a sadly neglected area in many mine sections. Available water pressure is sometimes too low, but generally the failing is more a lack of sufficient cross-section - pipe size, hose size, fitting size, are all too small, both in the supply to the machine and on the machine itself. Even if sizes were adequate when equipment was new, smaller sizes are often substituted when repairs are made. The trailing hose in particular, due to its length, will contribute a large pressure drop if too small". Despite these problems the USBM continued its interest in wet-head cutting and sporadic attempts were made throughout the 1980's to interest the mining industry in this concept. Probably the most serious of these was at the Keystone, No 2 Mine in West Virginia (Merritt, 1987).

At this mine adequate provision was made for clean water supply to the machine but the central problem confronting the successful application of the wet-head miner was the inability of the water seals to stand up to the vibration during cutting. The large diameter, lip-type seals could be totally destroyed by the abrasive nature of the water due to the ingress of particles whenever the trailing hose was lengthened or repaired. In addition, scale from the pipe walls also added to the abrasiveness of the water in the system. Perhaps the greatest problem of the early seal types was the tendency of machine operators to let the machine run dry if inadequate supply of water occurred, rather than stop production to fix the situation. This could in a matter of minutes, burn up the seal.

The trials at Keystone, No 2 Mine, were conducted jointly by the USBM and Acco Mining Sales and involved fitting a Lee Norse 265 continuous miner with two 150 mm diameter seal cartridge units from Canning Seals Ltd., to feed water to both the centre drum and the two cutter drums. These ring type seals, each enclosed in a stainless steel housing, could be run dry for protracted periods (up to 1000 hours) without any damage and because they were installed as a cartridge required no precise alignment while being installed on the machine. A further improvement over the 1970's design was that the seal was mounted outside the gearbox housing, so any leakage would merely go to atmosphere and not contaminate the gearbox and bearings.

By late 1987 it was being reported that these trials were a success. Over a six month period the wet-head machine out-performed the four other continuous miner sections in production per shift without incurring any undue extra maintenance. This performance occurred in mining the 2 m high Pocahontas No 3 seam on a two shift per day basis and included the cutting of a 250 to 750 mm thick shaley sandstone intrusion. The main reason quoted for improved performance was the improved visibility for the machine operators, who reacted very positively to the wet-head because it reduced visible dust very significantly. It was also reported (Merritt, 1987) that in the six months of operation, this machine was not involved in any frictional ignitions, despite the fact that this mine had a history of frequent ignition occurrences.

Despite the interest in both the 1970's and the 1987 trials of wet-head continuous miners, there is a total lack of further literature indicating progress. This surprising state-of-affairs is, in fact, explained by comments from the machinery manufacturers who have indicated that the high cost of producing wet-heads (including the cost of sophisticated seals) met with resistance from the coal mining companies and despite inquiries during the early 1990's no wet-heads were ordered until late in 1994.

3. Contact and communication with overseas mining companies, research institutions and manufacturers.

The following companies and establishments were known to have been or currently are involved with at least some aspect of wet-head cutting:-

1. Consol Coal, USA
2. D.M.T., Germany
3. Eickhoff, Germany
4. Hydratool, U.K.
5. Joy Mining Machinery, USA
6. Powercoal, Australia
7. USBM / NIOSH, USA
8. Voest, Alpine

This is not an exhaustive list but does give a good cross-section of representation. The first seven were happy to correspond or arrange for a visit to be made to discuss wet-head cutting and to see equipment. Unfortunately Voest felt that their system for roadheaders was already well developed and the information was all of a proprietary nature. The discussions with each of the other organisations are summarised below and a list of contact names, addresses, etc. is given in Appendix 1.

3.1 Consol, Inc.

This company is the largest producer of coal from underground mining in the United States, currently operating a total of 24 mining complexes, of which 20 involve underground operations. In 1996 Consol produced approximately 72 million tons of coal, of which 14 million tons were exported outside the United States.

Consol have been interested in applying water to the cutting drum of continuous miners since 1990. Initially the idea was to apply high pressure water ahead of the cutting pick in order to assist with cutting by reducing pick forces and also wear. The first attempt to apply water used polymer seals manufactured by Balseal. It

was found that unless the water was extremely clean and the seals were well protected against the ingress of dust, then seal life was too short. Other problems with the first design were the need to develop spray nozzles that didn't plug and a configuration on the cutting head that would allow better access to the seals.

In 1992 Consol approached Joy Manufacturing regarding a wet-head machine. Joy submitted a design but the machine was never built. Jeffrey was also approached and came back with a design for a double-drum i.e. inner, void and outer drum, with water filling the void. There were three problems with this design - the additional weight of the water, large diameter seals and the fact that the seals were to be buried in-board of the cutter motors. Consol worked with Jeffrey for 6 to 8 months. Consol then went to Eimco, who had already (about 1988) designed a wet-head machine for Jim Walter Resources. Their seals were much smaller and were mounted out-board to assist with maintenance i.e. water fed in at both ends moving towards the centre of the drum. At this time (early 1994) Consol had two Eimco machines ready for rebuild, so the decision was taken to build wet-heads. The Eimco design involves cartridge assemblies for the seals, which can either be elastometric or face plate (mechanical). The first head was completed late in 1994 with one seal of each kind (for performance comparisons). Both types of seal performed well, since dust ingress was prevented by good design.

The second wet-head built used elastometric seals which gave problems. Analysis of the seal material showed faulty manufacture (i.e. material properties). These were replaced and have worked successfully ever since. This machine went into service in 1995.

Problems are constantly experienced with the sprays becoming clogged and filtration is required at the back of each nozzle. Consol first used Hydra Tool nozzles with a cartridge filter behind the nozzle but any manufacturing debris left in the drum pipework quickly clogs the sprays. In practice the Kennametal cartridge has been found to be better because it is easily removed i.e. a staple-lock fitting.

Since these two machines were introduced (both are at the Buchanan Mine in Western Virginia) there has been one frictional ignition while cleaning a slab of roof material that had fallen on the floor. While it is difficult to be precise, it is felt that both machines would have had at least six frictional ignitions since their introduction

if they hadn't been equipped with wet-heads. An adjacent mine, also operated by Consol, is in a very gassy area with sandstone roof, and is currently experiencing 3 or 4 ignitions per week.

The mining crew are very happy with the wet-head CMs and this is generally related to the spectacular reduction in dust and improved visibility.

3.2 D.M.T., Germany

D.M.T. (German Mining Technology) is the research, development, consultancy, testing and instrumentation company within the Cubis Group, which deals primarily with coal mining. However, the current situation within the German hard coal industry, where 50 Mt p.a. is produced by 81 000 employed at 19 coal mines is the subject of a review, with the expectation that there will be a very significant reduction to as few as 6 remaining mines.

D.M.T. was involved with Voest-Alpine in the development of the aero safe jet system, where compressed air and water are used together to reduce the risk of frictional ignitions. This system has proved effective in extinguishing methane burning on flat surfaces (such as the coal face) and a new programme of experimental work is about to commence which will concentrate on rough surfaces e.g. a pile of loose coal on the floor. The effectiveness of adding small quantities of water to the air will be tested further as part of this programme.

It is surprising but in Germany there is no general requirement for frictional ignition suppression on longwall shearers and the hollow shaft venturi is not favoured. However, ventilation requirements on longwall faces are high and wet drums are used, with the water being provided for dust suppression.

Headings which are to be excavated by roadheaders are divided into three categories. The present requirements for these are:-

Class I $\leq 0,3\%$ CH₄ in general body of air.
 No in-line sprays required.

Class II $\geq 0,3 \leq 0,8\%$ CH₄
In line sprays required.

Class III $\geq 0,8\%$ CH₄
In line sprays required plus devices such as aero jet or spray bars on fixed part of the machine.

A description of how these requirements can be achieved in practice on a Voest - Alpine roadheading machine, together with test results has been published (Junker, 1996).

Changes in German legislation are currently being prepared and in future only one class of heading will be recognised, incorporating the most stringent requirements. The tough new regulations will require continuous monitoring of water pressure and flow to the frictional ignition suppression system, with the data being transmitted to surface. In addition purpose designed ventilation and air moving systems will be required on the machine boom and a misty water curtain must be maintained whenever the machine is cutting.

There is at present some flexibility in the type of spray used for frictional ignition suppression but typically all manufacturers choose sapphire nozzles with an 0,8 mm diameter orifice and a 25° cone angle. These sprays deliver about 3,2 l/min of water at a pressure of 125 bar.

3.3 Eickhoff, Germany

Eickhoff was founded in 1864 as an equipment supplier to the local mining industry in the Ruhr. The company currently has a workforce of 650 and a turnover of DM180 million, with DM100 million being in shearer sales, DM30 million in gearbox production, DM20 million in roadheader sales and the remainder in sales of conveyors, castings, coke plants and underground locomotives.

The roadheaders have the option of a wet-head and also compressed air on the head, with or without water. Most have additional water jets on the body of the roadheader to dilute the methane and to cause local circulation of air. The external sprays operate at 150 to 200 bar. The transverse head machines use a phasing

system but in-line heads do not. Both types can have pulsed water supply which is supposed to be just as effective but water volume can be cut by up to 50%.

Traditionally shearers have been supplied with water at 100 bar to the machine resulting in a spray pressure of about 70 bar. In Germany water is supplied to the back of the picks but no pick face flushing or hollow shaft extraction units are used.

Eickhoff had, until two years ago, a product line of 14 shearers. The company has since been restructured and rationalised, the workforce slimmed down and the workshops re-organised. They now have two shearers available - the SL 300 and SL 500. On previous machines water was fed through the planetary gearboxes in a static tube with the seal on the face side of the machine. Seal life was meant to be 6 weeks to 3 or 4 months but in many German mines was as low as 3 weeks due to the poor water quality. Water flow rates of 60 ℓ/min per drum were typical but did depend on drum diameter. In low seam shearers such as the EDW-300-LN the leading drum had water phased for 210°, while the trailing drum had 15° at both top dead centre and bottom dead centre.

The modern shearers (SL 300 and 500) have d.c haulage or a.c. with, in Germany, the option of eddy current coupling. This results in the need for cooling. At present machines are supplied with water at 100 bar and typical consumption is 225 ℓ/min. Most of this is, however, reduced in pressure to 20 bar before going through the motors and eddy current coupling (if present). If all water is sent to the drums then the high pressure water goes to the end-rings with the low pressure supplied to the rest of the drum body. However, in the wet conditions found in Germany mines the low pressure water is often returned directly to the mine's reticulation system.

Since shearers have between 35 and 55 picks per drum, water sprays per pick use about 2,25 ℓ/min each or less.

The SL 500 supplied to the Saar coalfield accepts its water supply at 18-25 bar and has an on-board pump capable of supplying 100 bar at 200 ℓ/min or 200 bar at 100 ℓ/min. The standard sprays operate at 18-25 bar but the dust extraction drum (rotary air curtain) requires water at a pressure of 100 bar. The seals in Eickhoff shearers are the same as those in the Joy shearer - both come from the United Kingdom.

Eickhoff report that drum rotational speeds have increased in recent years as the requirement for higher cutting speeds has become obvious. The lowest drum speeds 10 years ago were 23 rpm but these have steadily moved upwards to 36 rpm for a 1600 mm drum, with 3 picks per line. The highest number of picks per line known is 6, on a 2,4 diameter drum in Australia.

Eickhoff are unhappy about the increased drum rotational speeds, particularly with the large diameter drums, as they appreciate the increased risk of frictional ignition. However, they manufacture to the specification of clients.

3.4 Hydra Tools International (Pty) Ltd., U.K.

A visit was made to Hydra Tools International's plant in Sheffield, U.K. in January 1997 and a further meeting arranged in South Africa in October 1997. Hydra Tools International PLC is the successor to the long established mining supply company Hall and Pickles. Since being established in 1988, the company has expanded from tool production to drum manufacture through the acquisition of Green and Bingham Ltd. and has also consolidated its position by the purchase of competitor companies such as Hoy Mining Tools.

Hydra Tools International have been involved in the design of wet-heads for continuous miners since the early 1990's. The first application was at Cleveland Potash PLC, which was a good test site close to their factory. Because potash mining needs the minimum of water (potash is soluble), a phased water supply system was used and water jets applied for dust suppression. The second head supplied was for use at the Jim Walter's Resources No 7 mine in the United States. This is a very gassy mine and current operations in the Blue Creek seam involve cutting nearly 1 m of sandstone in the floor. As the compressive strength of this rock is approximately 100 MPa, the Joy 12 CM was equipped with a rock cutting drum, with radial picks.

The third wet-head drum supplied by Hydra Tools was for Matla No 3 Mine. Again this was equipped with radial picks but when installed in November 1996 failed to achieve production targets and was withdrawn for modification. This included changes to the spacing of the picks, the design of the tool box and the type of pick. Although radial picks were retained their shape was made approximately the same

as conical picks. Hydra Tools have the philosophy that in the event of a pick failure, the radial pick and holder give a much better protection to the spray and spray mounting than can be provided by a conical pick assembly. In addition to redesigning the head, the initial trials of the retrofit head on a HM machine showed that because of seam height the original 200° of water phase needed to be increased to 240°. With the drum at the top of its cut, the lower 30° of contact was cutting dry, with both the risk of an ignition and the creation of a great deal of dust.

The redesigned head has been involved in three further trials at Matla in 1997. At No 1 mine it was used in the approach to a dyke and for about 6 weeks in normal production. The seals and wet-head arrangements worked well but this second trial was terminated when the water hoses to the cutting drum were snapped off. It is believed that the wet-head was transferred to Matla No 2 mine late in 1997.

There are four further points that emerged at the October meeting with Hydra Tools:-

- a) their wet-head in the United States is still in service and doing well.
- b) their in-house test programme and work at Cleveland Potash indicates seals should last at least 3 000 operating hours. The two end seal assemblies take no more than two hours to replace while the middle one takes up to a shift to change.
- c) in the United Kingdom the leading coal producer, RJB Mining, is under increasing pressure to produce a Code of Practice for Frictional Ignition Prevention for Continuous Miners. Since wet-heads are required for longwall shearers and roadheads, the expectation is that a similar wet-head should be standard on continuous miners. Hydra Tools have assisted with this effort by producing a wet-head for a 12 CM 5 which will be tested by IMCL at Bretby as soon as a machine becomes available.
- d) although Hydra Tools are reluctant to discuss the cost of a retrofit wet-head drum they do indicate that they could supply a complete system at "well under \$90 000".

3.5 Joy Mining Machinery, USA.

Joy Mining Machinery, a division of Harnischfeger Industries, Inc., is the world's largest supplier of continuous miners. A visit was arranged to their plant at Franklin, Pa. Joy have been involved with wet-head development since the early 1970's but have not pursued it vigorously because customers have always indicated that they are unwilling to pay the additional costs.

At present Joy have one prototype wet-head continuous miner in use. The machine was originally built for a Jim Walter Resources mine but they were unwilling to accept delivery because of the increased cost of the machine. Eventually this machine was supplied to A.T. Massey's Clean Energy Mine at Sydney, Ky. Although designed for frictional ignition prevention, the head was modified at the request of the new client to provide better dust suppression.

The Joy wet-head has been designed using the British Coal protocol for heading machines (James and Band).

The pick-boxes each have a cylinder welded on the back face of the block with the spray protected inside. The specification for the cylinder material was a very hard stainless steel but the material actually used was much softer. In practice the miners roll the CM head on the ground to rotate it slowly for pick changes and this has resulted in distortion of these cylinders with the result that sprays could not be changed.

The sprays used were from Minnivation and produced a 20° solid cone spray using 1,36 l/min at 690 kPa. For the prototype machine this resulted in a water use of 106 l/min. When the client asked for dust suppression, Joy used 80° hollow cone sprays but mounted in the same cylinders i.e. behind the picks.

Following several manufacturing problems (problems with gearcase quality) the machine went into service in April 1996. After 3 weeks water leaked into the gearcase, contaminating the oil. The machine was returned to Franklin and took 2 months to rebuild. During trials it was found that the sprays choked and a better filter system was added (most of the foreign material was from the manufacturing process).

In September 1996 the machine went back into service and worked well until early January 1997 when it developed an oil leak totally unrelated to it being a wet-head. Since then it has been back to Franklin for a major overhaul during which the cylinder spray housings have been replaced by heat-treated ones.

Joy engineers are particularly pleased with the performance of the large rotary seals, which have survived the trial period intact. The rotating water seals are supplied by a U.K. company A.E.S. Engineering Limited at a cost of \$25 000 a pair. This seal has been chosen because it should last the life of a gearcase, approximately 18 months with the tonnages typically being mined. The 60 μm filtration of incoming water works well and protects both the seals and the sprays.

Joy shearers have wet drums with sprays mounted on the drum vanes to provide dust suppression (on pick face) and ignition suppression. However location of sprays is somewhat inaccurate at times. The sump shearers supplied to Australia for single entry development have the conventional shearer drum technology.

A recent order from Russia for 10 continuous miners has wet-heads specified but interestingly the U.K. market, which has been quite active as CM's are introduced, had not yet (April 1997) required wet-heads although some interest has been shown. (c.f. the comment in Section 3.4 above that the U.K. inspectorate has become active in this area late in 1997).

It is seen by Joy that in the U.S.A. the main attraction of wet-heads is for dust control. The current cost of this feature is \$95 000 and would be regarded as too expensive to protect against a very small risk of frictional ignitions (despite the fact that on-board suppression systems were abandoned because of the large number of small ignition causing false activation's). However, if the wet-head proves effective for dust suppression and the use of flooded bed dust scrubbers can be eliminated, their cost of \$60 000 - \$70 000 can be off-set against the wet-head cost making it much more attractive.

3.6 Powercoal Pty Ltd. NSW, Australia

Powercoal is the largest underground producer of coal in New South Wales. Because of their active involvement in the International Committee for Coal Research (ICCR), Powercoal are aware of the previous SIMRAC research into frictional ignition problems, which is of particular interest to them.

Powercoal is committed to using wet-heads on their continuous miners once the concept is proven. They have planned an underground experiment in 1998 to mount a Jeffrey wet head on a Jeffrey machine and to cut conglomerate roof in a well ventilated section of one of their mines. The purpose of the experiment will be to measure the hot spot, with and without the use of the water sprays. Infrared measurement techniques will be used and, if the hot spot temperature falls below 350°C i.e. a factor of safety of about 2 for the ignition of methane, production wet-heads will be purchased.

The cost of the Jeffrey wet-head is quoted as nearly A\$ 200 000 and the experiment, involving assistance from the University of New South Wales, will add considerably to the hardware costs. This project is the subject of a funding application to the Australian Coal Association Research Programme.

3.7 USBM/NIOSH

The United States Bureau of Mines has now officially closed and the remaining components have been incorporated into the National Institute for Occupational Safety and Health (NIOSH), an organisation with a total staff of about 1300 personnel. NIOSH, in turn, is part of the Centres for Disease Control and Prevention (CDC) within the Department of Health and Human Sciences (DHHS). Mine related research is conducted at the Pittsburg Research Centre where approximately 550 people are employed and at Spokane, Washington where there are approximately 50 staff. This means that the USBM staff of 1700 has been reduced to about 600. However, the core programmes of safety and health research are virtually unimpaired.

Work on the frictional ignition problem is conducted within the Explosions, Fires and Explosives group, which consists of 27 professionals and about 10 support staff.

However, no major effort in the frictional ignition field has been mounted since 1992 as it is felt that all the basic research is complete. The Centre still maintains an experimental rig consisting of a rotating drum in an enclosure, with sufficient available torque to use a single pick to cut sandstone. Rotational speed is variable from about 20 to 40 r.p.m. and the rig is occasionally used to provide a demonstration for visitors.

In early 1994 a one day "forum" was held for visitors invited from the Coal companies and machine manufacturers to present a precis of the USBM's research findings on frictional ignitions. Although, at the time, it was felt that interest was low, since that forum machine manufacturers have been active in designing and marketing wet-heads. In fact, several manufacturers have been back to the USBM/NIOSH to discuss progress and to seek some form of endorsement for their designs. Because of the upsurge in interest, NIOSH organised an open industry forum on November 18, 1997 to discuss progress on frictional ignition prevention and wet-head design. To indicate the degree of interest and to give further contacts, a copy of the programme and list of attendees is included as Appendix 2. The proceedings of this forum are unfortunately not yet available, but sufficient detail is given in Appendix 2 for individual authors to be contacted.

4 Current status of wet-heads

Although this project is mainly concerned with the development of wet-head technology for continuous miners, the scope of the original proposal and the title of this report requires that a brief report is also made on the current status of wet-head cutting drums for longwall shearers and roadheading machines.

4.1 Longwall shearers

The vast majority of shearers are produced in either Germany, the United Kingdom or the United States.

In Germany the manufacturer is Eickhoff, who now concentrate on two models, the SL 300 for seam heights between 1,4 and 3,5 m and the SL 500 for seam heights between 2 and 5,5 m. Although wet drums are not required in Germany for frictional ignition control, all shearers are, in fact, supplied with water to the drum for dust suppression purposes. The SL 300 relies totally on the water pressure supplied to the machine, while the larger SL 500 carries an on-board pump capable of accepting water at 18-25 bar and supplying 100ℓ/min to the two drums at a pressure of up to 100 bar. Both machines make use of phased water spray systems so that only the picks expected to be cutting are supplied with water, thereby minimising the use of water while maximising its effectiveness.

In the Eickhoff design water is fed to the rotating drums through a rotary seal located in the ranging arm and on the centre line of the drum. While previous shearer designs had the seals mounted on the face side, they are now in a readily accessible position on the goaf side and protected by a cover held on by four bolts. Eickhoff made all relevant drawings available showing the location and construction of the seal and water supply channels. Since the mechanical seals are about 20 mm in diameter they stand up well to vibration, can cope with dry running and tolerate dirt in the water reasonably well. Seal replacement is undertaken as and when necessary and is not viewed as a problem.

In the United States Joy Manufacturing use wet drums on their shearers mainly for dust suppression. Seal technology for the small diameter seals is not seen as a problem. When Joy positions sprays on a drum to meet the clients requirement for

frictional ignition suppression, they attempt to use the United Kingdom's requirements (Bretby criteria). Joy recognise the difficulty of correctly aligning sprays and are aware that this can be done inaccurately by themselves, drum suppliers and by mines themselves. Joy sump shearers have been supplied to Australia for roadway development and these machines are equipped with conventional shearer drum technology i.e. wet drums with a choice of spray locations.

In the United Kingdom the requirements for frictional ignition suppression are most stringent. The Codes and Rules (For) The Control of Frictional Ignitions On Shearers (Anon, 1993) run to 47 pages, containing precise specifications for the certification process for picks, pick boxes, drums and sprays.

The philosophy behind the U.K. Codes and Rules is that ventilation of the cutting zone by means of a machine-mounted ventilation device should be the primary method of protecting against frictional ignitions, while pick back flushing (PBF) sprays should be applied to give an extra level of protection. To provide for this second level of protection, all drums supplied to the British coal mining industry must incorporate facilities for PBF sprays irrespective of the intention or otherwise to use these sprays for ignition control purposes. The application of these sprays is mandatory on faces where the ventilation device is insufficient to provide adequate protection due to high methane emission rates. This is an extremely interesting concept i.e. ensuring that wet drums are available, with it being left to the discretion of the (brave) manager not to use the frictional ignition suppression sprays if he considers it safe to cut without them.

The quantity, quality and pressure for ignition control sprays are spelt out in detail in the Codes and Rules and are generally referred to as the Bretby requirements for Incendive Temperature Potential Protection (ITPP). In summary the requirements are :-

- a) All PBF sprays shall form a uniform solid cone.
- b) PBF spray nozzles must incorporate a filter within the range of 400 to 700 μm to protect the nozzle assembly from blockage.

- c) PBF spray nozzles must be designed to generate an adequate ignition control spray when supplied by water within the pressure range 7 to 19 bar.
- d) PBF spray nozzles must be clearly identified with respect to orifice size, by a standardised colour coding scheme. This should prevent misuse of nozzles for the wrong location on the drum.
- e) The maximum spray width (W) and Length (L) shall be measured on a plane set at the highest point of the steel body of the pick - XX in Figure 4.1. The distribution of water across this plane must be assessed.
- f) The leading edge of the spray shall, as a minimum, pass through and preferably below the base of the carbide tip on the leading edge of the pick - Point A in Figure 4.1.
- g) The length of the spray (L1) behind the pick shall exceed 40 mm
- h) The width of the spray measured across the plane XX at Point B shall be greater than twice the maximum width of the steel body of the pick measured across the seat of the carbide tip.
- i) An ignition control spray shall be deemed acceptable when :

$$\sigma P^{0.3} \geq 12$$

where σ = spray density (l/s/m²)
 P = spray nozzle pressure (bar)

The spray density is defined as

$$\sigma = \frac{Q \times 10^6}{15 \cdot \pi \cdot W \cdot L}$$

where Q = rate of water flow (l/min)
 W = maximum spray width (mm)
 L = maximum spray length (mm)

with both W and L measured on the XX plane

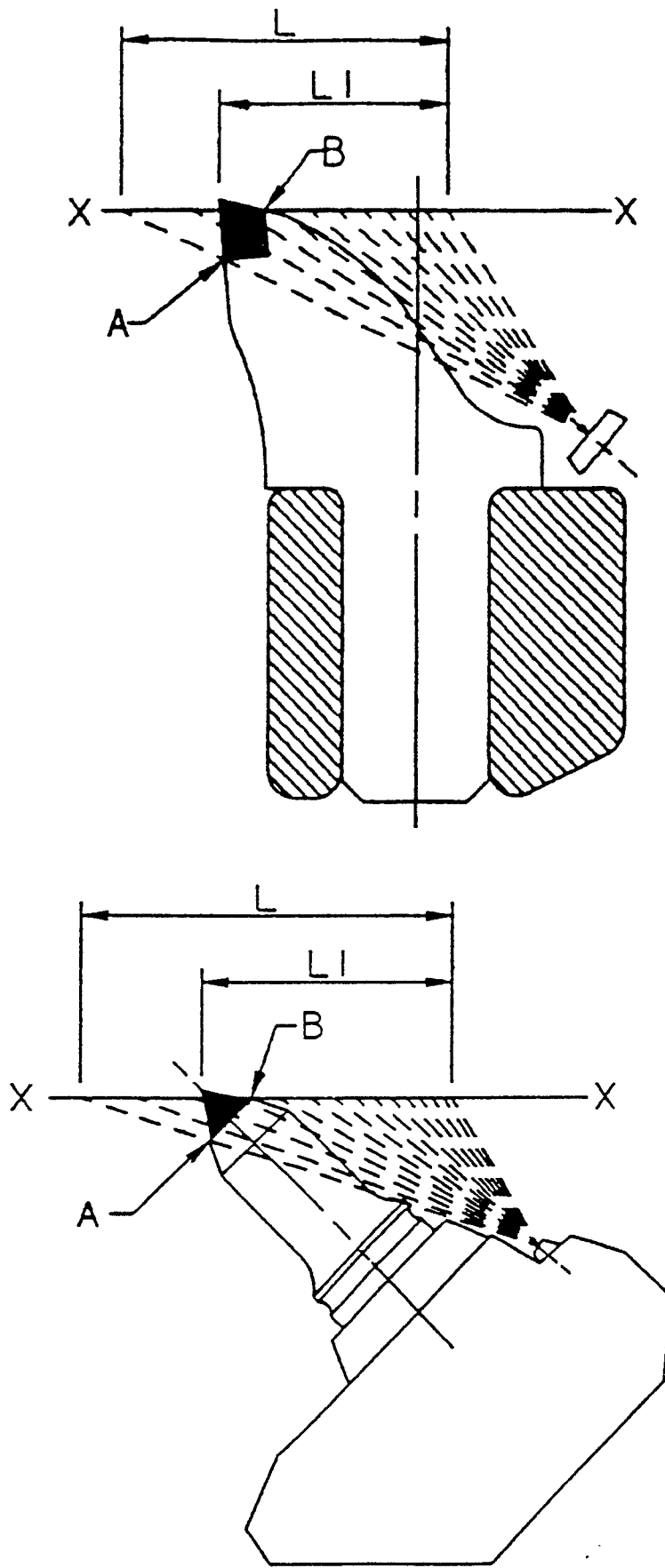


Figure 4.1 Diagrammatic representation of the parameters used in the "Bretby criteria" for ITPP.

- j) Where PBF sprays have been specified for ignition control purposes then interlocks, e.g. water flow and pressure switches, shall be provided to ensure the water flow and pressure are above the minimum prescribed whilst the shearer drum is rotating.

The Codes and Rules also deal with the commissioning procedures for PBF sprays, the need to record the water pressures and flows and the requirement to maintain these systems in an effective condition.

It can be seen from the above requirements that frictional ignition prevention by using water on shearer drums is taken very seriously and has been well researched over a considerable period. Since the basic requirements for nozzles, water spray patterns, etc. will be identical for continuous miners much of this work can be applied directly and machine manufacturers have taken advantage of this.

4.2 Roadheading machines

In the United Kingdom, where roadheaders have been used extensively for single entry development, the same philosophy is adopted as for longwall shearers i.e. the probability of a frictional ignition occurring is reduced by

- a) the supply of adequate ventilation into the heading to ensure methane is diluted to an acceptable level
- b) the use of local ventilation systems to provide air to the immediate proximity of the cutting element, and to prevent the formation of methane layers
- c) the use of water sprays correctly sited behind picks to cool hot material.

The three methods are listed in that order of priority in the notes for guidance on the topic (James and Band). Unlike the more detailed Code for longwalls the section on wet cutter heads does not indicate mandatory compliance but is mainly concerned with waterflow rates to the head.

The guidelines point out that provided similar water flow rates and pressures are used, then applying water to the back of the pick, rather than the pick face, does not impair dust control. The practice of applying water both in front of, and behind picks

is considered wasteful of water and is of questionable benefit. This guideline also incorporates research undertaken in the early 1990's which indicates that the same degree of frictional ignition protection can be achieved by trading water flow against increased pressure. The minimum requirements to achieve the Bretby criteria can be calculated for any design of pick, nozzle diameter, nozzle location and drum design. As an illustration one particular roadheader drum design incorporating 42 picks could meet the criteria in each of the cases given in Table 4.2.1.

Table 4.2.1 Alternative water requirements to provide Incendive Temperature Potential Protection for a specific design of roadheader

Case	Water Pressure Bar	Water Flow/Pick ℓ/min	Total Water Flow ℓ/min
1	4	2,3	95
2	10	1,8	77
3	19	1,5	64
4	39	1,1	50

Other developments in the United Kingdom have concentrated on using high pressure water jets on roadheaders to achieve the following:- improved cutting, longer pick life, reduced incendive sparking and better dust suppression. No real problems were experienced when the rotary seals were subjected to higher pressures but the quantity of water used at pressures of up to 700 bar can be excessive and lead to poor floor conditions. The use of phased water supplies becomes essential under these conditions and several systems have been used successfully (Anon, 1991).

The definitive work on roadheading machines has, however, been conducted in Germany by D.M.T. and published extensively in research reports (Marx, 1989) and in the literature (Junker, 1996). D.M.T. has undertaken research on behalf of the German regulatory authorities and has been active in developing frictional ignition prevention systems for companies such as Voest-Alpine, Paurat and Eickhoff.

The requirements for wet drum cutting in Germany have already been stated in Section 3.2 above. At present the wet cutting heads meet the requirements using one or more of the following systems

- modified individual pick controlled sprays
- sectorial controlled spray system (sector $\geq 180^\circ$)
- sectorial controlled spray system with pulsed water (sector $\geq 180^\circ$)
- air and water spray system with an all around spray system for longitudinal cutting heads
- sectorial controlled spray system (sector $\geq 180^\circ$) with air and water
- special water spray system for transverse cutting heads consisting of a bar with nozzles spraying from gearbox forming a misty water curtain around the head.

The modified individual pick control system is relatively new and requires some explanation. Each pickholder includes a valve. When cutting, the forces on the pick cause the shaft of the pick to move into the toolholder against the pressure supplied by a spring. This causes the valve to operate allowing a flow of 3,2 l/min of water at a pressure of 120 bars to quench the area immediately behind the pick. The additional modification in the system is, however, a small bypass that remains open even when the pick is not cutting. This allows a constant flow of 0,42 l/min from each nozzle and enables the system to be continuously monitored for blocked or washed out nozzles. The nozzles themselves now tend to be sapphire, which allows improved changing of the nozzle (only the tip is changed from the front side), less blocked nozzles and improved manufacturing quality.

D.M.T. have promoted the use of the "Combined Safety System", which consists of a modified individual pick controlled water spray system and air jet blocks mounted on both sides of the boom. This combined system has three advantages

- the high pressure water spray prevents hot spots forming in the trace of the pick
- the mist and compressed air cool down hot particles and sparks being emitted by the cutting head

- the large volume of air at high velocity dilutes the methane concentration commonly found in the pile of broken coal at the face.

The compressed air and water consumption rates for the various suppression systems in use in Germany are given in Table 4.2.2.

In conclusion, it is felt in Germany that sound and effective systems are in place to prevent frictional ignitions being caused by roadheaders even when cutting sandstone in gassy mines. However, at the most dangerous sites the inspectorate still insist on active on-board suppression systems to act as a second line of defence.

Table 4.2.2 Compressed air and water requirements for frictional ignition suppression on roadheaders in Germany.

System	Machine	Compressed Air		Water	
		Flow (m ³ /min)	Pressure (bar)	Flow (m ³ /min)	Pressure (bar)
Air and in-line water sprays	Paurat - E134	10,5	2,5	21	2,5
	Paurat - E200	17	2,5	28	2,5
	Paurat - E250	10,5	2,5	21	2,5
Sectorial controlled system	Paurat - E250	17,3	2	35,6	1,0
	Eickhoff - ET160			128	120
	Eickhoff - ET250			138	120
Sectorial controlled system with pulsed water flow	Alpine Miner 85			60	120
	Alpine Minor 105			74	120
Modified individual pick controlled spray system	Alpine Miner 85			25	120
	Alpine Miner 105			31	120
Special water-spray bar with side nozzles	Westfalia-WAV 300			51-65	150

4.3 Continuous miners

At present it is known that at least four manufacturers of continuous miners have wet-head machines available, either as production machines or as prototypes (Voest-Alpine and Eimco are regarded as separate companies, although both are part of Tamrock Coal). In addition Hydra Tool International PLC manufactures retrofit wet-heads.

a) Voest-Alpine

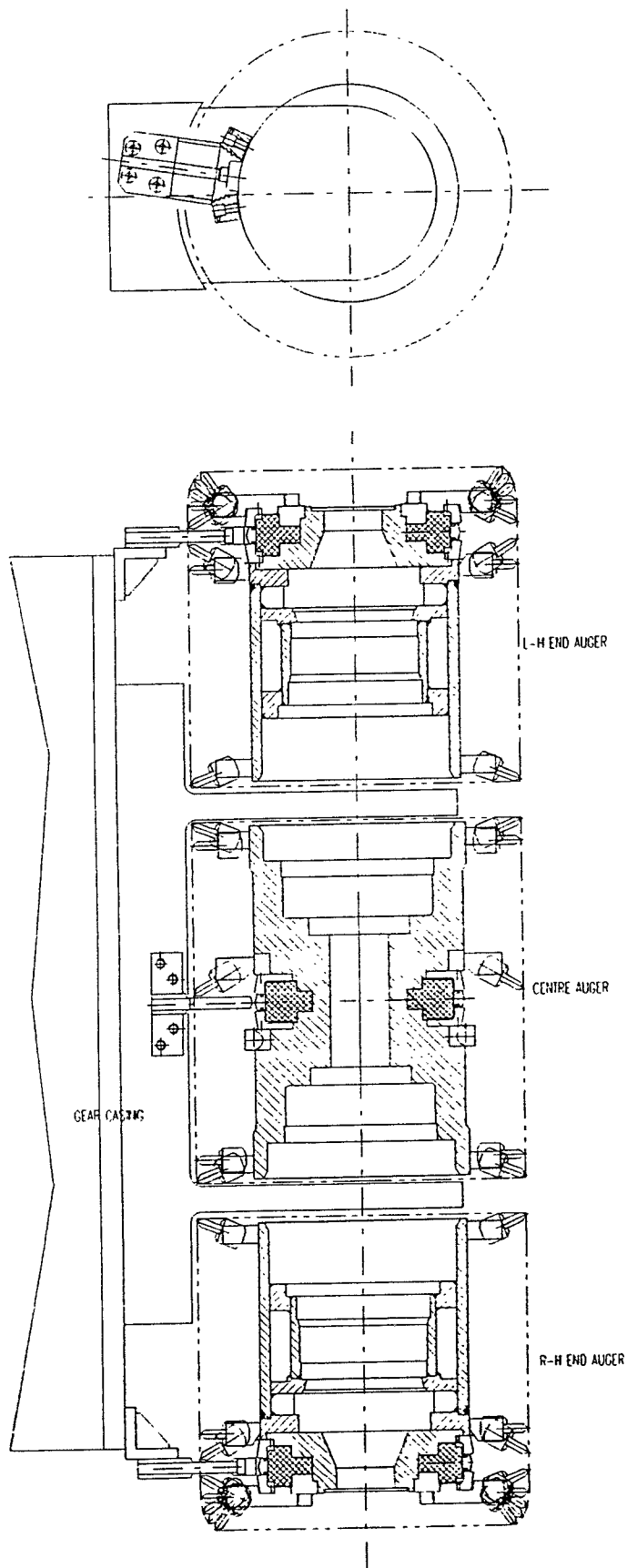
Voest-Alpine produces two continuous miners, the Alpine Bolter-Miner (ABM) 20 which has pick back flushing (PBF) sprays as standard equipment and the ABM 14, where PBF sprays are optional. Both models are commercially available and used in several countries. The amount of information on the water seals and spray system that is readily available is limited but it is known that the water supply is phased and that at a pressure of 10 to 12,5 MPa each spray delivers 0,9 ℓ/min of water. The machine has the facility to change water flow rate by controlling the pressure.

b) Jeffrey

Jeffrey were involved with the early trials of wet-heads in the 1970's and have worked on the concept of a wet-head continuous miner on several occasions but have not manufactured one in recent times. In the past few years they have worked with Hydra Tools to retrofit one of their miners at the Cleveland Potash Mine in the United Kingdom with a wet-head (see section 3.4 above). In the early 1990's Jeffrey also worked with Consol, Inc. in designing a wet-head miner but this was not built. However, Jeffrey have indicated that they would be prepared to build a wet-head miner if they could find a mining company willing to collaborate in developing a prototype (see Section 3.6 above).

c) Hydra Tools International (Pty) Ltd.

Hydra Tools have now produced three retrofit wet-heads - the prototype used at the Boulby Mine of Cleveland Potash, U.K., the head at No 7 Mine of Jim Walter Resources, U.S.A. and the head at Matla Coal Mine. Unlike most of the other systems, the Hydra Tool water supply system is external to the head. The location of the three water transfer seals is shown in Figure 4.3.1.



The drawing shows a plan view section of a typical hard head continuous miner, converted to the Hydraphase™ system. The water transfer arm, shown on the end elevation, is attached to the gear casing to form an integral part of the assembly. Similarly, a water transfer arm, provides the centre split head with a supply of water. The gap left by the introduction of the water transfer arms, is generally less than the bit spacing and consequently has no detrimental effect on the cutting efficiency of the miner.

Figure 4.3.1 Location of water transfer seals for the Hydra Tools system.

The philosophy behind the Hydraphase head, as it is known, has been spelt out in the design criteria, which may be summarised as follows

- the design of the wet-head system must be such that it meets “all the Bretby requirements” for Incendive Temperature Potential Protection (ITPP). This means it will have genuine frictional ignition and dust control characteristics.
- the system can be retrofitable to any type of continuous miner without the necessity for the co-operation or assistance of the OEM.
- in the event of a system failure, the following must be possible :-
the operator must be able to revert back to the original situation prior to the wet-head’s introduction, in order for effective mining to continue;
there must be no detrimental effect on the machine or the cutting drum;
the faulty component must be capable of being replaced on a maintenance shift underground with minimal disruption.
- introduction of the wet-head system should not impair the performance of the machine’s mining characteristics or create a major increase of it’s care and maintenance schedules.
- the ultimate objective is to design a system which will continue to operate effectively until such time as wear of the cutting head dictates its removal.

Hydra Tool have provided a great deal of data on their system and this is included as Appendix 3 of this report.

To date the main problems experienced by the Hydraphase system has not been in the water supply side but in the cutting characteristics of the drum. Hydra Tool believe strongly that sprays cannot be adequately protected behind damaged conical picks and use radial picks in their design, although in recent trials the pick shape chosen has resembled the profile of a conical pick. It is felt by Hydra Tool and Matla that the drum design will need further modification to give a cutting performance at least equal to conventional drums before the wet-head will be acceptable to the mine. Protection of the spray system is important as Joy have found to their cost (see Section 3.5 above).

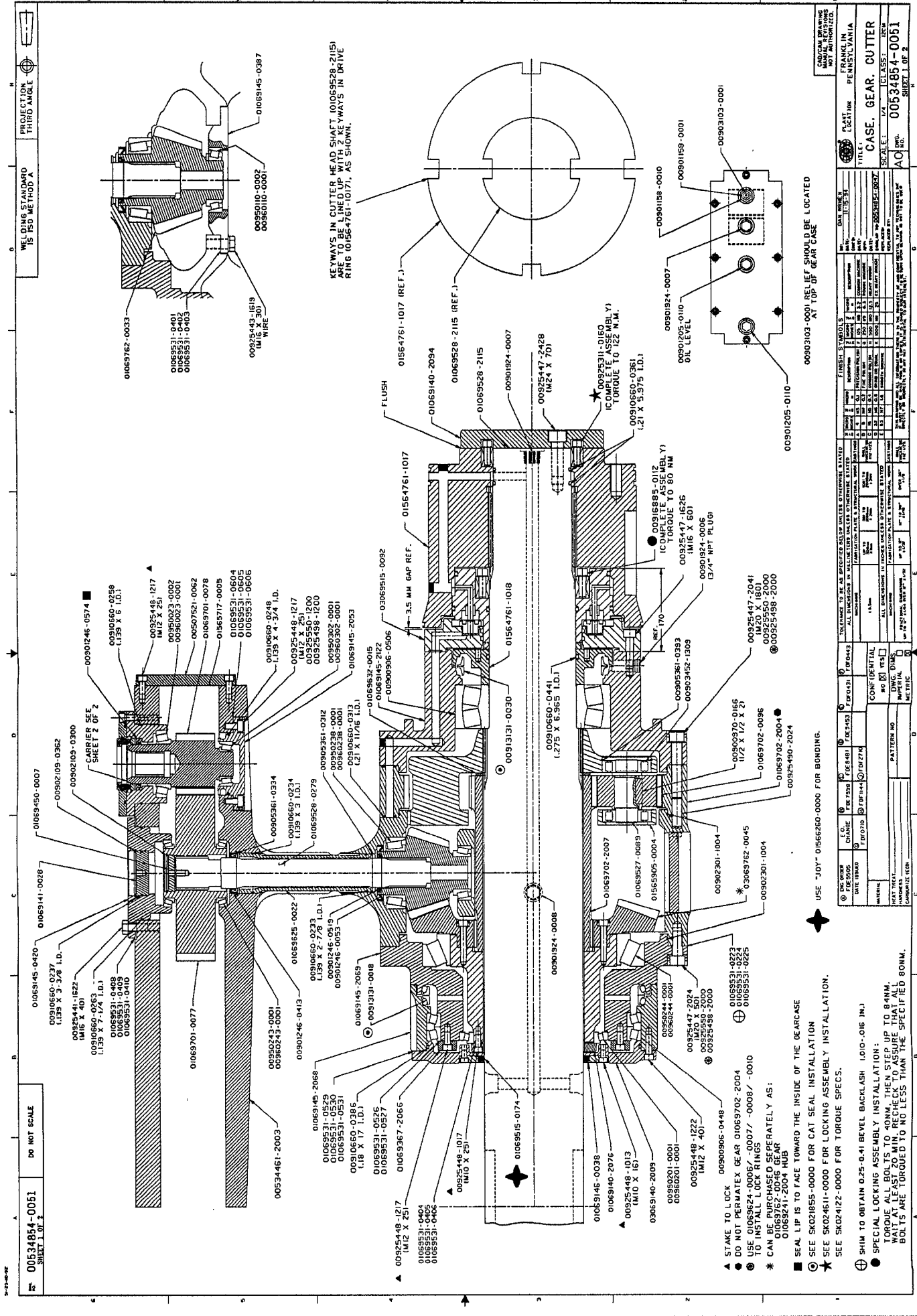
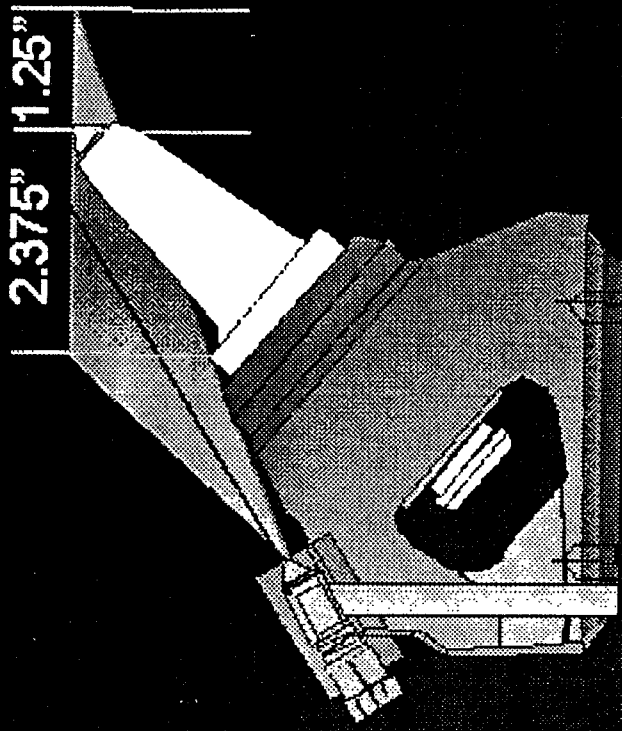


Figure 4.3.2 Location of the rotary water seal on the Joy wet-head.

Bit Block and Spray Arrangement for Wet Head Gearcase



Quick Disconnect Sprays for easy replacement or cleaning

Minnivation 20 ° Solid Cone Jet with Screen
0.34 GPM @ 100 psi

Joy Journal Pin machined for Spray Housing

Joy J30 or J25 Bit Block with Material Added to Forging

Flow Rate: 26.5 GPM for standard 10'10" head with 3" spacing, double scroll drums (78 blocks)

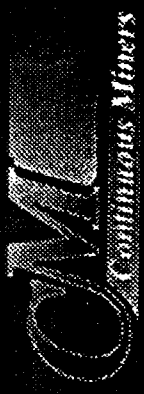


Figure 4.3.3 Diagrammatic representation of the Joy bit block and spray system.

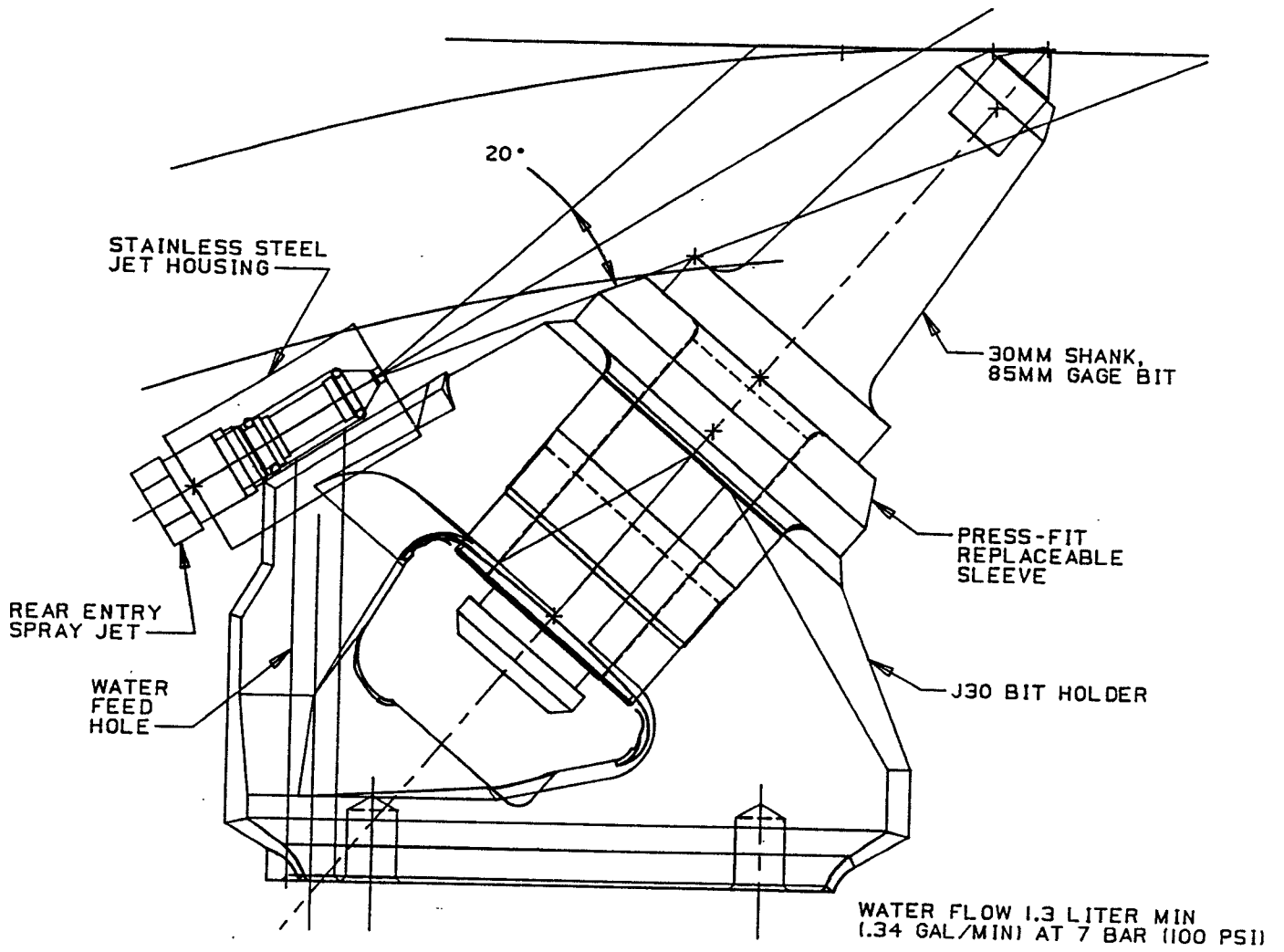


Figure 4.3.4 Diagram showing location of Joy spray in protective cylinder.

d) Joy Manufacturing

Joy is still in the early stages of developing a wet-head cutter despite having had one such machine in production for most of 1996. Perhaps the most important aspect of their experience to date is their confidence in the A.E.S. Engineering Ltd. seal. Although these seals are expensive at \$25 000 a pair (see Section 3.5), they have proved reliable in use. The location of the seals and the water channels is clearly shown in Figure 4.3.2, which was kindly supplied by Joy Manufacturing.

Joy have designed their Incendive Temperature Potential Protection (ITPP) spray system in accordance with "the Bretby criteria". Figure 4.3.3 gives a schematic representation of their system, while Figure 4.3.4 gives greater detail of the spray mounting on the back of the pick box. Despite the problems experienced with the stainless steel jet housing (Figure 4.3.4) being crushed, Joy believe that use of the correct grade of hard material can overcome this problem.

- e) Eimco, which is now part of Tamrock Coal manufactures continuous miners in Bluefield, West Virginia. Their present range of drum miners is called the Dash series, which is the successor to the well known 2810 series. The three models in the series cover three ranges of cutting heights

Dash One	1	-	1,9 m
Dash Two	1,2	-	2,4 m
Dash Three	1,5	-	3,4 m

By early 1997 four wet-head machines had been sold to Consol, Inc. (see Section 3.1) and Cyprus-Amax. According to Eimco and Consol these machines have been shown to be successful in controlling frictional ignitions, reducing airborne dust and increasing bit life. Apart from the use of faulty seal material on one machine, the large diameter seals have been reported to be successful in prolonged use in production. Eimco can also retrofit a wet-head on any of their existing miners during refurbishment.

Eimco list the most important aspects of their wet-head system as follows:-

- Double lip seals at water to oil areas and cat seal abrasive solid protection for water seals.

- Adapted to proven, reliable, existing cutterhead drive utilizing interchangeable mechanical face and u-cup lip seals. Seal material is corrosion resistant and the seal faces are wear resistant.
- Gearcase water passages and water seals designed for single seal, single gearcase, passage operation. Dual seal porting and routing allows for single seal operation at full flow by shifting external valve. External water seal leakage detection points and external water side lip seal lubrication ports.
- All gearcase water passages hard plumbed, corrosion resistant, o-ringed. Drum water channels incorporated into bit block base. Dedicated water supply on machine with improved filtration. Simplified end drum water routing through o-ringed removable tube and simple water hose connections to all drums.
- Recessed quick change stainless steel cone spray nozzles utilizing o-ring seals, staple retention and large integral filter screen.
- Seal replacement as a cartridge unit without gearcase disassembly. Seals have integral protective covers, installation plates. Mechanical face seal and U-cup lip seal interchangeable.

Unlike the Joy machine which transfers the water to the cutting head through one pair of seals, Eimco have elected to duplicate their system in order to allow wet-head cutting to continue even when one seal malfunctions. An external valve allows water to be applied to both channels (normal operation) or to either independently. This arrangement is shown in Figure 4.3.5, while Figure 4.3.6 shows greater detail for the right-hand seal.

The Eimco wet bit-holders are shown in Figure 4.3.7. From this drawing and the knowledge that each spray delivers approximately 0,9 l/min at 690 kPa pressure, it is almost certain that the frictional ignition suppression system will not comply with the "Bretby criteria". In particular, the lower edge of the spray will not pass below the lowest part of the carbide tip (Point A in Figure 4.1). There is, however, nothing to prevent the bit-holder being redesigned to achieve compliance.

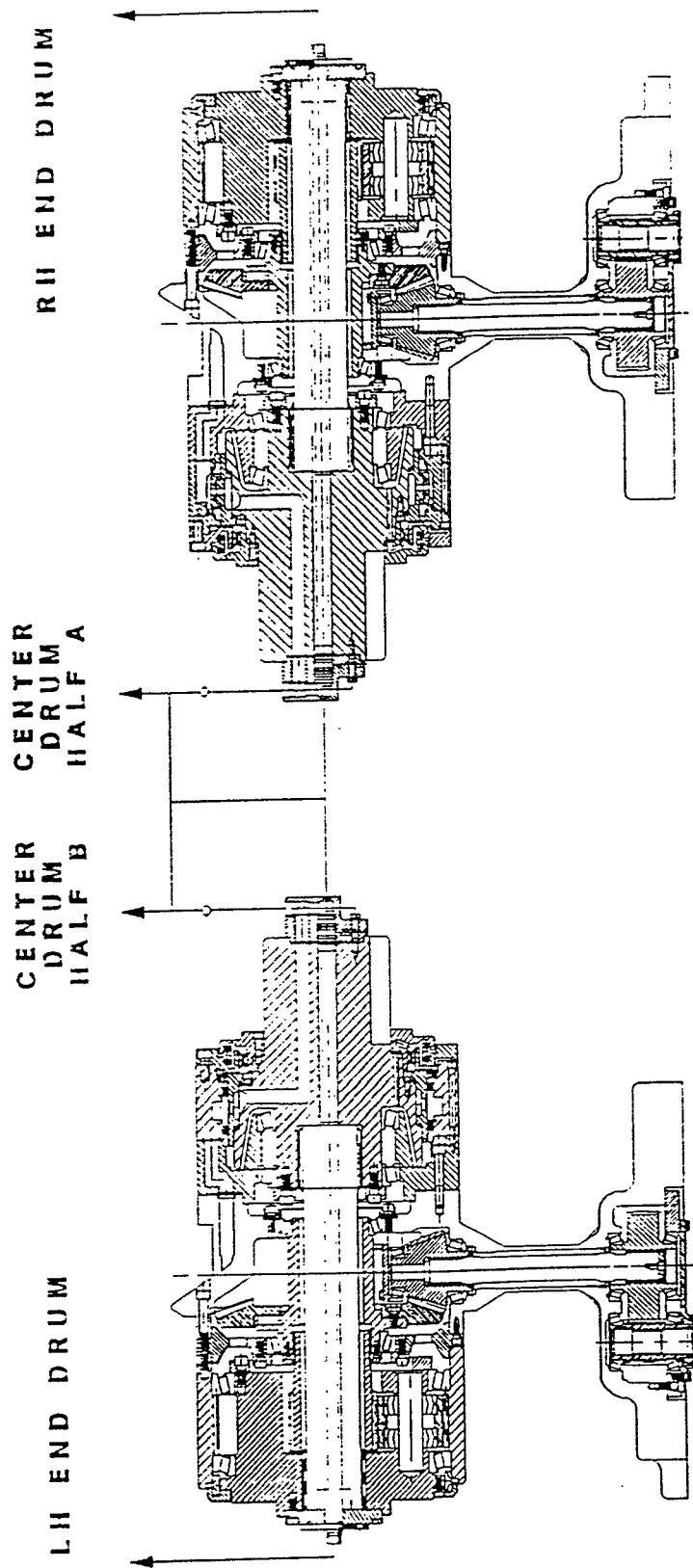


Figure 4.3.5 Duplicate water delivery system for Eimco Dash Miner.

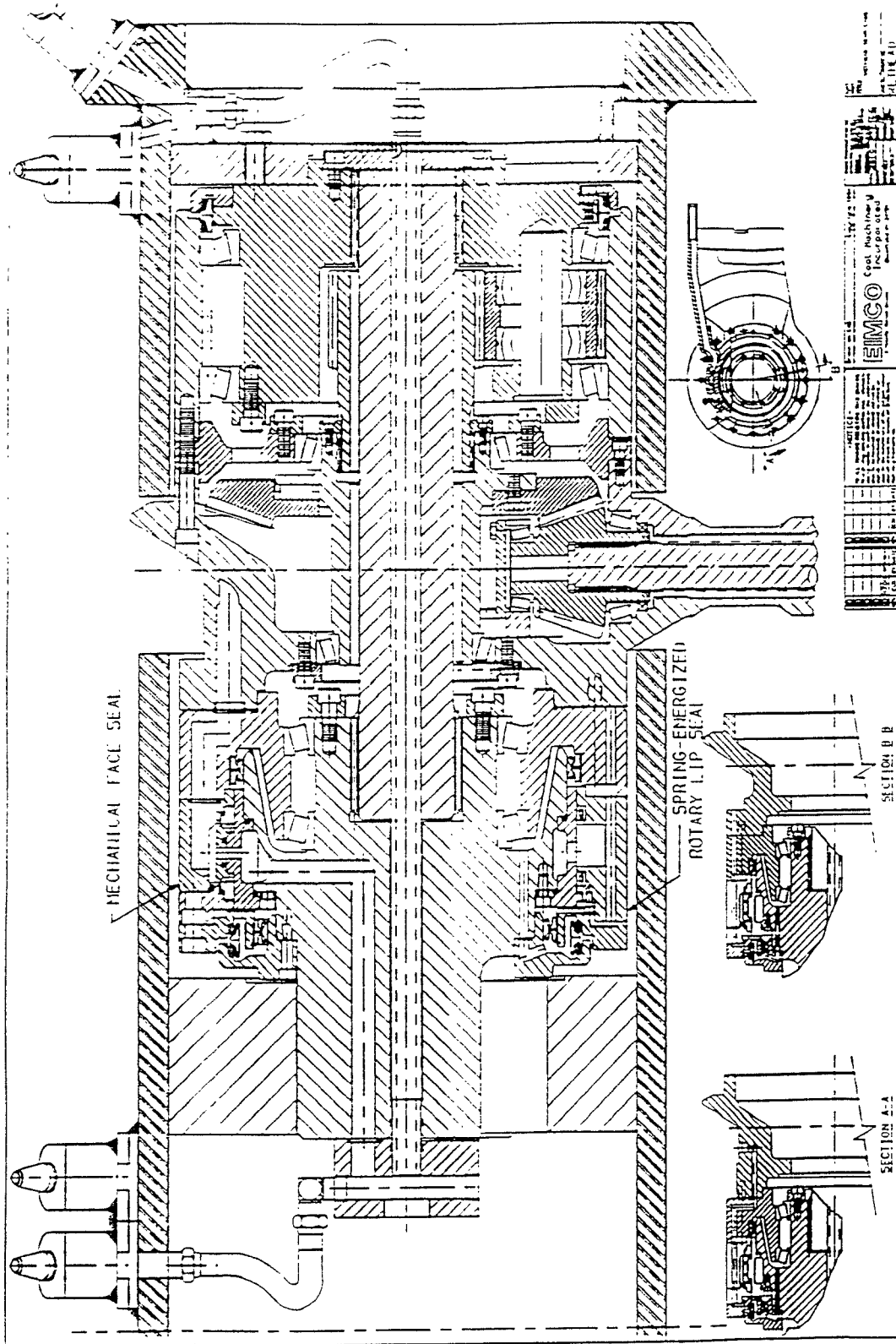


Figure 4.3.6 Details of right hand seal and water transfer system for Eimco continuous miner.

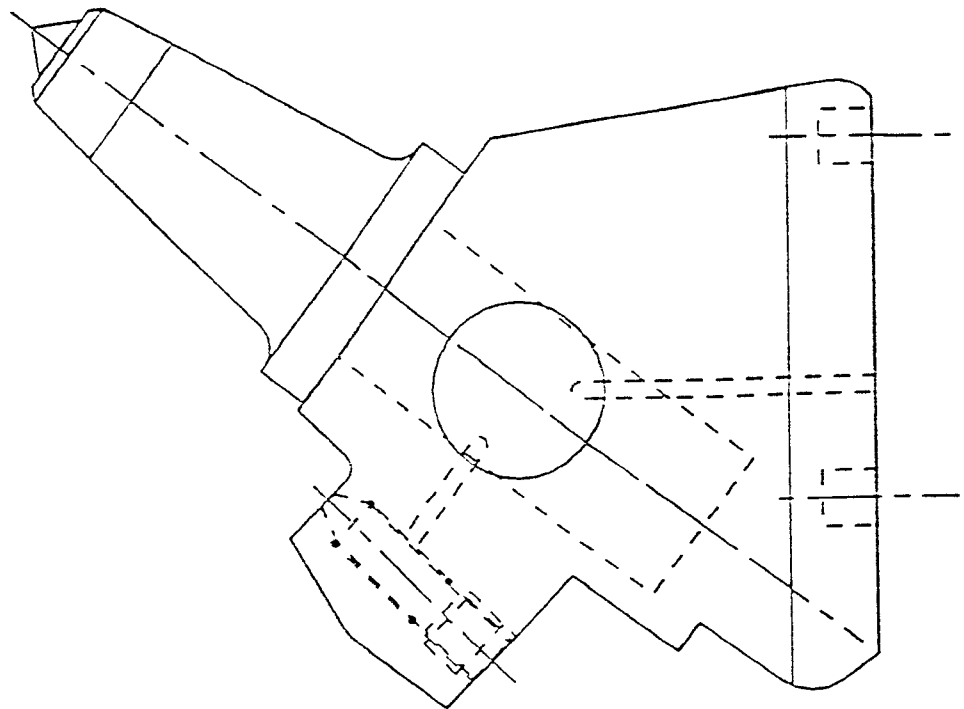
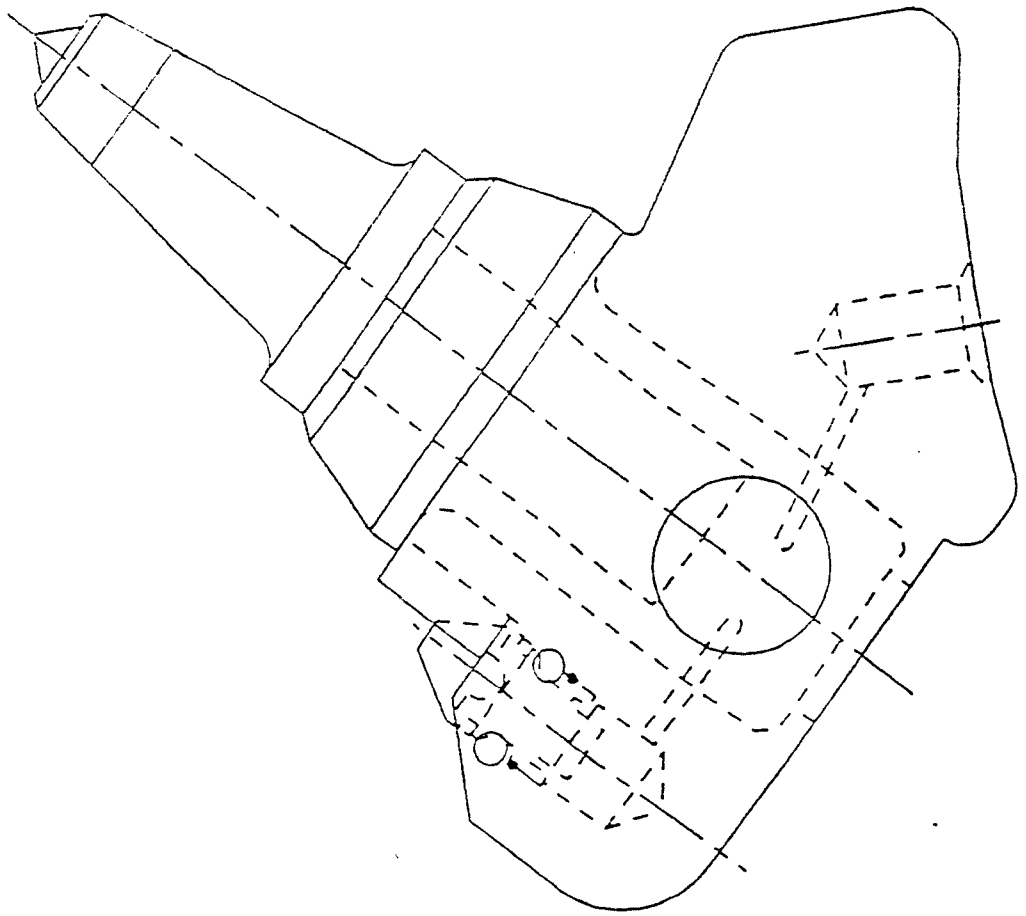


Figure 4.3.7 Eimco bit block and water spray system

Conclusions

Frictional ignitions continue to be a problem whenever coal seams containing even modest quantities of methane are excavated by machines. Since the methane held in the seam is at a concentration well above its upper inflammable limit, coal cutting and the release of methane ensures that the gas passes through its explosive range as it is diluted by the mine ventilation. Since this process takes place at or near the cutting picks there is always the opportunity for a frictional ignition to occur, given the right circumstances.

It has been established from the literature and personal contacts that the first line of defence against an ignition of any magnitude is effective local ventilation at the cutting drum in order to limit the volume of methane/air mixture in the explosive range to a minimum. The second line of defence is to make sure that no incendive sparking or material hot enough to ignite methane is present in the proximity of the explosive concentration. It is generally agreed that the best way to achieve this is through the use of water sprays located behind each pick. For these to be effective certain criteria must be met and these have been spelt out in Section 4.1 of this report. Although these criteria were developed to achieve Incendive Temperature Potential Protection (ITPP) for shearer drums, there is nothing to suggest that they are not equally applicable for continuous miners and roadheading machines.

Research and the development of frictional ignition prevention devices for longwall shearers has been undertaken for at least 30 years. A range of suitable devices for ventilating the cutting drum and providing water for both dust suppression and pick back flushing is now available and shearer manufacturers can offer machines and cutting drums specifically designed to minimise the risk of frictional ignitions. More recently work in Germany has produced wet-head systems which, either alone or in combination with compressed air, can give an equal level of protection for roadheading machines. Current developments in this area involve further refining of these systems and the remote (surface) monitoring that the devices are, in fact, operating.

The parallel development of wet-heads for continuous miners has been delayed by about two decades because of the need to use large diameter rotary seals to transfer water to the cutting drums. Although seals were available they were found,

in practice, to be incapable of withstanding the effects of machine vibration and poor water quality. This problem has now been solved although the seals, at a cost of up to \$25 000 per pair, are expensive. Three machine manufacturers (Joy, Eimco and Voest-Alpine) now offer wet-head continuous miners, while Hydra Tools International provide the option of a retrofit wet-head for any continuous miner. Although operational experience with all four systems has been limited to a few machines and only a few years, confidence that reliable wet-head continuous miners can be made available is growing.

Interest in the use of wet-head machines has been detected from Australia, the United States, the United Kingdom and Russia, as well as from the South African industry. Once machines are equipped with wet-heads water can be used both for ignition suppression or, equally importantly, for the reduction of respirable dust levels. The additional cost for a continuous miner if a wet-head is specified, is \$95 000 but nearly 70% of this can be offset if water on the cutter picks reduces the make of dust to the point where on-board scrubbers are no longer required.

Finally, it appears that no further research is required into the use of wet-heads for frictional ignition prevention. The basics have all been thoroughly researched and progress in the design and improved reliability of wet-heads for continuous miners will only be achieved if more machines are purchased and used. It must be noted, however, that the prevention of respirable dust by the application of water at the cutting pick is far more effective than the control of dust once it is airborne. If wet-heads are going to be introduced in significant numbers, then our whole strategy for protecting the workforce against respirable dust needs to be reviewed, as does the research programme supported by SIMRAC e.g. part of the funding devoted to the capture of dust particles may well be better employed in understanding the optimum location and type of spray, water flow rate and pressure required to minimise the generation of dust.

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APPENDIX 1

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APPENDIX 2

One day forum on friction ignitions

NIOSH, Pittsburg - November 18, 1997

Programme and list of attendees.

OPEN INDUSTRY FORUM on FRICTIONAL IGNITION

Tuesday, November 18, 1997

- 8:00 - 8:20 AM Registration
- 8:20 - 8:30 AM Welcome
Rich Metzler, PRL, NIOSH, Pittsburgh, PA
- 8:30 - 10:00 AM Overview of PRL Frictional Ignition Research
Michael J. Sapko, PRL, NIOSH, Pittsburgh, PA
- Characterization of Frictional Ignitions
Steve Schatzel, PRL, NIOSH, Pittsburgh, PA
- Bit Holders for Frictional Ignition Control
Mike O'Neill, Joy Technologies, Franklin, PA
- Performance Study of Conical Cutting Bits Using Wet Drum on a Simulated
Continuous Miner, Venkata B. Achanti, Dept. of Mining Engineering, West Virginia
University, Morgantown, WV
- 10:00 - 10:15 AM Break
- 10:15 AM - noon Wet-head Continuous Miner and Shearer Drum Tooling
Bob Montgomery, Kennametal, Bedford, PA
- New Bit Technology and Improved Bit Life
Steve Stehney, Sandvik Rock Tools, Bristol, VA
- Methane Monitoring and Control on Longwall Faces
Andrew Cecala, PRL, NIOSH, Pittsburgh, PA
- Preventing Frictional Ignitions on Highwall Mining Equipment
Jon Volkwein, PRL, NIOSH, Pittsburgh, PA
- noon - 1:00 PM Lunch
- 1:00 - 2:30 PM History and Experience with Continuous Miner Wet Cutter Head
Mike McMillion, CONSOL, Inc., Morgantown, WV
- Wet-head Continuous Miners
Roger O'Quinn & Maurice LeBegue, Tamrock Coal - Eimco, Bluefield, WV
- Retrofit Wet-head Continuous Miners
Paul Band & Doug Hibbs, Hydra Tools, Tuscaloosa, AL & Morgantown, WV
- Wet-head Continuous Miners
Steve Monroe, Joy Technologies, Franklin, PA
- 2:30 - 3:00 PM General Discussion
- 3:10 PM Frictional Ignition Demonstration, Carrie Lucci, PRL, NIOSH, Pittsburgh, PA

List of Attendees
Frictional Ignition Forum
Pittsburgh Research Laboratory, NIOSH
November 18, 1997

Name(s)	Company	Phone Number
Jurgen Brune	Consol Inc. 1800 Washington Road Pittsburgh, PA 15241	412-831-4566
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Jack Holt Bill Tolliver Larry Patts	Consol Inc: 1800 Washington Road Pittsburgh, PA 15241	412-831-4053
Michael McMillion Pramod C. Thakur	Consol Inc. Research & Development Rt1, Box 119 Morgantown, WV 26505	304-983-3207
Mike Bryan Doug Hibbs	Hydra Tools Inc. Rt#3, Box 685-B Morgantown, WV 26508	304-284-0111
Paul Band	Hydra Tools Inc. 5240 Kauloosa Avenue Tuscaloosa, AL 35403	205-758-1283
Samuel L. Cario	Cyprus Emerald Res Corp. P.O. Box 871 Waynesburg, PA 15370	412-627-2251
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Venkata B. Achanti	West Virginia University Dept of Mining Engineering Morgantown, WV 26506	304-293-7680 x348
Carla Marcum	MSHA HC66, Box 1762 Barbourville, KY 40906	606-546-5123

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Steve Monroe Mike O'Neill	Joy Technologies 120 Liberty Avenue Franklin, PA 16323	
Roger O'Quinn Maurice LeBegue	Tamrock Coal - Eimco 210 Bland Street Bluefield, WV 24701	304-327-0260
Tom Olzer John Zachwieja	Consol Virginia Operations Drawer L Oakwood, VA 24631	540-498-8254
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Richard Salyers John Calhoun	MSHA P.O. Box 560 Norton, VA 24273	540-679-0230
Doniece Schlick Scott	MSHA 135 Gemini Circle, Suite 213 Birmingham, AL 35209-5842	205-290-7302 X133
Randy Morris Paul Saunders Brian Lieving	Cincinnati Mine Machinery Co. 2973 Spring Grove Avenue Cincinnati, OH 45225-2190	513-541-6303

Roland Tallerico Dave Powell Randy Bishop	Cyprus Plateau Mining Corp. P.O. Box 7007 Price, UT	801-472-0475
Dwight Kreiser	Mountain Coal Company West Elk Mine P.O. Box 591 Somerset, CO 81434	970-929-5050
Bill McCracken Bill Self	McCracken and Associates Bristol, TN	423-968-1721
Derrick Tjerlund Harry Verakis	MSHA Triadelphia, WV	
Chuck Lazzara Mike Sapko Carrie Lucci Jacquie Janksy Ken Cashdollar Andrew Cecala Jon Volkwein Steve Schatzel	NIOSH Pittsburgh Research Laboratory P.O. Box 18070 Pittsburgh, PA 15236	412-892-6601

APPENDIX 3

Details of the

Hydra Tools International (Pty) Ltd

Hydraphase continuous miners

**HYDRA
TOOLS**
INTERNATIONAL (PTY) LTD

HYDRAPHASE CONTINUOUS MINER



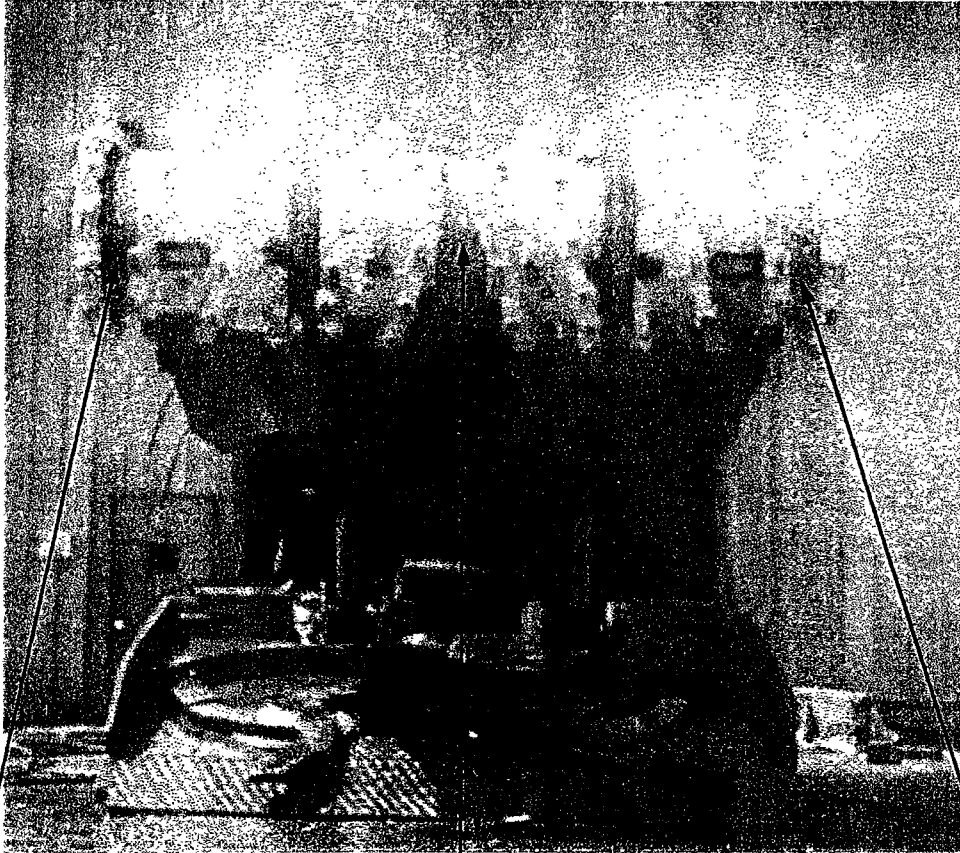
PRESENTED BY:-

HYDRA TOOLS INTERNATIONAL (PTY) LTD
P. O. BOX 15046
FARRARMERE
BENONI 1518
REPUBLIC OF SOUTH AFRICA.

Patent Applied For

Tel:- 011 817 3613
Mobile:- 083 271 2938

LOCATION OF WATER TRANSFER POINTS

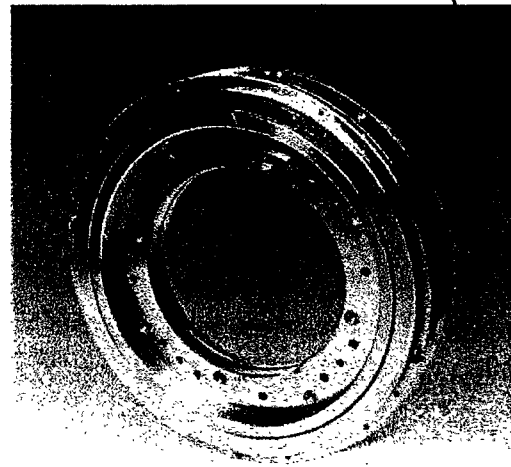


The photograph shows a typical continuous miner machine. The seal/ phasing element is housed in a cartridge form and is applied to the machine in the three areas indicated, one for each cutting drum.

The outer two cartridges are fitted by the removal of the end cutting rings, and sliding the units onto an integral shaft. Water connections are made and the end cutting rings re-fitted.

Water for the central split drum is applied in a similar manner, via a cartridge unit. The drum is specially adapted to accept the cartridge unit build up.

Non rotating protection rings insure that the cartridge unit cannot be damaged by any form of debris.



TECHNICAL INFORMATION

The water transfer arrangement has been designed to fulfil the following minimum design parameters, and are constantly under review and development.

Water Pressure	Working pressure can be up to a maximum of Minimum working pressure is 5 bar - 75 psi - 0.5 MPa	20 bar - 300 psi - 2.1 MPa
Water Flow	Connections to the seal arrangement are via a 0.5" (12 mm) diameter hose, the figures show the capacity of this size hose at the above pressure. The limiting factor is determined by the internal build up of the continuous miner machines water system and the allowable product saturation level.	A maximum of 90 l/min - 20 GPM through each cartridge unit.
Environment / Water Phasing	Phasing ensures water is only used in the critical area, which in turn improves the surrounding working environment. Water conservation is also achieved through the water phasing system, which is an integral part of each cartridge.	
ITPP Control	The approved and well proven Incendive Temperature Potential Protection (ITPP) pick, block and spray system, provide the best protection for frictional ignition control and reduced dust levels.	
Water Source	Can use motor cooling water or a dual water feed. Additional external supply can be included. Pressure can be increased by the inclusion of an onboard pump.	
Filtration Requirements	Hydraflush filter is protected by a Hydracyclone filter. The Hydraflush Filter is an automatic backflushing filter, which operates each time the system is energised.	Hydracyclone :- 100µ Hydraflush:- 50µ
Rotational Speed Seal life	Nominally 60 RPM. Trials indicate that seals will achieve 2,000 working hours before replacement of the seal cartridge unit becomes necessary.	2,000 hours
Manual Override to reset to spray bars	There are manual valves, within the water control module, to switch off water from the head sprays and isolate them. This allows the machine to continue cutting with its' original arrangement of spray bars, until cartridge replacement is convenient.	
Cartridge Replacement	The cartridge unit is the property of Hydra Tools, and will be serviced by Hydra Tools personnel when necessary. It is effected by removal of the end ring, disconnection of the water supply, and sliding off of the cartridge unit. On the hard head, a third cartridge arrangement is unclamped from the centre portion of the drum, dismantled and re-assembled. There are no user serviceable parts within the cartridge unit.	
Machine Interlock	Requirements for pre-start warning interlocks vary. A water control module is fitted onto the continuous miner machine, which meets M.S.H.A. approval. It is designed to switch the water from the spray bar to the head sprays on machine start up, automatically, via the 110 volt machine start up circuit.	
Cutting System	All heads are equipped with Hydra's well established long life radial cutting system.	

DRUM SPECIFICATION - 1



BLOCK Manufactured from BS 970 655M13 alloy steel. Slotted top close tolerance 50x30 Heavy Duty system. Fully carburised top area and pad, to give a surface hardness of 700Hv (30kg) with optimum core strength, enhancing life and protecting spray locating device.

BIT Heavy duty bit, with close tolerance, incorporating wider bearing heel and toe area. Riblock fastening for ease of insertion/extraction.

TIP Various grades and widths of carbide available to meet specific cutting conditions.

SYSTEM WATER Quick Release ITPP water spray incorporates 500 μ mesh filter. This spray is accurately aligned to provide exact water direction and meets specified ITPP regulations.

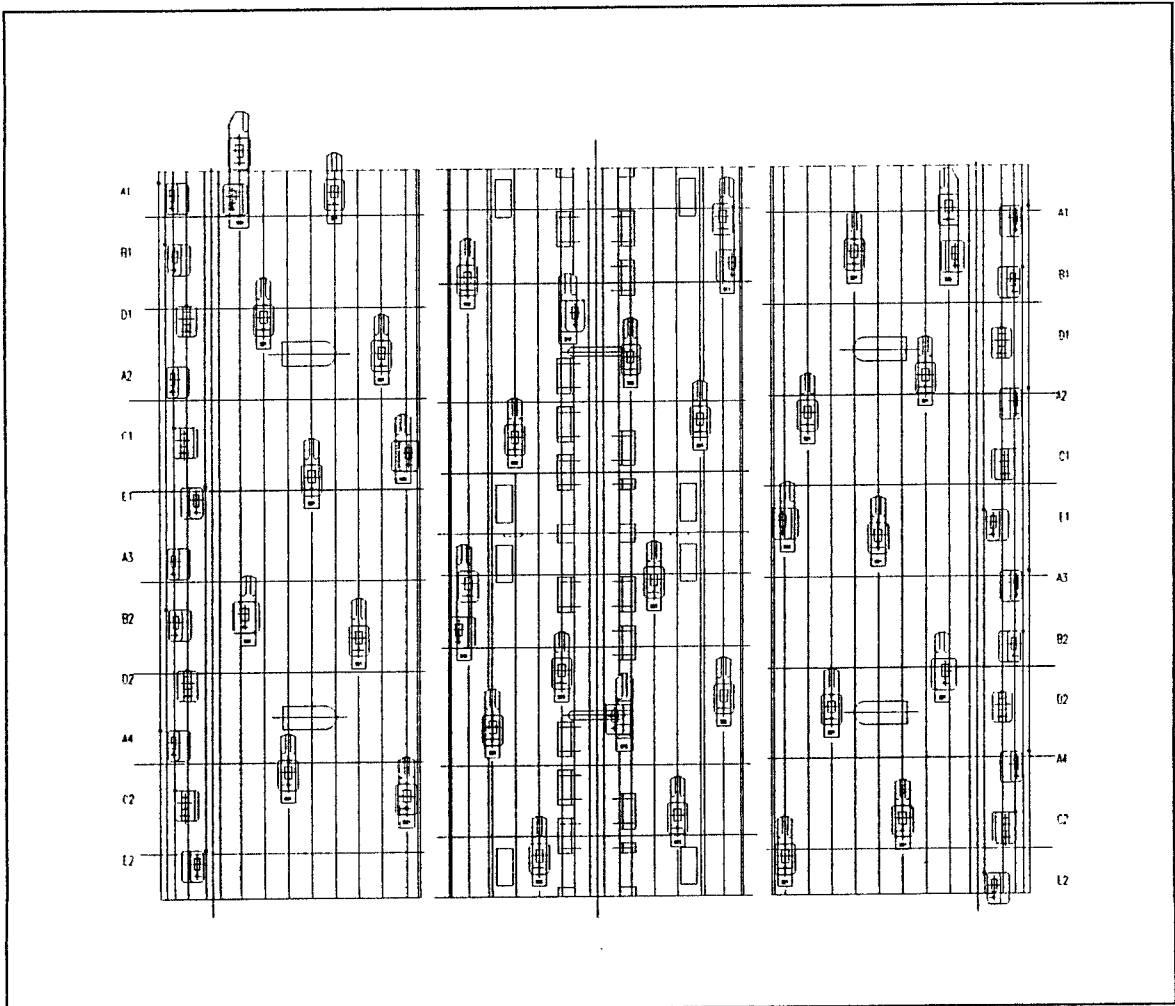
SPRAY A high quality aluminium bronze unit offers a multitude of spray alternatives to optimise water availability. Hole sizes are available from 0.030" to 0.060" (0.7 to 1.5 mm), giving a solid cone spray. The spray angle can be specified between 30° and 70°.

DRUM SPECIFICATION - 2

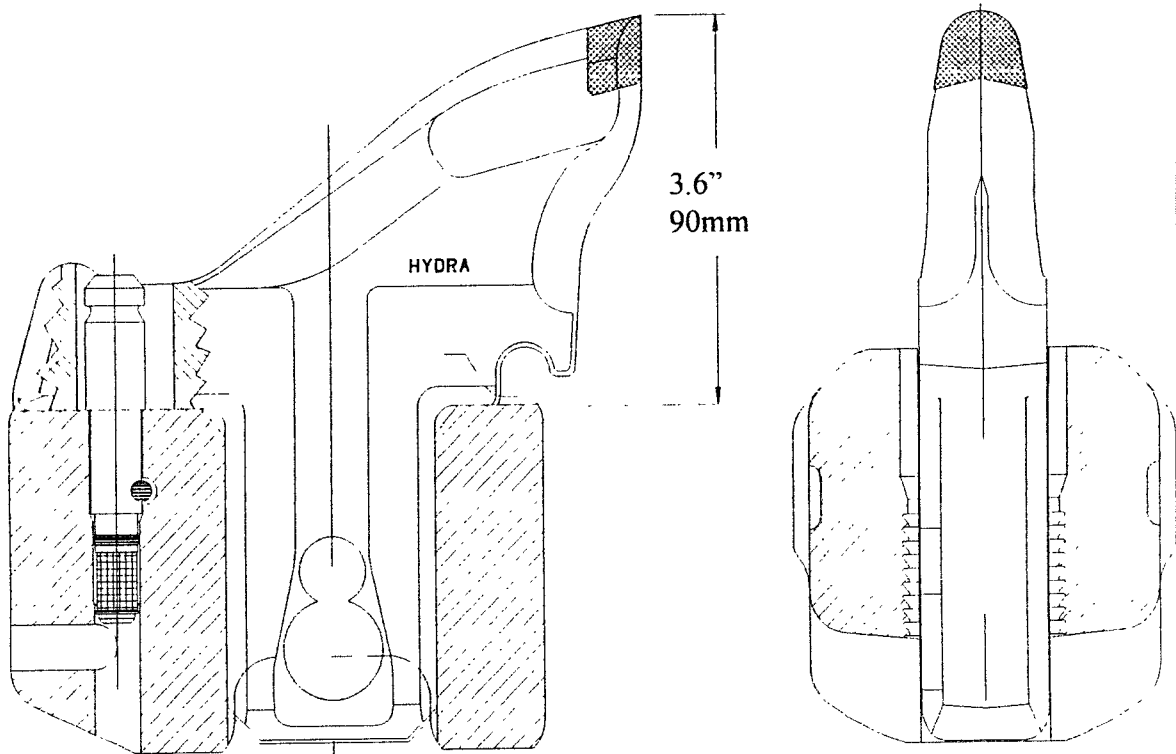
The drum life is increased through the Heavy Duty Tooling System. Each drum will be designed to exact customer requirements, giving priority to:-

1. Geological conditions.
2. Reduction of dust levels.
3. Frictional ignitions.
4. Productivity.
5. Faster loading ability.
6. Reduced downtime.
 - no block loss.
 - long life easy change bits.

Typical Lacing

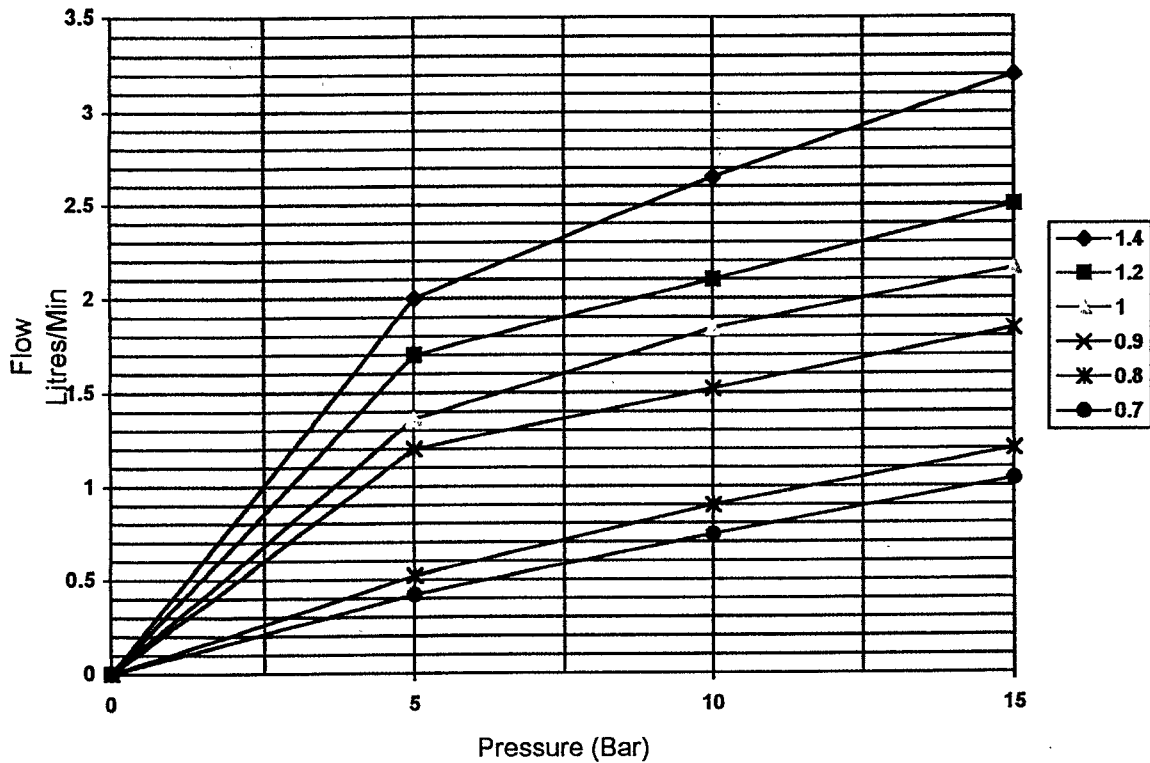


RADIAL TOOLING SYSTEM



Block No.	Type 1B BL
Bit No.	Type 1M
Spray & Pin Ass.	MC 00517

WATER FLOW

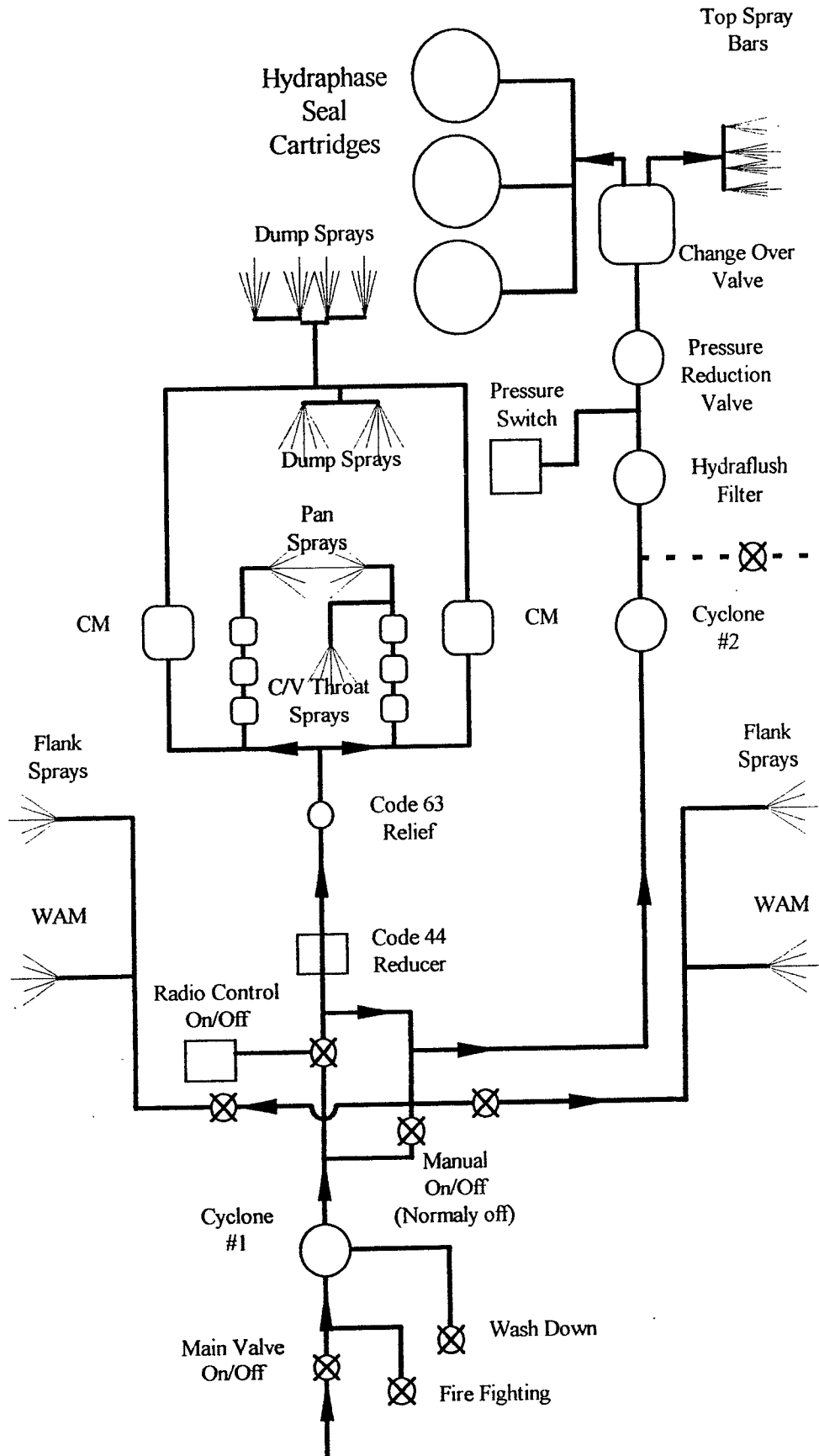


Spray Size	Pressure Bar (psi)			
	0	5 (75)	10 (150)	15 (225)
1.4mm (0.055")	0	2.00 (0.53)	2.65 (0.70)	3.20 (0.84)
1.2mm (0.047")	0	1.70 (0.45)	2.10 (0.55)	2.50 (0.66)
1.0mm (0.039")	0	1.36 (0.36)	1.84 (0.49)	2.16 (0.57)
0.9mm (0.035")	0	1.20 (0.32)	1.52 (0.40)	1.84 (0.49)
0.8mm (0.031")	0	0.52 (0.14)	0.90 (0.24)	1.20 (0.32)
0.7mm (0.028")	0	0.42 (0.11)	0.74 (0.20)	1.04 (0.28)

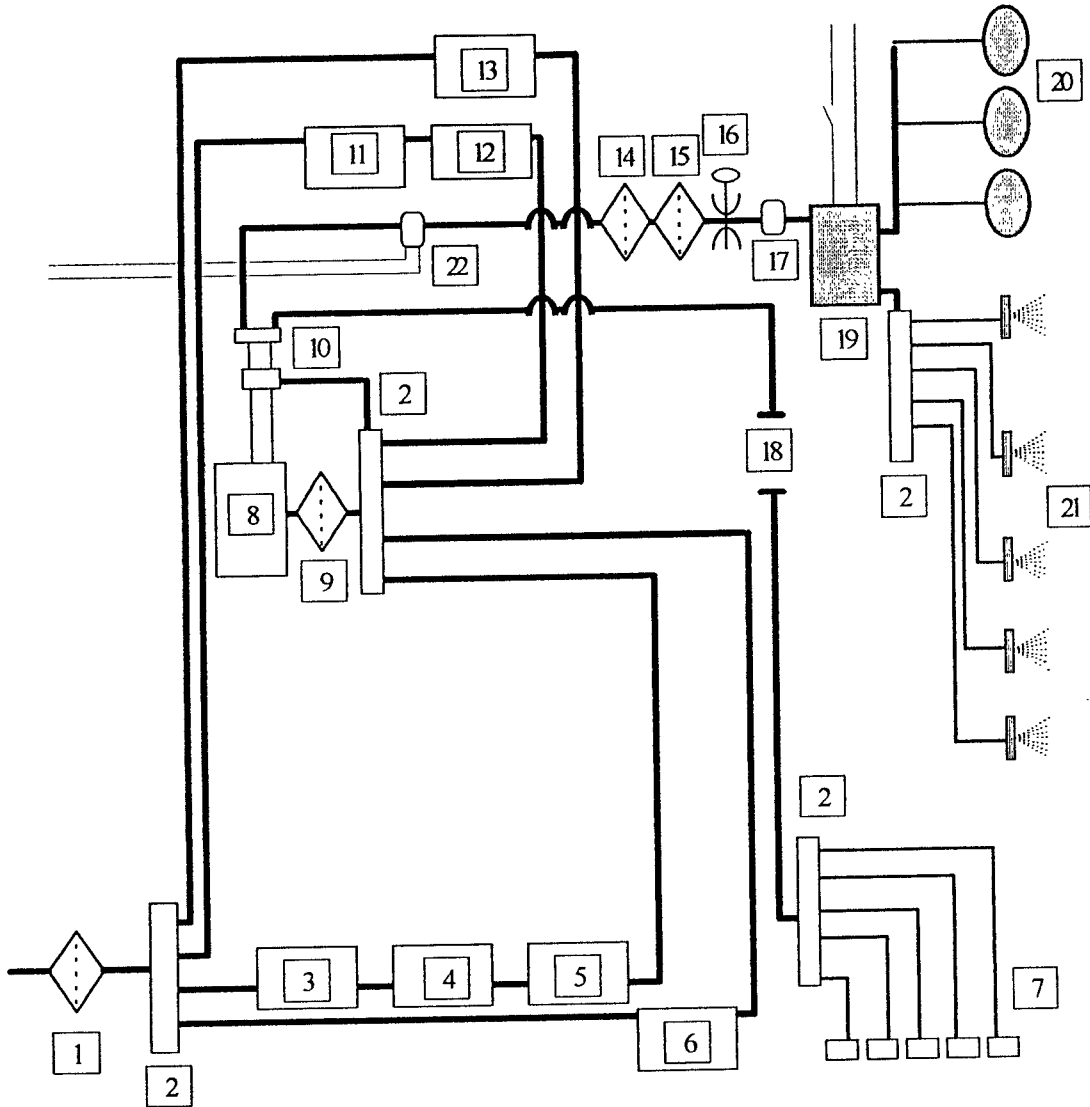
The above table shows typical flows in litres/min (GPM) at varying water pressures for individual sprays. To calculate the total water usage, multiply the above figures by 0.75 (for the phasing effect) and then by the total number of sprays.

No of sprays	60			70			80			90			100			110			120		
Press (BAR)	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15	5	10	15
Flow in Litres / Minute & considers a 25% dry section phasing effect.																					
1.4	90	119	114	105	139	168	120	159	192	135	179	216	150	198	240	165	218	264	180	238	288
1.2	76	94	112	89	111	131	102	126	150	115	141	169	127	157	187	140	173	206	153	189	225
1	61	82	97	71	97	113	81	110	129	92	124	145	102	133	162	112	152	178	122	166	194
0.9	54	68	83	63	80	96	72	91	110	81	102	124	90	114	138	99	125	152	108	137	166
0.8	23	40	54	27	47	63	31	54	72	35	61	81	39	67	81	43	74	99	47	81	108
0.7	20	33	46	22	39	55	25	44	62	28	50	70	31	55	78	35	61	86	38	67	94

SCHEMATIC 'D' - SPLIT WATER FEED

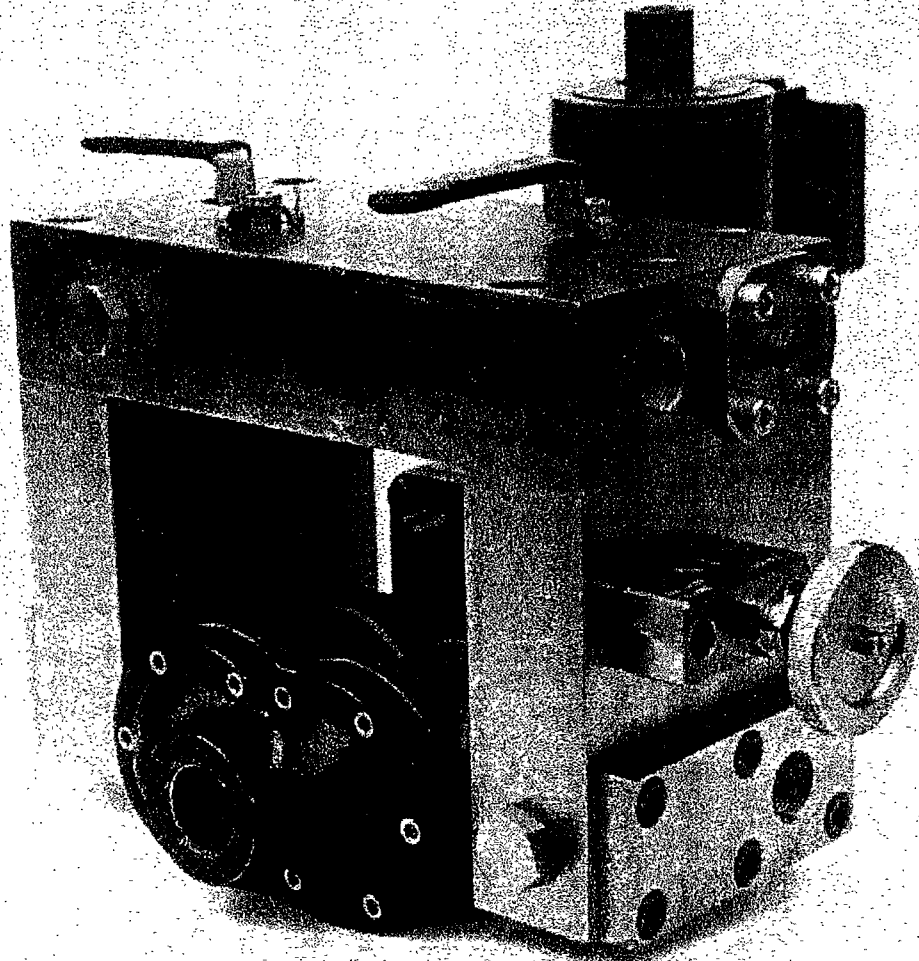


SCHEMATIC 'F' - SPLIT WATER FEED (Incorporating pump)



- | | |
|-----------------------------|--|
| 1 Machine Filter (existing) | 12 Gath Motor |
| 2 Manifold | 13 Cutter Motor |
| 3 Pump Motor | 14 Hydracyclone Filter |
| 4 Traction Motor | 15 Hydraflush Filter (Automatic Backflush) |
| 5 Gath Motor | 16 Pressure Reducing Valve (Code 44) |
| 6 Cutter Motor | 17 Pressure Relief Valve (Code 63) |
| 7 Sprayers (Scrubber Unit) | 18 Scrubber Unit Disconnection |
| 8 Water Pump | 19 Change Over Valve |
| 9 Filter (existing) | 20 Seal Cartridges |
| 10 Relief Valve | 21 Spray Bar |
| 11 Traction Motor | 22 Water Flow Switch (Code 240) |

CHANGEOVER VALVE



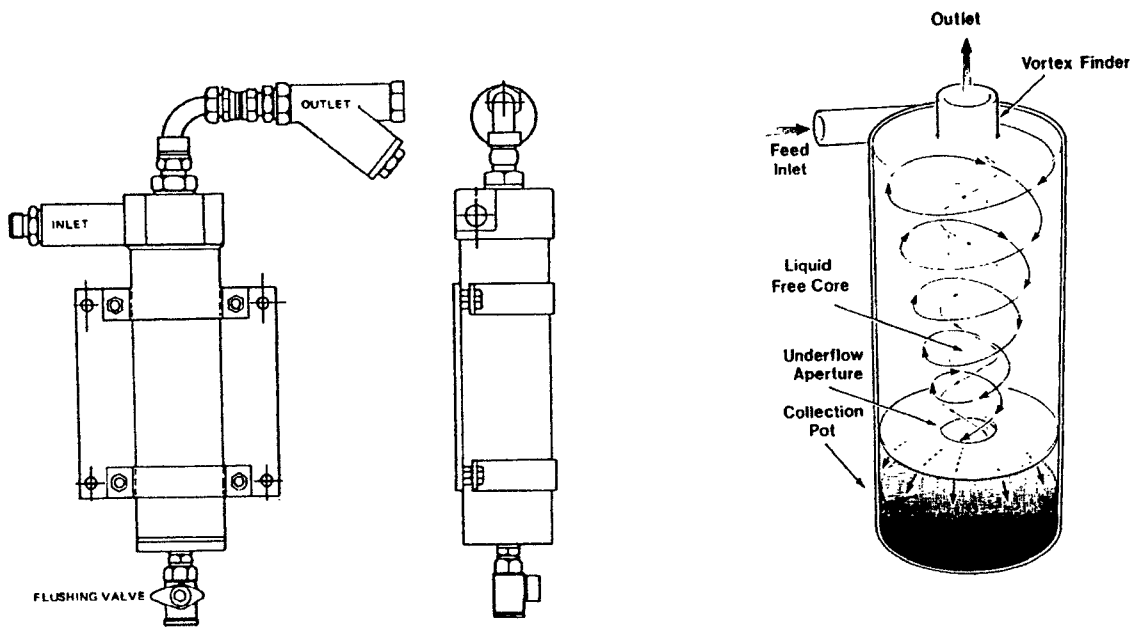
Water is turned on to the continuous miner machine by hand, and is detected by the water flow switch.

Under start up conditions, water is allowed to the seal at a reduced pressure of 2 bar (30psi), and to the cutter spray bar at the system pressure say 10 bar (150psi). Once the pre-start warning mode has been satisfied, the solenoid operated water control valves are activated from the 110 volt motor start up circuit. It is necessary to maintain this electrical power. Once the electrical signal is removed, the solenoid operated water control valves revert to their start up position, under spring force, directing the water to the spray bar.

In case of seal failure, the miner can continue to be used by isolating the seal. This is achieved by manually closing valve 1 and opening valve 2.

The solenoid is approved and meets the requirements of the HSE & M.S.H.A.

HYDRACYCLONE FILTER

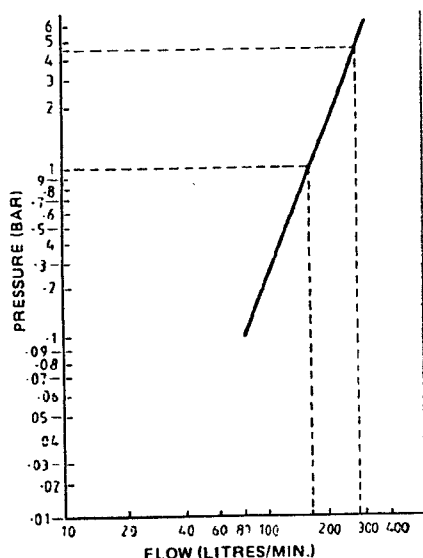


The **Hydracyclone** filter, works on the principal of separating dirt particles from the water by rapid centrifugal acceleration of the dirty water.

As water enters the filter tangential, the particles are thrown to the side of the chamber. They are collected in a compartment at the base of the filter.

A handle is provided to manually flush the filter at the start of each shift.

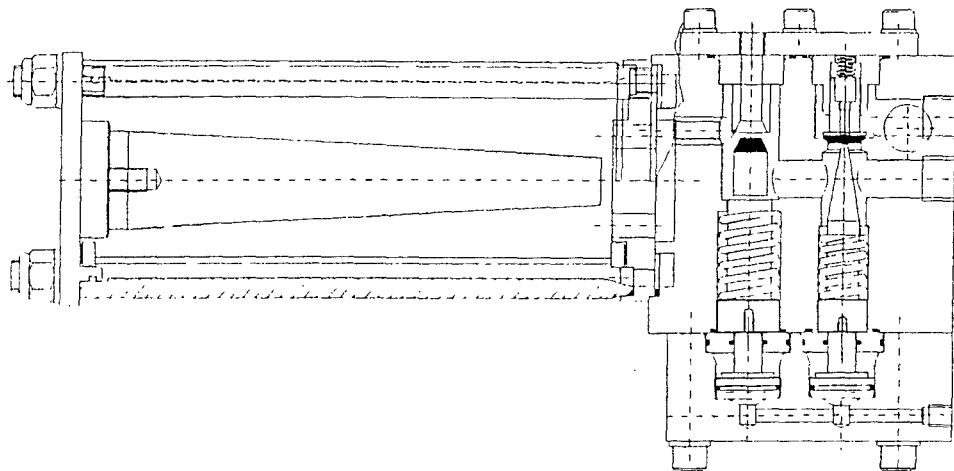
A strainer is provided on the exit of the filter to provide a back up during the start up and shut down of the filter, when the efficiency of the filter is reduced.



SPECIFICATION

Overall unit height.	708 mm 27.9"
Unit Width.	530 mm 20.9"
Unit Depth.	130 mm 5.1"
Operating pressure Max.	150 bar 2000 psi
Unit Capacity Min	37 L/min 8 GPM
Unit Capacity Max	270 L/min 60 GPM
Filtration Specification	95% of 100 μ

HYDRAFLUSH - AUTOMATIC BACK FLUSH FILTER

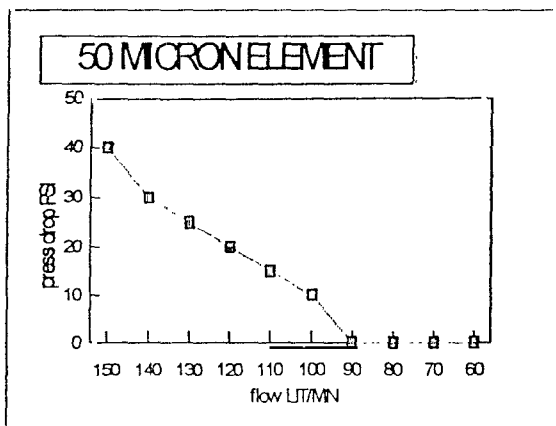


The **Hydraflush** automatic backflushing filter has been designed to work on a total loss water hydraulic system, used within the mining industry.

As its name suggests, the system performs a backflushing operation automatically without the need for any operator involvement, whenever the water flow is allowed to the unit. The uniqueness of this hands free feature allows the unit to be fitted remotely on the machine.

The principal of its operation is simple. Each time water is allowed into the unit, the unit detects the back pressure and initiates a series of valves to operate in sequence performing the backflushing function.

The above capacity and filtration specification is available but can be varied to suit individual requirements. Modification to the specification will result in change of the units overall length.



SPECIFICATION

Overall unit height.	480 mm 18.9"
Unit Width.	134 mm 5.3"
Unit Depth.	187 mm 7.4"
Operating pressure Max.	150 bar 2000 psi
Operating pressure Min	5 bar 75 psi
Unit Capacity	270 L/min 60 GPM
Filtration Specification	50 μ

PRE START UP CHECKS**Actions required where necessary**

Before starting up the machine check the following points:-

1. BITS & SPRAYS

ALL BITS should be in good condition, no tips missing or badly worn.

ALL SPRAYS should be in good condition, capable of delivering Water and undamaged.

If at all worn or showing damage replace before mining commences.

2. WATER FEED ARMS & HOSES

BOLTS & HOSES should be in place and intact. Bolts should all be tight

Loose bolts should be tightened. Loose or damaged hoses or feed pipe should be tightened or replaced.

3. PRESSURE REDUCING VALVE

This unit restricts the system pressure and protects against surges that may occur due to variations in demand on the mine's main water supply.

Any damaged hoses or loose joints should be replaced or tightened where necessary.

4. WATER PRESSURE GAUGE

This unit is connected to the Pressure Reducing Valve and should be checked on start up to ensure correct pressure
Maximum Pressure should be 250 p.s.i.
Minimum Pressure should be 100 p.s.i.

If pressure on the gauge is not within limits, i.e. 100-250 p.s.i. refer to the Hydraphase Fault Finding Guide.

5. HYDRACYCLONE FILTER

This filter is designed as a first line of protection and **MUST BE FLUSHED AT LEAST ONCE EVERY SHIFT**
All hoses and joints should be checked for leaks

Throw handle to open position prior to starting machine. Allow to flush for 2-3 seconds. Return handle to closed position. Any damaged hoses or loose joints should be tightened or replaced

Actions required where necessary**6. HYDRAFLUSH AUTOMATIC BACKFLUSH FILTER**

This unit will automatically flush as system pressure develops This will take approximately 1-3 seconds and will exhaust through the drain valve approximately 1-2 litres of water. Flushing will repeat as the system's water is turned off. Hoses and joints should be checked for leaks.

Any damaged hoses or loose joints should be replaced or tightened where necessary.

If unit is not flushing correctly consult Hydraphase Fault Finding Guide

7. CHANGE OVER VALVE BLOCK

This unit will automatically change the machine from spray bar mode to wet head mode upon start up and stop.

It can also be used as back up mode should the seals fail.

This is done by changing direction of the handles as shown on the unit's diagram.

Hoses to and from the unit should all be checked for leaks.

Any damaged hoses or loose joints should be replaced or tightened where necessary. The electrical connection should also be checked for possible damage. If unit does not function as described refer to the Hydraphase Fault Finding Guide.

8. FLOW & PRESSURE SWITCH

This unit protects the seals by preventing or discontinuing running of the cutter motors should minimum flow and pressure not be met or maintained.

Any damaged hoses or loose joints should be replaced or tightened where necessary. The electrical connection should also be checked for possible damage. If unit does not function as described refer to the Hydraphase Fault Finding Guide.

Should any of the above checks show a fault then refer to the **HYDRAPHASE CARE & MAINTENANCE INSTRUCTIONS** or **FAULT FINDING GUIDE**.

If all is OK machine is ready to operate.

NOTE: The system relies on having water to each of the three seal areas. Lack of pressure in the system will cause damage. The above checks are extremely important. Please make sure they are carried out before each shift start up.

In order to gain maximum benefit from the Hydraphase Wet Continuous Miner Head it is important to adopt the following Care and Maintenance instructions. This should ensure maximum productivity and life from the system and at the same time minimise dust levels whilst maximising frictional ignition protection.

WATER MUST NEVER BE DISCONNECTED OR DIVERTED FROM THE CARTRIDGES FOR ANY REASON.

CARTRIDGES

On a Hard Head Continuous Miner there are three cartridges, two outer ones which are single units and may be fitted and removed in a one piece section, a centre cartridge which has to be split and therefore is built and disassembled in several pieces. The cartridges house both the sealing and phasing elements of the system and are designed to distribute water to each spray (one housed in every block) throughout the cutting drum. The Hydraphase system will only survive provided that flow and pressure are maintained to each of the separate cartridges, which in turn will ensure lubrication to the seals and phasing ring.

CARTRIDGE REPLACEMENT

It is recommended that the cartridges are exchanged every six months under Hydra's "CARTRIDGE EXCHANGE SERVICE". The mine maintenance personnel will be able to exchange the outer cartridges, the centre split cartridge however, should ONLY be changed by Hydra's nominated service engineers.

Change times, two hours for each of the two outer cartridges and one shift (eight hours) for the split centre.

Exchange cartridge refs are:

Outer Solid Cartridge:

Centre Split Cartridge:

PRESSURE REDUCER

The pressure reducing valve is designed to eliminate the possibility of pressure surges which could blow the seals with consequential loss of pressure throughout the system.

HYDRACYCLONE FILTER

This unit is not an absolute filter, it is designed to separate particles down to around 100 microns and requires manual flushing as stated in the Operating Instructions. It is designed to last the full life of the machine and must always be installed in the vertical position. The unit filters water before it enters the Hydraflush filter.

HYDRAFLUSH FILTER

The automatic back flushing filter unit filters water down to 50 microns each time the system is pressurised and depressurised. Once every three months the main filter element should be removed and scrubbed clean before replacing. Spare filter elements are available from Hydra Tools, see parts list.

CHANGEOVER VALVE

Filtered water enters the valve block at the inlet port. Before the cutter motors are activated, the water is fed to conventional spray bars mounted on the gearcase. When the cutter motors are activated a solenoid switch mounted on the changeover valve, automatically diverts the water flow from the spray bars to the "Hydraphase" cartridges. Whenever the cutter motors are switched off the water is automatically fed back to the spray bars.

In the event of seal failure "Back Up Mode" can be selected by closing valve one and opening valve two (as shown on the diagram attached to the unit). The "Back Up Mode" feeds water to the spray bars.

The changeover valve ensures that a limited amount of flow remains to the Hydraphase cartridges at all times whilst the machine is operating regardless of mode, this ensures that any remaining seals remain intact.

FLOW/PRESSURE SWITCH

This unit is designed to protect the system should the minimum requirements of flow and pressure not be met.

If the flow rate is less than eight gallons per minute and/or if the flow pressure is less than 100 p.s.i. then the cutter motors will fail to start.

The switch will also stop the cutter motors if the above requirements are not maintained during cutting operations. For low flow/low pressure problems refer to the "Fault Finding Guide".

WATER FEED ARMS

These are strongly manufactured items designed to protect the water feed cases and the connections to the cartridges. They are bolted in position and may be welded if required for extra security. In the unlikely event of these arms being damaged they must be replaced immediately as loss of water feed to the seals is the likely consequence.

All of the above items of equipment are of equal importance to the successful operation of the system. Should any item become dislodged, damaged in any way or removed, the consequential loss of the Wet Head is inevitable.

PHOTOGRAPHS

