

AN INTRODUCTION TO SCREW-TYPE PUMPS WITHIN THE MINING INDUSTRY (*)

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ABSTRACT

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It is probably stating the obvious to say that the prime function of any mine is solely to extract and process minerals. In this sense therefore, mine pumps would not normally be classed as productive equipment, but more often as necessary evils. Nevertheless, it is a fact that in the U K as a whole that the amount of coal and water being brought out of the mines at the present time is roughly the same. This puts the importance of mine pumps into perspective particularly when we consider that even when there is no production of coal or minerals, pumps must still be run in order to keep the mine workable.

In 1939 at Clay Cross Colliery in Derbyshire a new type of pump was first introduced into the Mining Industry, a Mono pump C6D, direct forerunner of the currently used D6D, or D62 type. Today over 5000 screw-type pumps are in operation underground within British Coal, and this simple principle pump, now known universally by its manufacturer's name - Mono pump, has very much become the backbone of Colliery water control.

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THE SCREW TYPE PUMP

Principle of Operation

The heart of the screw type pump is the single helix resilient rubber stator of twice the pitch length of the metal rotor. the rotor of constant circular cross section makes an interference fit inside the stator, and creates a continuously moving caving as it rotates. The cavity progresses towards the discharge, advancing in front of a continuously forming seal line, thus carrying the pumped material with in as shown in Figure 1.

The Unique principle of design gives low internal velocities, even at maximum speeds, and offers remarkable resistance to abrasion. The hard chrome plated stainless steel rotor and resilient rubber stator form an ideal commination for handling gritty water and abrasive slurries the pumps are robustly constructed and have the ability withstand operational abuse, but are light in weight and compact, they require no foundations, are easily installed and will work on any incline from horizontal to vertical.

This type of pump will prime with ease on any suction lift up to 8.3 metres, and will pump on shore with any feeder up to full capacity, given a suitable size of suction pipe. The construction has been kept as simple as possible. and the pump embodies a single rotating element without valves or gearing. Consequently, maintenance is very easy replacement parts can be fitted with the pump in situ.

PUMP CHARACTERISTICS

Self priming

For normal purposes the stator of the Mono pump is invariably made of rubber. The resilient nature of this material makes it possible for the rotor to be actually an interference fit in the stator, so that there is extremely close contact along the whole of the seal line. This Feature together with the absence of valves and cylinder clearances, renders the pump and extremely efficient air exhauster. Provided that sufficient liquid is present to maintain a lubricating film between the stator and rotor, this enables the pump to work with any proportion of air and water (snoring) indefinitely.

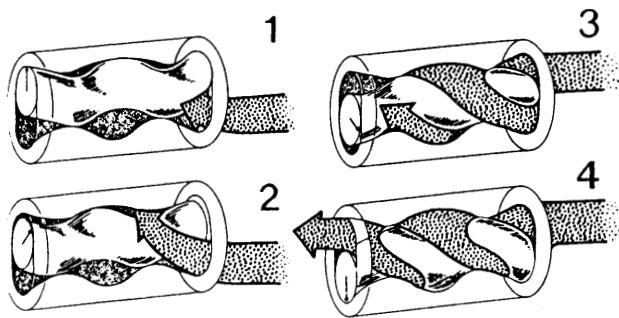


Figure 1 Stages for the screw-type pump

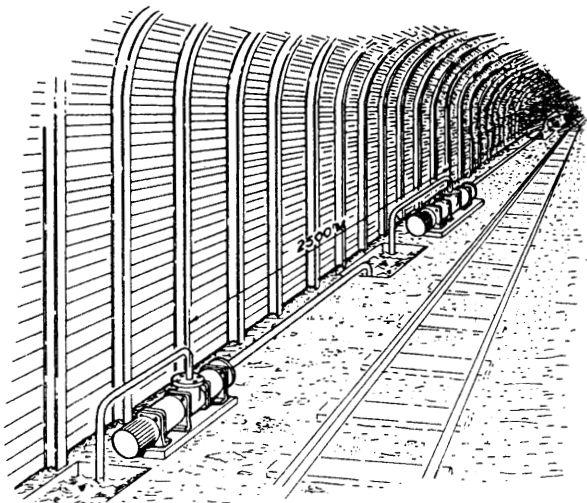


Figure 2 Inbye Drainage, typical pumps CMD72. CAE2. CLM412

Providing that the suction pipe is at a suitable diameter to carry the required mixture of air and water, it can prime itself with a suction lift as high as 8.3 metres of water, and will operate from zero inflow, up to the full capacity of the pump.

Positive displacement

Since the pump gives a positive displacement, the head developed is independent of the speed, and the capacity is approximately proportional to the speed.

The pump has a uniformly high efficiency over a wide range of heads, a characteristic of great value in meeting the varying condition of the Mining Industry.

Combining this characteristics with the rotary motion and continuous flow it will be seen that the Mono pump incorporates the advantages of both the reciprocating and the centrifugal types of pumps.

Non pulsation flow

The seal line, which is a curve of constant shape, moves continuously through the stator at a constant axial velocity. Because of the cavity that exists, due to rotor and stator design, the rate of displacement is uniform and the liquid flows in an absolutely steady stream without any pulsation, churning or agitation. This smooth and even flow is of great advantage in overcoming adverse suction conditions.

Simplicity

The Mono pump comprises of a single rubber stator in which revolves the single metal rotor. This is an extremely simple mechanism. It only has one gland, which is generally arranged on the suction site, so that it does not have to be packed against pressure.

There are no valves or gearing, and therefore no lubrication is required. It is a feature of particular interest to engineers that the few parts which are subject to wear can be readily and quickly replaced by unskilled labour.

Light weight and compactness

Although the Mono pump is constructed on very robust lines, the total weight is moderate and the unit as a whole is handy, and can be moved about with ease. It is designed to run at standard motor speeds, so that it can be directly coupled to electric, compressed air or hydraulic motors without the complication and added weight of intermediate gearing.

Multistage pumps

The length of the motor and stator provides a helix angle of rather more than 360 degrees, so providing a complete seal. For higher heads, however, the length of the rotor and stator is increased so as to provide two or more complete seals in series, and the head is thus developed in stages. Single stage pumps are suitable for heads up to approximately 46 metres, and two stage pumps up to 90 metre and four stage pumps for heads up to 200 metres.

Abrasion resistance

Due to design of the rotor and stator, the position of the seal line is continuously changing both on the rotor and the stator, this is the chief reason for the remarkably ability of the Mono pump to handle liquids containing abrasive materials. If for instance, a piece of grit is momentarily trapped between the rotor and stator, the resilient rubber stator yields to it without damage, in the same way as a rubber tyre passes over a stone, and owing to instant separation at the two surfaces, the gritty particle is at once released again and swept away by water.

There is no possibility of pieces of the grit being embedded and dragged along between the two surfaces. This is the chief cause of heavy wear of the most positive displacement pumps when gritty water is being handled.

The exceptionally low velocity of the fluid through the pump, and its steady continuous motion also contribute to freedom from wear. The pump will handle heavy coal slurries or abrasive cement and grout mixture.

Versatility

The Mono pump is used for pumping of a wide range of liquids and slurries, whether hot or cold, free flowing or highly viscous,

corrosive and/or abrasive and containing hard or soft solids. It is therefore possible to standardise on Mono pumps for many varying Mining duties. To make full use of the versatility, Mono pump has produced varying types of pump design to suit all applications, all working with the rotor and the stator principle.

APPLICATIONS FOR SCREW TYPE PUMPS UNDERGROUND

Inbye and Drainage duties

The Mono pump is particularly suitable for all inbye and drainage duties, and a range of pumps have been developed on the bases of Mining experience and with the collaboration of mining engineers. This has resulted in a robust pump able to withstand the conditions encountered in use underground, but which is comparatively light and portable (Figure 2). It requires no foundation, and is easily installed and will work on any incline. Construction has been kept as simple as possible, consequently maintenance is easy and replacement parts can be fitted without taking the pump out of the pit enabling mining to proceed unhindered.

For inbye duties Mono pumps are normally fitted with a rubber stator which has sufficient resilience to handle abrasive laden water with minimum wear, and will withstand heads up to 45 metres per stage. Hard chrome plated stainless steel rotors are for corrosive waters on abrasive duties.

In developing the Mono pump for Mining services, considerable attention has been given to the need to provide water for lubricating the stator when the pump is drawing air (snoring). The standard snorer bypass will establish the necessary lubrication between the rotor and stator indefinitely. But there are instances where a pump might be unattended for a considerable amount of time, or where feeders might more frequently diminish, or even cease to flow for long spells. To provide Adequate protection for these contingencies, as well as the snorer bypass, automatic float controls are used.

As the self-priming ability of the Mono pump quickly restores the full rated capacity, when snoring ceases there is no loss of pumping efficiency. Ideally with all positive displacement pumps, starting pressure should be relieved by a non return valve, situated not less than 3 metres away from the pump. In all

applications where the static head is greater than about 30 metres, or where the delivery pipe is more than 180 metres long a non-return valve should be fitted. This minimum of 180 metres applies when the pipe is the same diameter as the pump branches.

It is advantageous in cases where there is a considerable length of suction pipe, to fit a non-return valve a distance from the pump equal to about one third the length of suction pipe. Suction lines should always be in good condition, and of the non-collapsible type. All positive displacement pipes should never be run against a closed line. It is always good policy to keep the length of the suction pipe down to a minimum

For drainage duties at the coal face and dip headings, where the quality of water being met may be considerably below the capacity of the pump, and conditions are usually extremely arduous, great care should be exercised in selecting and installing the most suitable size of Mono Pumps. Within the industry the MD42 (D4D) and the MD62 (D6D) have been the most regular choice for this duty, running at 960 rpm. These two stage pumps can deal with static heads up to 90 metres, giving the benefit of keeping the pump alongside a coal-face as it advances. For transferring from a main pump lodgement to another the D72 (D10D) running at 720 rpm has long since become the British Coal standard.

There are instances underground where there is a nuisance water in an isolated area, causing problems. These areas usually have no electricity available to run an electric pump drive. In order to overcome this expensive problem of wiring in an electric supply a Mono D3 pump has been used satisfactorily. The pump has been arranged to take its drive off the bottom returning belt of a conveyor via a friction wheel, which is detachable from the belt during times when the pump is needed, the water is pumped up and onto the coal conveyor to be taken away. With a pump speed of 950 rpm, which is achievable, a capacity of up to 1800 litres can be pumped away.

Another application for this unit is the spraying of whitewash underground with the attachment of a spray nozzle to the end of a flexible discharge pipe. the pump is self-priming up to 6 metres, and gives pressures of 4.5 bar. Larger units can be supplied for the above duties, (D4 and D6's).

A great saving of time and labour can be effected by installing a Mono pump for cleaning the sludge from shaft bottoms, sump and

lodgements, drainage and de-sludging cage pits and wells. The water in the sump should be lowered by the main pump as near the bottom of the sump as possible, leaving only sufficient to keep the sludge liquid. the proportion of water required will vary according to the site conditions. But the following may be taken as a guide:

Where the silt is fine and only moderate abrasion is to be expected, and the suction lift does not exceed 4.5 metres, the sludge should be diluted with an equal quantity of water. For higher suction lifts up to a maximum about 6 metres or where considerable abrasive material is present, twice the quantity of water should be added. It must be sufficient to reduce the concentration to such a point that the pump delivers its full capacity. The water and sludge should be thoroughly agitated to keep the silt in suspension, and this agitation should be continued whilst the sludge pump is at work. Particular care being taken to see that there is no clogging of the suction pipe by settled solids.

For a sump of considerable area it may be necessary to move the pump around the sides, as long suction pipes are unreliable for this type of application. A suction strainer can be fitted to the suction pipe to keep out the large solids. After de-sludging is completed, the pump should be thoroughly washed out. Before starting, care should be taken to see that the pump is full of water to lubricate the stator during priming. The sludge can then be delivered to tubs at the pit bottom for emptying at the surface. If the sludges are to be pumped any great distance then care should be taken in selecting the size of main to keep the velocity up to approximately 1.5 metres per second to prevent the silt from settling out in the pipe.

'L' range pumps incorporate further features offering extended reliability in arduous draining conditions, together with higher capacities (up to 150000 litres per hour), and the ability to operate against heads of up to 200 metres (20 bar). These features include Flexishaft, a polymer coated high strength stainless steel flexible drive shaft which ensures corrosion and abrasion resistance within the suction chamber, and moulded to metal resilient stator suitable for the higher pressure involved.

A typical application is in transfer from inbye standages, where a CLM4 high pressure pump direct driven at 720 rpm pumps up to 30000 litres per hour. Operation up to the maximum head of 200 metres which replaces several existing pumps in the series. It can

be installed with a silt strainer in a semi permanent sump, and can be arranged for float controlled operation.

Another installation involves a CLRI high capacity pump operating at 470 rpm against a head of 45 metres. It is used to transfer up to 125000 litres of water from a lodgement per hour.

Dust control

The Mono pump has been applied to all forms of dust suppression, and because of its positive action, it is usually fitted with a relief valve so that pressures and quantities delivered at spray points can be adjusted (Figure 3).

At the coal face on wet cutting operations D3D and D4D pumps are in use, feeding the spray nozzles on the cutter chain at pressures up to 6 bar, and also feeding water jets onto the cutter heads for dust suppression and the cooling of rock drills.

A D3D Mono pump is being used satisfactorily for spraying conveyor loading and transport points. It is arranged in the gearhead and the drive taken from the conveyor motor.

For larger spraying operations D4, D4D, D6 and D6D size pumps have been adapted for supplying several sprays from one standage the pressures varying from 3 - 6 bar, running at 960 rpm.

Mono pump sizes D4 and D6 are extensively used on the British Coal design of dust extractor and air scrubber units. Water is supplied via a Mono pump to a spray nozzle at the fan inlet. The water is atomised in the fan, and the dust is collected by the water and filtered out. The dust laden water falls into a settlement tank, and the relatively clean water is then re-circulated.

Other uses of Mono pumps on dust suppression are above ground on water tanker duties. These tanks are employed in the summer months for spraying water to dampen down coal dust at collieries, and more so at opencast mining sites and quarries.

Water is also pumped by D4D and D6D pumps for the infusion of water into cracks, and crevices, or via drilled holes into cavities in breakaway rock. The water again being taken from standages and pumped up to pressures of between 4 and 9 bars.

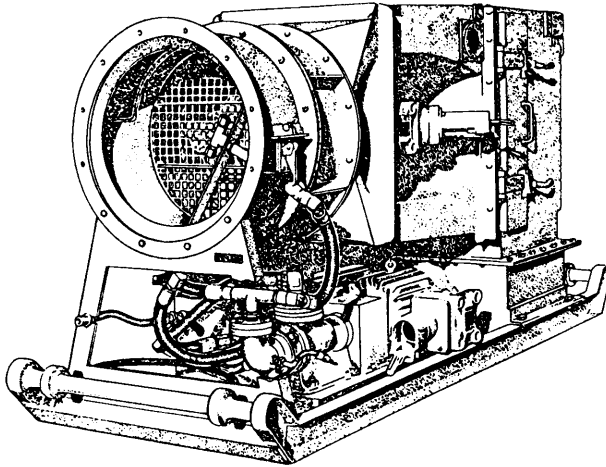


Figure 3 Irrigated air filter Typical pump sizes CMD 30.40.60.
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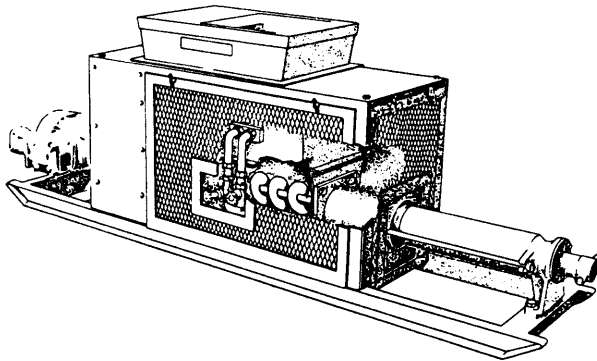


Figure 4 Pump packing, typical pump WT821

Pump packing

Due to its excellent ability to pump abrasive slurries, the screw type pump is now being used at the coal face for the final mixing of two-part cementitious packs (Figure 4). This application uses a helical auger to feed the material into the pump chamber from where it is pumped homogeneously into the pack. 'T' range wide throat pumps are also extensively used for injection spraying and placing of high viscosity grout plaster and cement type mixes. Several types of mobile machines are available, consisting of water and power metering systems, integral drives and Mono wide throat pump.

Various plaster compounds have now been developed designed to seal vertical and overhead surfaces of mine roadways to prevent the leakage of air ventilation. Here Mon T420 and T620 throat pumps are used running up to 250 rpm. A smooth pump output ensures an even application of coating applied in a minimum amount of time. They are low in density and have good adhesion, and can therefore be built up to span gaps, fissures and cracks. This reduced the hazards of fire and spontaneous combustion.

An MT420 wide throat pump is used to inject and aqueous based resin into holes drilled into the coal face in order to improve strata control. The holes are up to 15 metres deep and the pump drive at 100 revs/minute delivers up to 280 litres per hour at pressure up to 9 bar. The pump is hopper fed with the resin, which has a consistency varying from a cream to a thin paste.

A more demanding duty is in the placing of Hardstem, Hardstop and similar materials. It has been found necessary to seal the faces of packs of waste material that form the walls of airways or roadways, as there is a danger of spontaneous combustion, and of air contaminated by gases that issue from the pack. Prior to the development of Hardstop this was a laborious operation. Here again, Mon pumps are extensively used driven at up to 300 rpm, pumping up to 9000 litres per hour and with varying pressures up to 10 bar.

Roof falls underground are common, often leaving large cavities in which methane gas can collect, this increase the risk of explosions. In order to avoid further falls, and to prevent gases collecting, Mono pumps are used with fire retardent slabs to provide a speedy and economical method of filling the cavity. The fire retardent slabs supported on steel arches, are used to shutter off the base of the cavity at roof height. The Mono wide throat is used

to pump slurry directly into the cavity above until it is completely filled

The units can also be used to make emergency fire breaks, and will deliver up to 20000 litres per hour against total heads of 150 metres, which means the machines can operate up to say 400 metres from the discharge area, dependant upon the consistency of the grout mix.

SCREW TYPE PUMPS IN COAL PREPARATION

One of the outstanding features of the Mono pump is its ability to deal with viscous fluids and abrasive materials in suspension. This makes it an ideal pump for handling coal slurry waste products, and chemicals on coal preparation plants. In coal preparation plant systems, varying concentrations of solids are dealt with, and the factors deciding the size and speed of the pump are the quantity of slurry to be pumped and the concentration of solids to be handled. As the concentration of solids increase the speed at which the pump is run is decreased using variable speed drives. On dense medium systems Mono pumps are used to handle the magnetite solution which effects the gravitational separation of solids.

If we take a typical coal preparation plant shown in Figure 5, the first process is usually separate the minus 15 mm product by passing the crushed run-of-mine coal over wet screens. The main product then goes on to be graded, separated and washed.

The minus 15 mm coal underflow from the initial wet screening process is pumped to a rotary vacuum filter for 'desliming' using a MD72 (D10D) Mono pump with a variable speed drive. It is at this point of the process that 'L' Range Mono pumps running at a maximum of 500 rpm can either pump these 15 mm tailings to a 'Vorsyl' cyclone for further separation, or to thickeners where flocculants are added again utilising the 'MD' or 'L' Range Mono pump, depending on capacity. These flocculants are shear sensitive and also very expensive.

The mono pump is able to handle the flocculants without breaking them down. Also being positive displacement the Mono pump is able to be used as a metering pump, to stop wastage of expensive flocculants due to overdosing. The resulting slurry from the thickener or buffer holding tanks with a solids content of 15% is pumped to the top of the compaction cone, and again dozed with

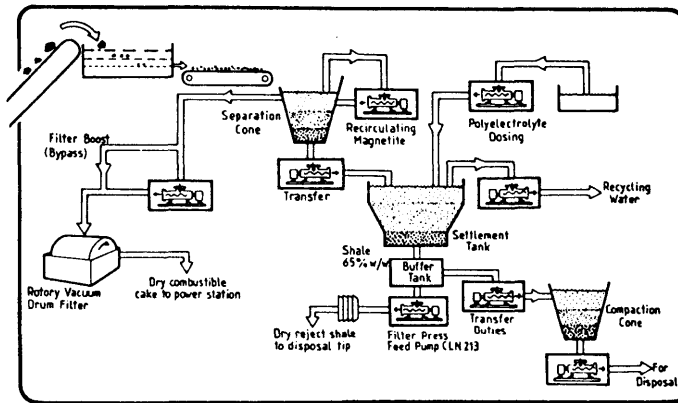


Figure 5 Typical coal preparation plant

floculant. The particles of shale or tailings settle out, and at the base of the cone the material has a solids content approaching 70 - 75%. A 'T' Range Mono pump under the cone operates intermittently working in co-operation with density probes. To transfer the tailings into the funnel located over a conveyor belt, which removed them from the plant, the pump acts as a valve controlling the take off rate from the cone. An MT821 pump running at 90 rpm will pump up to 3 tonnes of tailings effluent per hour.

Mono pumps are also used on pumping the material from the vacuum filters to conditioning floatation cells, where CRESOL based oil is added, from which coal is reclaimed as pulp. Recovered froth is dewatered and the tailings from the froth floatation cells are pumped into thickeners and flocculated and the resultant slurry is pumped directly on one or more filter presses. The steady performance of the Mono pump against increasing pressures is used with advantage to ensure a firm and even cake from the filters in a short space of the time. Operating pressures are usually between 3.5 and 7 bar with solids concentration varying from 20 to 35%.

In calculating the total head against which the pump is to operate, suitable allowances have to be made for the high frictional loss of slurries as compared with water, this frictional loss varying

considerably according to density. To keep small solids in suspension, it is necessary to maintain a fluid velocity of from 1.5 metres to 2.1 metres per second. Therefore particular care should be exercised in selecting the size of delivery pipeline. When selecting the size of the pipe to obtain this velocity, ensure that the total head does not exceed the maximum head limits of the pump. Although the Mono pump is capable of priming itself, the density of the slurry, together with the high frictional loss in the piping usually necessitates slurry pumps being installed, with a low suction lift rather than a positive head. With the latter, problems follow due to solid settling in the pump suction chamber during idle periods. To obtain the maximum life from the wearing parts, the pump and piping should be thoroughly flushed out at the end of the pumping period, particularly, when the pump may be idle for some hours.

CONCLUSION

Since their introduction into the industry in 1939, the screw-type pump using the progressive cavity principle has been almost exclusively supplied by Mono Pump Ltd., of Audenshaw, Manchester. Its simplicity, robust design and ease of maintenance have meant that it has remained the most commonly used underground pump for the last 50 years.

The 'D' range mono pump, still the most commonly used in the industry is only now being replaced by a new range known as 'Merlin'. The Merlin mono pump, still very similar in design to the old 'D' range is to become the new standard within British Coal, alongside the existing 'T' and 'L' ranges.

The most important features of this type of pump, and those which make it most attractive to the mining engineer are, in summary:

- o Self priming of up to 8.4 m suction head
- o Positive displacement with speed -proportional flow
- o Volume flow rates of up to 150 cubic metres per hour
- o Pressure heads of up to 20 bar/200 m
- o Ability to handle a range from liquids from water through to thick slurries
- o Simple design with ease of maintenance.