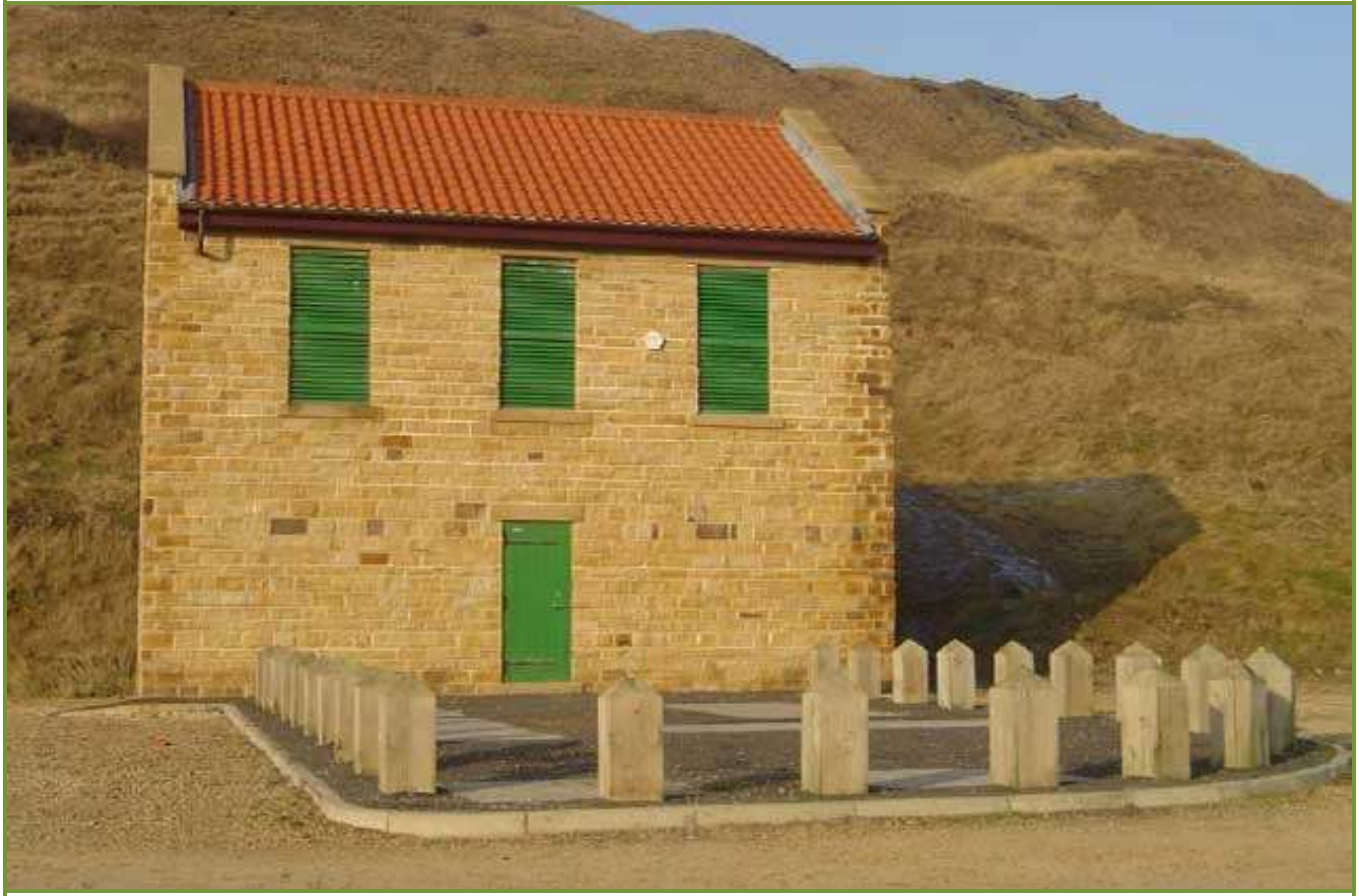
Retroflo
REVOLUTIONARY PUMP CONTROL

● CASE STUDY
SKINNINGGROVE TRANSFER PUMPING STATION



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New Control Regime December 2007 – January 2008
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EXECUTIVE SUMMARY

This report follows 38 days of successful operation, with a total of 128 successful Pre-Blockage Detection routines implemented and no operator intervention to remove blockages from pumps. The benefits of the new regime are explained:

Pre-Blockage Detection

Reduction in OPEX reactive maintenance costs

Since implementing the new regime no operator / maintenance intervention has been required to remove blockages from the pumps. Also, following this initial period, upon splitting the pumps, a massive improvement in the condition of the volute and impellor with respect to deposited debris was observed and documented.

Pre-Blockage Detection

Reduction in OPEX efficiency costs

Initially it was envisaged that the majority of the benefit of installing the new control regime would be blockage alleviation. As the site was already fitted with VSD drives we assumed that maximum efficiencies may already be achieved; however by initiating pump reversal cycles on detection of partial blockages and returning the pump to optimum operating conditions, this equates to a 12% decrease in power during normal operation. Prior to implementing the new regime these increases in operating costs would go unnoticed.

Flushing Cycle

Improvement of Wet Well condition

A vast improvement in the condition of the Wet Well is observed due to success of the Flushing Cycle. The Flushing Cycle serves to cleanse the Wet Well which reduces the threat of blockages to the pumps and reduces the need for routine cleansing.

1. INTRODUCTION

The new intelligent control regime and associated works commenced December 2007, being fully commissioned and operational by 9th January 2008. This report follows a period of successful operation and using data obtained, aims to highlight the benefits of the system.

2. SCOPE OF MODIFICATIONS

In brief the scope of the Project comprises the following:

2.1 Duty Rotation

Modification to the existing pump duty rotate initiation i.e. the inclusion of an operator adjustable duty pump maximum run timer and provision for duty rotate after every process stop. This now provides frequent duty rotation and reduces the potential for blockages.

2.2 Pre-blockage Detection

Provision of a new intelligent sequence, which provides dynamic monitoring of the pump operating characteristics. When a pump is monitored outside of its normal operating characteristics, indicative of a potential pump blockage event, corrective action is taken to remedy the problem i.e. reversal of the suspect pump. If successful the blockage is removed and normal operation resumes; however following a maximum of 3 unsuccessful reversal cycles the suspect pump is tripped and locked-out by the PLC. This saves operating costs by ensuring pumps are not operated inefficiently. Following pump lock-out, the standby pump assumes duty and is operated. Should this pump become tripped, the locked-out pump is reset, assumes duty and is operated. This reset actions ensures that following catastrophic failure of the remaining pump, pumps locked-out by the control system are operated, however inefficiently, thus mitigating the risk of non-compliance with the imposed consent flow. An alarm is forwarded to the Regional Telemetry system informing the operators that action is required. This may be used to indicate that pumps are operating inefficiently and operating costs are increased. The pump Pre-blockage Detection sequence is operational between the duty pump stop level and high level set-points.

2.3 Consent Alarm

Modification of the existing Consent Alarm, whereby in place of alarm indication only which originally instigated an immediate site visit, upon detection of the Consent Alarm trigger the system attempts to remove blockages from the suspect pump by means of pump reversal cycles. If successful, the blockage is removed and normal operation resumes; however as with Pre-Blockage Detection following a maximum of 3 unsuccessful reversal cycles the suspect pump is tripped and locked-out by the PLC. The standby pump assumes duty and is operated. Should this fail pump fail to deliver Consent flows, only at this point is the original Consent Alarm forwarded to the Regional Telemetry system. This now ensures that every attempt is made to deliver Consent flows by the pumps available, and only after both pumps have failed to deliver Consent flows is a site visit required. This new Consent Alarm regime reduces the reactive maintenance costs by reducing the potential for site visits.

2.4 Flushing Cycle

Modification of the existing Flushing Cycle to enable selection of the desired Flushing Cycle liquor volume to:-
a) Ensure adequate dilution of settled solids during the Flushing Cycle, to minimise the risk of blockage events.

b) Provide prolonged operation of the pumps to ensure rising main self cleansing velocities are achieved, at regular intervals, to prevent deposition in the main.

During the Flushing Cycle the level in the wet well is now allowed to fill to a predetermined Engineer adjustable level. The greater the level, the greater the volume, resulting in a greater settled solids dilution ratio and longer pump operation duration to achieve the above.

2.5 Flow Meter Failure

Optimisation of the existing control system following works flow instrument failure. The works flow meter is located at the Treatment Works, the flow signal being generated to the Transfer Station PLC via the communications network. Originally when the flow signal to the Transfer Station PLC was lost the pumps were inhibited to protect the works from unknown flow rates. Immediate manual operator intervention was required to prevent spill events. Under the current modified regime, upon flow meter failure the pumps remain operational. The duty pump responds to the normal duty pump start and duty pump stop level set-points and operates at a fixed speed. This speed is selected to best deliver the required consent flow rate without compromising the works. As with the Consent alarm, this new regime reduces reactive maintenance costs by reducing the potential for site visits.

3. NEW OPERATING PHILOSOPHY.

3.1 Duty Pump Operation

The existing variable speed Transfer Pumps operate on a Duty / Standby basis.

Whenever a pump is called to run or to stop in H.M.I Automatic, the pump runs in reverse for 30 seconds in order to help de-rag the impeller. This is now a function of the PLC.

At the duty pump start level the duty pump is operated in reverse direction (at 60% speed reference) for 30 seconds to remove any debris which may have settled around the suction point since its last operation. Following this the duty pump is operated in the forwards direction at 100% speed reference for 30 seconds (referred to as ‘boost’) to prevent ragging of the pump impeller.

The pump speed is then controlled to maintain a pre-determined level within the wet well; currently set at 1.60 metres. This method of control provides the best platform to achieve maximum efficiencies, as pumped flow theoretically matches influent flow.

When inflow increases the level in the wet well also increases, as a result the pump speed is increased and delivered flow increases. Alternatively, when inflow decreases the level in the wet well decreases, the pump speed is decreased and delivered flow decreases.

The speed of the duty pump is controlled to deliver a minimum of 60 l/s. During times when the influent flow drops below this 60 l/s set-point, the level in the wet well will eventually fall below the duty pump stop level. At this point the duty pump is operated in the forwards direction at 100% speed reference for 10 seconds (also referred to as ‘boost’). This is to prevent both solids deposition in the line and ragging of the pump impeller. The duty pump is then operated in reverse direction at (60% speed reference) for 30 seconds prior to stopping, to remove any debris which may have settled around the suction point during operation. Duty is rotated; the standby pump assumes duty status – the duty pump assumes standby status and both pumps remain stopped until the duty pump start level is again monitored, at which point operation is repeated.

3.2 Pre-blockage Detection

At any time during normal operation, with the duty pump in operation and the monitored wet well level below the High Level set-point, should the control system detect the pump operating outside of its normal operating characteristics remedial action is taken:

A. The duty pump is stopped. The system does not perform a boost operation prior to stopping to prevent compounding the potential blockage event. At this point Pre-Blockage Detection monitoring is disabled.
B. The duty pump is operated in reverse direction (at 60% speed) reference for 30 seconds in attempt to remove the blockage, after which, the duty pump is operated in the forwards direction at 100% speed reference for 30 seconds. Normal operation resumes and Pre-Blockage Detection is re-enabled.
C. If the blockage is still evident, the reversing cycles continue for a maximum of 3 attempts after which the suspect pump is tripped and locked-out by the PLC. An alarm is forwarded to the Regional Telemetry system.
D. The standby pump assumes duty and is operated as the duty pump. Should the control system detect this pump operating outside of its normal operating characteristics, a maximum of 3 pump reversal sequences are implemented, after which the pump continues to operate and an ‘Efficiency Alarm’ is forwarded to the regional telemetry system. This provides indication that despite there being no current threat to the Consent, the pump is operating at reduced efficiencies and operating costs are increased. This enables action to be taken to address the problem.
E. If at any time a pump is locked-out by the PLC and the operating pump becomes failed due to other reasons, the tripped pump is reset and operated by the PLC irrespective of efficiencies and costs to prevent compromising the Consent.

3.3 High Level

The speed of the duty pump is controlled to deliver a maximum of 82 litres per second. During times when the influent is greater than 82 l/s the level in the wet well will rise to the ‘High Level’ set-point. At this point a High Level alarm is forwarded to the Regional Telemetry system. Pre-blockage Detection is disabled and Consent Alarm monitoring is effective. The system continues to controls the pump to deliver 82 litres for the duration of the High Level event.

3.4 Consent Alarm

When the level in the wet well is monitored above the High Level set-point, Pre-Blockage Detection is disabled. This is to ensure that greater emphasis is placed on the importance of processing flows during spill events rather than reduced efficiencies and increased operational costs due to partial blockages. It isn’t desirable to perform repeated reversal sequences when in spill conditions, provided Consent flows are being achieved. Only when the delivered flow drops below the Consent value are reversing cycles considered desirable, if not essential.

The Consent alarm action effectively mirrors the Pre-blockage Detection routine, with different trigger criteria. With the duty pump operational during High Level conditions, if the pumped flow rate is monitored below the Consent value for a time period of two minutes, remedial action is taken.

A. Pump reversal sequences are initiated to remove partial blockages.
B. If the blockage is still evident, the reversing cycles continue for a maximum of 3 attempts after which the suspect pump is tripped and locked-out by the PLC.
C. The standby pump assumes duty and is operated as the duty pump. Should the delivered flow again fall below the Consent value a maximum of 3 pump reversal sequences are implemented, after which the pump continues to operate and the original ‘Consent Alarm’ is forwarded to the regional telemetry system.
D. If at any time a pump is locked-out by the PLC and the operating pump becomes failed due to other reasons, the tripped pump is reset and operated by the PLC. This is to ensure the flows are delivered irrespective of any deficit between Consent and actual flows. Reduced flows are better than no flow at all.

4. BENEFITS OF THE NEW REGIME.

4.1 Pre-blockage Detection

Pump Blockage Alleviation As of Friday 15th February the control system had performed a total of 128 Pre-Blockage Detection pump reversal sequences. It would be incorrect to state that every one of these potential blockage events would have resulted in a breakdown situation requiring maintenance intervention, however we should consider the following;

A small blockage in the pump body presents a greater threat to further debris passing through the pump, which tends to collect and add to the original problem. Pre-modification this manifested until the pump could no longer deliver Consent flow or the pump protection caused the pump to trip i.e. Over-current or Over-temperature etc. This resulted in a breakdown situation requiring operation and maintenance personnel attending the site, removing the pump from its location and removing the blockage; a timely and costly procedure. Removing the smaller debris upon initial pick-up prevents the large build up which ultimately may lead to a breakdown situation. Each one of these blockages events, if not addressed could eventually over time lead to a breakdown situation requiring operator and maintenance intervention.

4.1.1 Pre-Modification Photographic Data

The following pictures (figures 4.1.1.a & 4.1.1.b) depict the condition of the pumps prior to implementation of the new control regime. The extent of the blockage is clearly visible. The pumps were still operational despite the partial blockage, operating at 100% speed with reduced flows and with no indication to operations of the problems.

Figure 4.1.1.b *Figure 4.1.1.a*

Figures 4.1.1.a & 4.1.1.b – Details the typical extent of a blockage in pump impellors prior to implementing new intelligent control regime.

The following pictures (figures 4.1.1.c & 4.1.1.d) depict the compactness of the solids removed from the pumps prior to implementing the new regime. Experience suggests that without operator intervention the solids shown would eventually lead to pump failure.

Figure 4.1.1.c *Figure 4.1.1.d*

Figure 4.1.1.c & 4.1.1.d – Details the compactness of the blockage material; indicative of compounding over time.

4.1.2 Post Modification Photographic Data.

The following pictures (figures 4.1.2.a & 4.1.2.b) indicate the condition of the pumps, 15th February 2008, following 38 days of successful operation without any operator or maintenance intervention to remove blockages.

Figure 4.1.2.a

Figure 4.1.2.b

Figures 4.1.2.a & 4.1.2.b – Detail the obvious improvement after implementing the new regime

It can clearly be seen that there is a vast improvement in the condition of the pumps.

4.2 Pre-blockage Detection: Pump Efficiency savings

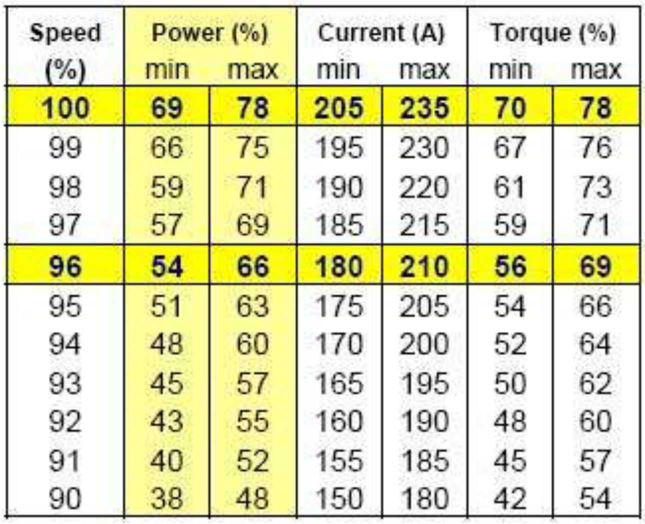
Pump Pre-blockage Detection monitors the characteristics of the pumps when the station is not in High Level. Historically it is during High Level situations that problems occur. Settlement of the solids is intensified over prolonged pump operating periods. The pumps pick up these solids; performance is affected, energy consumption and costs are increased.

When in High Level conditions the pumps are controlled to maintain a forward flow to the works of 82 l/s. Under optimum operating conditions each pump is observed operating at approximately 96% speed reference to deliver 82 l/s (slight variations exist). Over time settlement is intensified and the pumps pick up debris.

Ordinarily, (when not in High Level conditions), Pre-blockage Detection would detect theses partial blockages and perform reversal cycles; however as previously described, provided Consent flows are being achieved, reversal cycles aren't implemented.

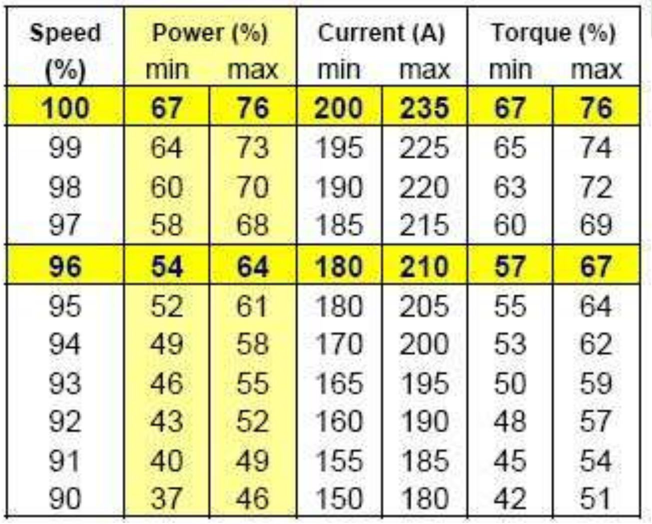
Consequently this debris continues to impede the pumps performance and the control system increases the speed of the under-performing pump in an effort to deliver the required 82 l/s. The end result is a pump operating at 100% speed reference (as opposed to 96% speed reference) to deliver the equivalent (and maybe less) flow rate.

Whilst this 4% increase in speed may sound negligible, from the pump operating data observed on site this actually equates to a much larger increase in power, torque and current, as detailed below.



Speed (%)	Power (%)		Current (A)		Torque (%)	
	min	max	min	max	min	max
100	**69**	**78**	**205**	**235**	**70**	**78**
99	66	75	195	230	67	76
98	59	71	190	220	61	73
97	57	69	185	215	59	71
96	**54**	**66**	**180**	**210**	**56**	**69**
95	51	63	175	205	54	66
94	48	60	170	200	52	64
93	45	57	165	195	50	62
92	43	55	160	190	48	60
91	40	52	155	185	45	57
90	38	48	150	180	42	54

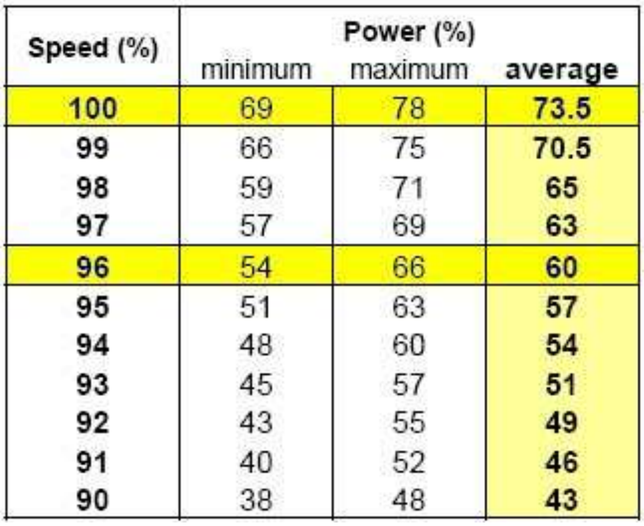
Figure 4.2.a
Details the observed operating data for
Pump No.1: Power, Current & Torque



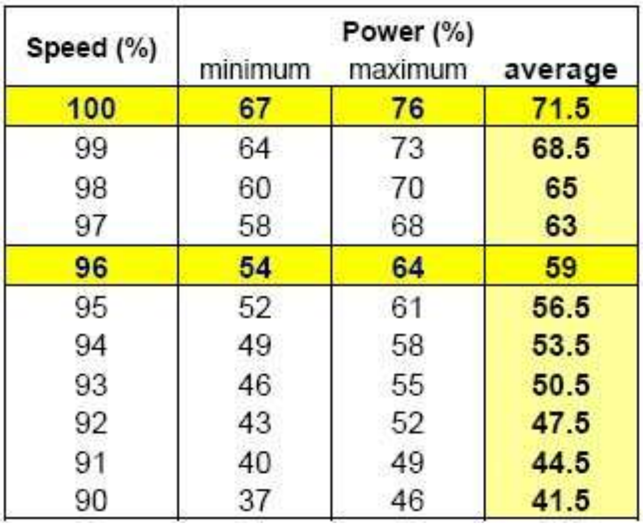
Speed (%)	Power (%)		Current (A)		Torque (%)	
	min	max	min	max	min	max
100	**67**	**76**	**200**	**235**	**67**	**76**
99	64	73	195	225	65	74
98	60	70	190	220	63	72
97	58	68	185	215	60	69
96	**54**	**64**	**180**	**210**	**57**	**67**
95	52	61	180	205	55	64
94	49	58	170	200	53	62
93	46	55	165	195	50	59
92	43	52	160	190	48	57
91	40	49	155	185	45	54
90	37	46	150	180	42	51

Figure 4.2.b
Details the observed operating data for
Pump No.2: Power, Current & Torque

The average observed reduction in power for Pump No.1 when reducing Pump speed from 100% to 96% speed reference is 13.5% whilst the average observed reduction in power for Pump No. 2 is 12.5% for the same reduction is speed (see figure 4.2.c overleaf)



Speed (%)	Power (%)		
	minimum	maximum	**average**
100	69	78	**73.5**
99	66	75	**70.5**
98	59	71	**65**
97	57	69	**63**
96	54	66	**60**
95	51	63	**57**
94	48	60	**54**
93	45	57	**51**
92	43	55	**49**
91	40	52	**46**
90	38	48	**43**



Speed (%)	Power (%)		
	minimum	maximum	**average**
100	**67**	**76**	**71.5**
99	64	73	**68.5**
98	60	70	**65**
97	58	68	**63**
96	**54**	**64**	**59**
95	52	61	**56.5**
94	49	58	**53.5**
93	46	55	**50.5**
92	43	52	**47.5**
91	40	49	**44.5**
90	37	46	**41.5**

Figure 4.2.c *Figure 4.2.d*
Details the minimum, maximum and average Power for Pump No.1 & Pump No.2.

Pump Power consumption via calculation

Theoretically the decrease in power consumption from 100% pump speed to 96% pump speed may be calculated by applying the following recognised equation:

$$\frac{kW2}{kW1} = \left(\frac{N2}{N1}\right)^3$$

where

N1 = Full Speed (%) = 100%
N2 = New Speed (%) = 96%
kW1 = Full Power (%) = 100%
kW2 = New Power (%) = ???%

$$\frac{kW2}{100} = \left[\frac{96}{100}\right]^3 =$$

$$\frac{kW2}{100} = \left[\ 0.88\ \right]^3 =$$

$$kW2 = 100 \text{ X } 0.88 = 88\%$$

$$kW2 = 88\%;\ \text{a reduction of } 12\%$$

Conclusion

These observed site data and calculations serve to prove that a decrease in pump speed from 100% pump speed to 96% pump speed equates to a minimum reduction of 12% power. Without Pre-Blockage Detection and the facility to detect and counter partial blockages, when partially blocked the pumps will eventually be operated at maximum speed, resulting in increased operating costs. This increase in costs would go undetected until a catastrophic blockage occurs resulting in a breakdown situation. Pre-blockage Detection ensures that the pumps operate efficiently at all times whilst also reducing the potential for breakdown situations. By removing partial blockages when in low level conditions this provides a 4% reduction is speed, a 12% reduction in power and prevents further debris from collecting.

4.3 Pre-Blockage Detection

System recovery from potential blockage situations

4.3.1 Normal Operation

During low flow conditions the pumps are started and stopped between two predetermined level set-points and controlled to maintain a further pre-determined level. Currently a minimum flow rate of 60 l/s is set which deems that in times of low flow the wet well level reaches the stop level at regular intervals, the duty pump maximum run timer (currently set at 1 hour) doesn't expire. This can be seen in the figure be seen in figure 5.1.a

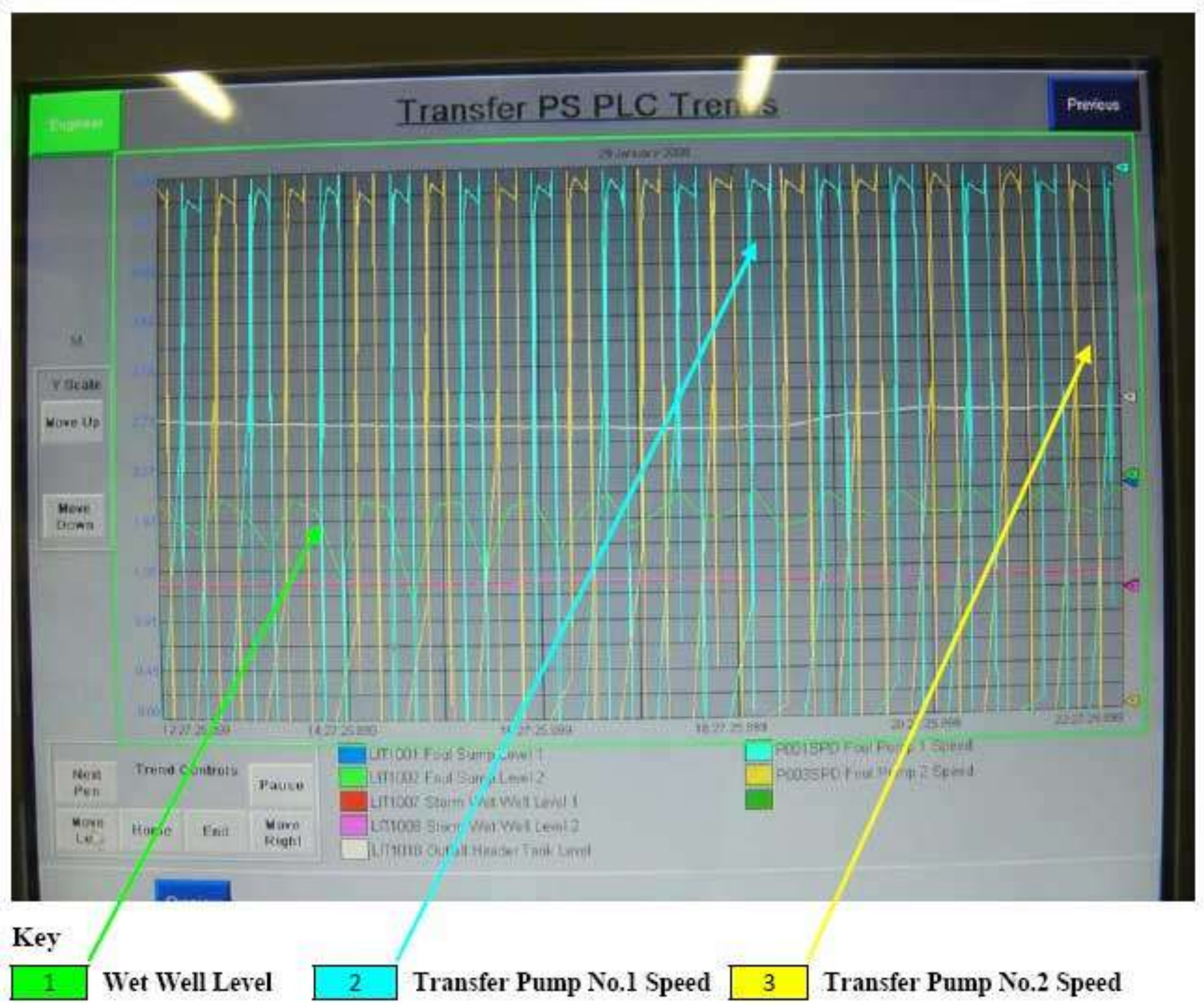


Figure 4.3.1.a – Details normal pump operation in times of low flow.

The blue (2) and yellow (3) trend lines are indicative of Pump No.1 and Pump No.2 speed reference (respectively), which is indicative of pump operation duration. It can be seen pump operation is sequential i.e. Pump No.1 operates for a time followed by Pump No.2, repeated for the duration of the displayed time period.

Each pump operating period is approximately 12 – 13 minutes. This indicates that the inflow for the monitored time period was less than 60 l/s (the minimum operating flow of the pumps) as duty pump stop levels and duty rotation are achieved.

The green line (3) is indicative of the Wet Well level; however this details average level data. Due to the construction of the well (steep benching) the well below a certain level is emptied rather quickly and fills in an equally quick manner. The result when observing this historic data is that average wet well levels are displayed for the time period, rather than the precise levels corresponding to pump speed; hence the seemingly erratic level.

4.3.2 High Level Operation

Once the wet well level is monitored at high level, Pre-Blockage Detection is disabled. It is during these conditions that settlement is intensified, and operating pumps tend to pick debris. Provided Consent flow values are being delivered by the operating pump, remedial action (pump reversal cycles) isn't taken. The remedial action is postponed until the station has recovered from High Level conditions and Pre-Blockage Detection is re-enabled.

Figure 4.3.2.a – Details normal pump operation in times of high flow (and subsequent High Level).

It can be seen in figure 5.2.a (above), during High Level conditions (1) each pump operates sequentially for 1 hour (2 & 3). During the High Level situation, debris is picked up by the pump which affects performance operation. To counter this impedance the pump speed is eventually ramped to 100% (as opposed to 96%). These situations may exist for numerous days.

4.3.3 Pre-Blockage Detection; pump reversal sequences

Figure 4.3.3.a – Details pump reversal sequences following recovery from a wet well high level situation

As the storm situation abates and inflow reduces below 82 l/s the level in the wet well begins to decrease. It can be seen that Transfer Pump No.1 & No.2 again operate sequentially for 1 hour (1 & 2). The level in the Wet Well is decreasing (A). Once the level in the Wet Well is monitored at a level where Pre-Blockage Detection is re-enabled (B), operating pumps with potential blockages are addressed by the Control system.

Pump No.1 is in operation and the peaks and troughs in the trend line (3) indicate the initiation of reversal cycles to remove the blockage. From this diagram we can deduce that the reversal cycles were successful as consecutive sequential operation of each pump is observed (4 & 5), with a corresponding low level (C).

These successful recovery cycles aren't isolated to a single event; in fact these have been witnessed on numerous occasions, as detailed below.

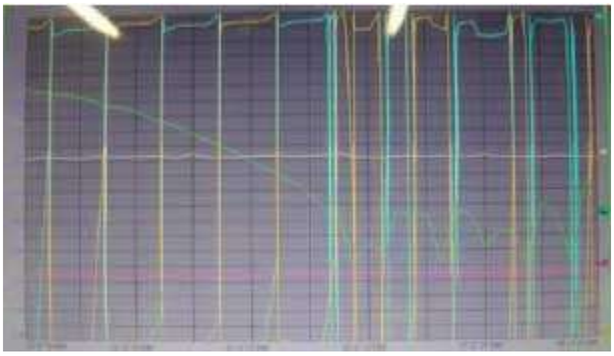


Figure 4.3.3.b-11th January 2008

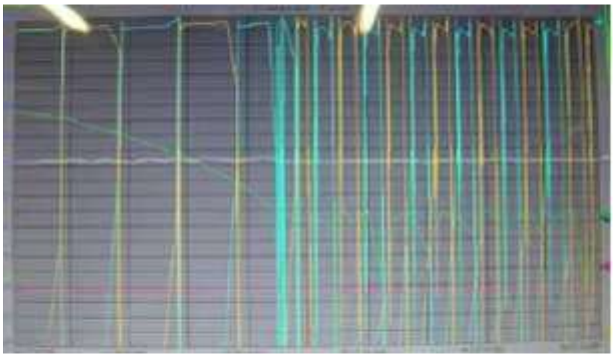


Figure 4.3.3.c – 18th January 2008

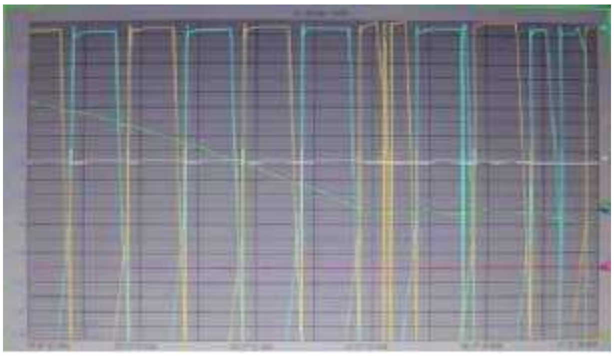


Figure 4.3.3.d – 23rd January 2008

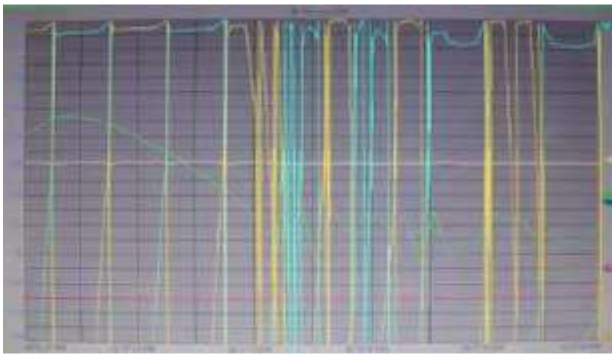


Figure 4.3.3.e - 6th February 2008

4.4 Flushing Cycle

The regular flushing cycle provides emptying of the Wet Well to below normal operating levels, providing a daily scouring effect. The ability to select the desired volume of water used for the flushing cycle ensures that adequate dilution of the settled solids is achieved, reducing the potential for pump blockages during the cycle.

This coupled with Pre-Blockage Detection, which monitors and protects the pump during the flushing cycle, ensures that flushing cycles are effective and solids removed are from the Wet Well.

The reduction of solids in the Wet Well maximises pump operation and theoretically increases the success rate of the Pre-Blockage Detection pump reversal sequences. In short, Pre-Blockage Detection complements the Flushing Cycle and successful Flushing Cycles complement Pre-Blockage Detection. The result is a clean wet well, again observed following 38 days of successful operation.