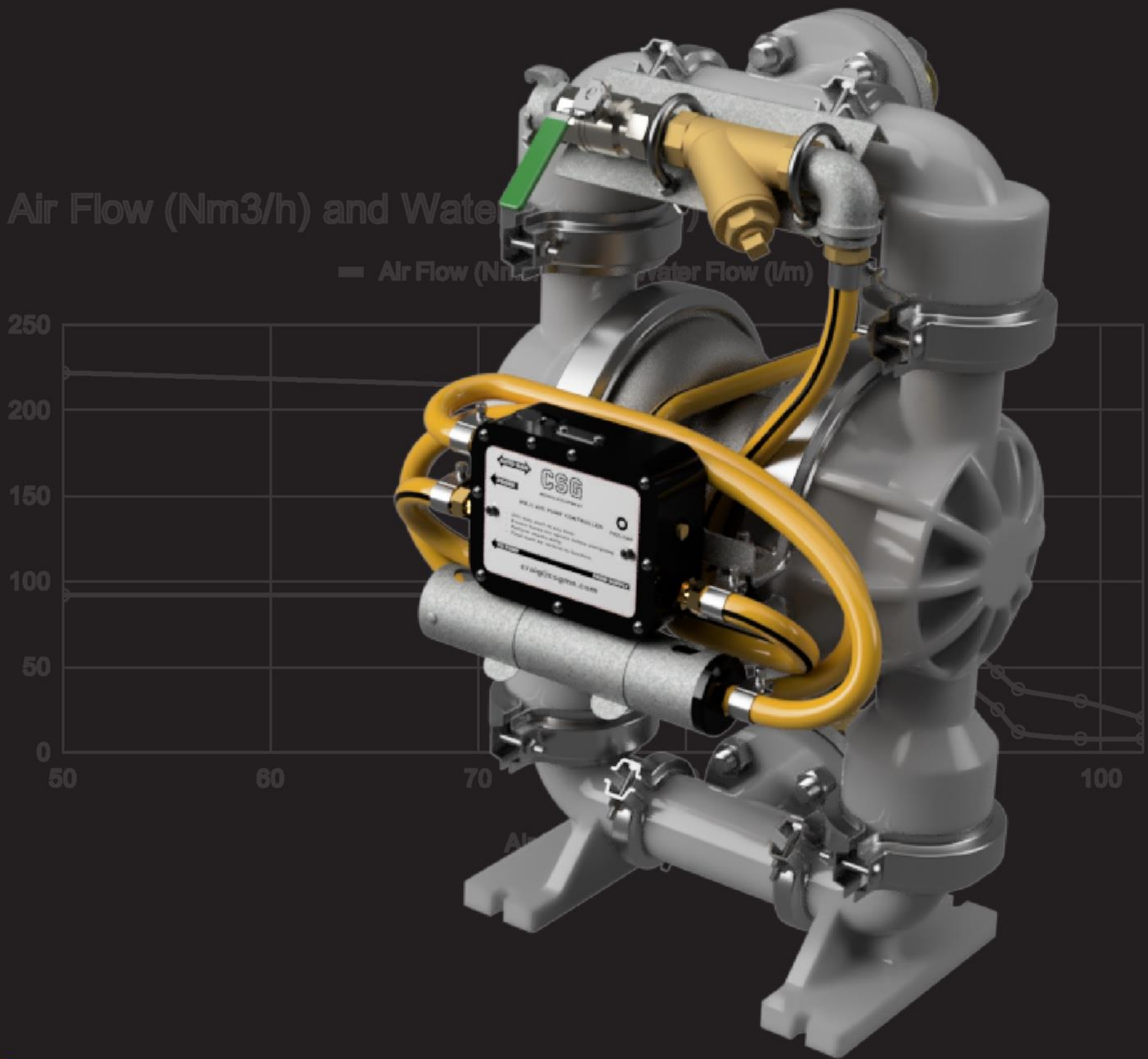
05 MAY 2020

BROADMEADOW

Maintenance Snapshot

28 November 2018 – 20 April 2020



A summary of data from **MK2** pump controllers and diaphragm pumps rebuilt by NOME Services**.**

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Introduction

Water management in an underground coal mine is critical for personnel and infrastructure safety. It also ensures work can continue in line with expected schedules. Diaphragm pumps have long been the industry standard for underground dewatering. However, these pumps have a relatively short service life and high maintenance costs. The pumps also run continuously requiring significant expenditure on infrastructure and electricity to ensure sufficient air supply. A compressed air audit from an underground mine in northern New South Wales (NSW) showed more electricity expenditure for their air compressors than their longwall shearer.

Nome Services (NOME) in conjunction with CSG has developed a controller to reduce energy consumption and maintenance costs while increasing pump service life and air pressure at the coal face. The Mk.II Air Pump Controller automates pump usage and ensures it operates only when water management is required.

1. Trial at BMA's Broadmeadow Mine

The Mk.II Air Pump controller has undergone an extended trial and testing period with BMA's Broadmeadow Mine (BRM) located in the Bowen Basin in Queensland. The staged trial period has seen a total of 71 controllers installed on pumps across the mine. This report contains data and information related to the trial including cost comparisons, failure modes, maintenance and upcoming NOME innovations.

The trial progressed as follows:

Date	Controllers
11/2018	6
02/2019	20
12/2019	45
TOTAL	71

A total of 71 controllers have been in operation for a combined 15,092 days of service.
Based on data provided by BRM, these NOME Mk.II controllers have reduced air consumption by approx. 65 m^3min^{-1}.

Overall cost saving
During the trial period, the controlled pump fleet has saved BRM $367,756 in maintenance and electricity costs. On an annual basis, 71 pumps fitted with controllers and maintained by NOME will save $705,966.

2. Cost comparison

The major costs associated with diaphragm pumps are maintenance and energy consumption.

2.1 Maintenance

Service life
The average service life for a pump without a controller is 60 days. NOME has calculated that a controlled pump will last an average of 274 days. This calculation includes those pumps that have been tagged out due to

damage. This average has been determined by calculating the time between rebuilds for pumps returned to the NOME workshop during the trial period (9 pumps).

The longest documented time in service so far for a controlled pump is 498 days. This is from the day of installation at the mine site to the day it was received back at NOME.

Figure 1. *Calcification of pump after 498 days in service*

Figure 1 shows the ball chamber of the diaphragm pump after 498 days in service. Although the pump was still able to cycle, mineral build up restricted water flow making it ineffective. This pump was then tagged out of service. Pumps without a controller (uncontrolled pumps) usually fail due to seal or diaphragm wear in a far shorter time frame.

Maintenance costs

For the purpose of comparing a controlled pump fleet to an equivalent uncontrolled fleet, it has been assumed rebuilds on uncontrolled pumps are required every 60 days at a cost of $900. The extended service life of controlled pumps mean that rebuild costs incurred by the mine will reduce as they are stretched to longer intervals.

NOME has completed 60 rebuilds on BRM pumps as part of the controller fit out. The average cost has been $700 per rebuild. This represents a significant saving of $200 for each rebuild.

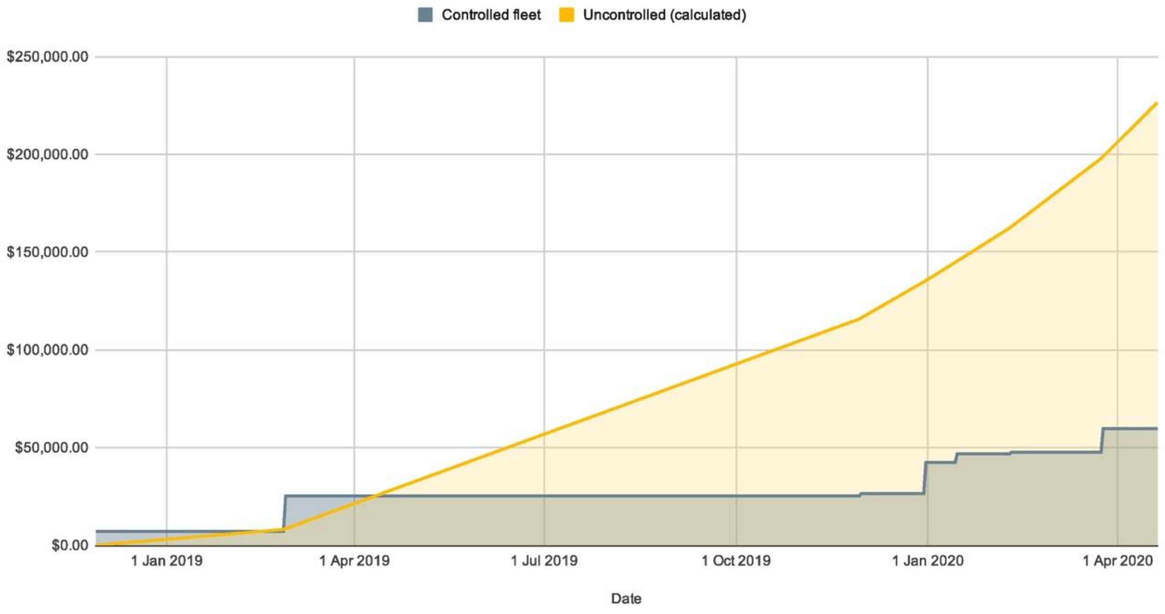

Figure 2. *Maintenance cost comparison for controlled and uncontrolled pumps*

Figure 2 shows the cost comparison of BRM's use of 71 controlled pumps and the costs of an equivalent number of uncontrolled pumps. The graph reflects the addition of pumps at various intervals during the trial period (refer section 1).

Maintenance cost assumptions during trial period

Assuming an average 60-day service life for uncontrolled pumps, the accumulated 15,092 days in service would require 251 pump rebuilds. This equates to $226,380 in maintenance costs over the trial period at $900 per rebuild.

Actual costs incurred during trial period

During the trial period, 9 out of 71 controlled pumps have come back to the NOME workshop for a rebuild. Total maintenance cost (rebuilds and parts replacement) on the controlled pumps has been $7,505.48. Repairs and maintenance to controllers account for less than $100 of this amount. The total cost to the mine since starting the trial is $73,205, including the cost of new controllers. This represents an actual saving of $153,175 on expected costs for the time period.

Maintenance costs extrapolated over 12 months (71 pumps)

Based on a 60-day service life and current rebuild costs with a different provider, uncontrolled pumps will have maintenance costs of approx. $388,800 over a 12-month period.

Based on an extended service life (274 days) and lower rebuild rates offered by NOME, controlled pumps will have maintenance costs of approx. $51,300 over a 12-month period. This represents a cost saving of $337,500.

2.2 Energy consumption costs

If the pumps that have been returned to the workshop for reasons other than wear (e.g. damage) are discounted, the average service life for controlled pumps increases to 364 days. Given the average service life of an uncontrolled pump is 60 days, it is reasonable to assume that a controlled pump operates for approx. 16% of the time leading to an extended service life.

Assuming an energy tariff of $0.13307/kWh and an energy demand of 5.3kW to supply 1.1 m3min-1 of air to each pump, the energy cost of the uncontrolled fleet during the trial period (15,092 days) would have been **$255,454**. This equates to an annual energy cost of **$438,650** to run 71 uncontrolled pumps.

With an approx. 84% reduction in running time, energy costs for the controlled fleet have been calculated at **$40,873** for the trial period. This is a saving of **$214,581** in energy costs so far and will save **$368,466** over the next 12 months. The mine's carbon footprint will also reduce by **2,215t** per annum.

3. Spending breakdown

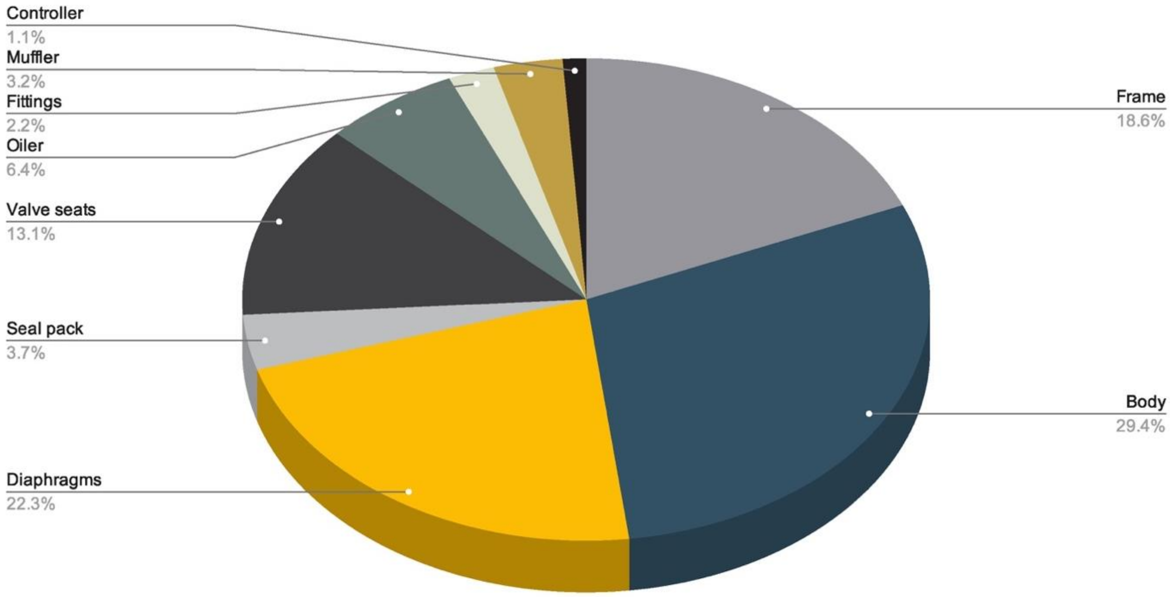

Figure 3. *Maintenance spend by pump part*

Figure 3 shows the maintenance costs for various parts of the diaphragm pump. Costs are included for both wear and damage, however those attributed to frame, body and oiler are almost entirely due to damage.

4. Failure modes

Equipment failures have been identified and recorded during the trial period. These relate to both the controller and the pump.

4.1 Controller failure modes

Excessive oiling
Feedback from site has highlighted that when an inline oiler is installed upstream of a Mk.II controller, the controller can cease to function.

The inline oiler provides lubrication to the pump and is not required for the controller to operate. It is recommended that inline oilers are installed downstream of the controller to alleviate this issue.

Number of occurrences = unknown.

Blocked nozzle

A controller failed due to an obstruction in the probe nozzle.
This can be fixed on site by referring to the user manual. Installing a standard inline filter with a mesh size of <0.5mm upstream of the controller reduces the chance of this failure occurring.

Number of occurrences = 1.

Electrolytic corrosion

A controller has presented with corrosion between the pilot valve piston and return spring sufficient to impede the piston's movement.
The return spring is not required for proper function of the pilot valve, so the return spring has now been removed from controllers.

Number of occurrences = 1.

Fitting failure

The internal T piece fitting on the controller has failed on two occasions for unknown reasons.
The controller design has been changed to alleviate this issue. The Mk.III controller (available within two months) is a monolithic valve block with no internal fittings.

Number of occurrences = 2.

4.2 Pump failure modes

Diaphragm failure – fatigue

The diaphragm will crack over time due to material fatigue. Diaphragms are available in a number of different materials, some of which may be more suitable than neoprene.

Figure 4. Example of diaphragm failure due to fatigue

Diaphragm failure – abrasion

Diaphragms are the most expensive wear part on the diaphragm pump. Abrasion damage is less common than fatigue, however it still represents a significant cost.

Figure 5. Example of diaphragm failure due to abrasion

Valve seat wear

The standard injection moulded polyurethane valve seats and neoprene balls experience wear that causes the check ball to jam or fall into the diaphragm chamber.

Figure 6. Example of pump failure due to valve seat wear

4.3 Alternative materials for diaphragm pump parts

NOME is currently testing Wil-Flex™ and polyurethane diaphragms which have better abrasion resistance than the standard neoprene. Figure 7 shows that neoprene is not an optimal material for these types of parts and there are more suitable alternatives.

	Compound	Flex Life	Abrasion Resistance	Chemical Resistance/Applications						Operating Temperature Limits (Min/Max)	Cost ($)
				Keytones & Aldehydes	Acetates	Aromatic Hydrocarbons	Chlorinated Hydrocarbons	Oil & Gas	Water/ Wastewater		
Thermoplastic (TPE)	Polyurethane	A	A						✓	-12° to 66°C [10° to 150°F]	$
Thermoplastic (TPE)	Wil-Flex™	A	A	✓	✓				✓	-40° to 107°C [-40° to 225°F]	$
Thermoplastic (TPE)	Saniflex™	B	A			✓				-29° to 104°C [-20° to 220°F]	$$
Thermoplastic (TPE)	Geloast®	C	B					✓		-40° to 82°C [-40° to 180°F]	$$
PTFE	PTFE	A	B	✓	✓	✓	✓	✓	✓	4° to 104°C [40° to 220°F]	$$$
Rubber	Neoprene	B	C						✓	-18° to 93°C [0° to 200°F]	$
Rubber	Buna-N	C	C					✓		-12° to 82°C [10° to 180°F]	$$
Rubber	EPDM	B	C	✓	✓					-51° to 138°C [-60° to 280°F]	$$
Rubber	Viton®	C	C			✓	✓			-40° to 177°C [-40° to 350°F]	$$$

Figure 7. *Alternative materials that may be suitable for pump part manufacture*

5. NOME innovations

Valve seats

NOME is testing the use of machined nylon valve seats to improve abrasion resistance. Machined valve seats have a tighter mechanical tolerance when compared to moulded ones, giving an optimal O-ring groove and a better seal between joints at high pressure.

Figure 8. *Valve seats made from nylon*

Figure 9. Valve seat installed in pump

Pump frames

NOME is also manufacturing its own pump frames with improved design specifications than ones generally used for pumps. The pump frames are smaller than standard and have been designed to reduce coal build up which can lead to manual handling risk.

Figure 10. *Pump frame manufactured by NOME*

6. Maintenance timeframes

NOME currently has a maintenance turnaround time of 7 days for 10 pumps. This can be scaled up if sufficient volume exists. NOME uses several suppliers to ensure parts availability and will be maintaining sufficient inventory of wear parts such as diaphragms, valves and seals to meet demand.