THE REAL COST OF REDUCED FLOW– MAINTAINING PUMP EFFICIENCY

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ABSTRACT

Wear in an operating pump is inevitable. As a pump wears, it is normal that the flow rate will decrease. Not all pumps wear at the same rate, pumps that are the same but used even slightly differently will wear at different rates. However, pump manuals typically specify the period between maintenance with no reference to the wear. Economic justification is becoming increasingly relevant, and maintenance can at times be viewed as an unnecessary expense. This paper is a desktop case study that reviews the ongoing energy cost for a pumping system that has worn. Two different scenarios that commonly cause reduced flow are examined, each for two different intensities that result in 10% and 20% reduction in flow. The results show that for the pump and scenarios reviewed, the ongoing excess energy consumption may be ½ to 1 ½ times the flow reduction. Another finding is that the pump duty point has moved further from the Best Efficiency Point, indicating that the rate of wear will increase if operation is continued. The case study demonstrates a process that can be utilised and allows the wear for a specific pump to be evaluated.

1.0 INTRODUCTION

Determining the optimum time to perform pump maintenance has challenges.

Too soon, wasted money on parts and labour,
Too late, possible breakdown, interruption to service, irreversible damage.
If there is redundancy in place, is there any cost of delaying maintenance?

Specific energy is the amount of energy required to pump a kilolitre of fluid. It can be calculated and monitored on a SCADA system by trending the power divided by flow rate.

$$Specific\ Energy\ \left(\frac{kWh}{kL}\right) = \frac{Power\ (kW)}{Flow\ Rate\ \left(\frac{kL}{h}\right)}$$

Knowing the difference between operating specific energy, and what it could be if the pump were in as-new condition may allow for maintenance activities to be prioritized. For this case study, a decrease in flow of 10% and 20% will be reviewed and the specific energy lost compared to the pump and system being in original (as-new) condition.

2.0 DISCUSSION

The two main mechanisms that reduce flow are identified by the head developed by the pump in comparison to what head should be developed if the pump and system were in 'as-new' condition. Essentially, the flow reduction can be a manifestation of the pump developing more head than expected, less head than expected, or a combination of the two.

The underlying problem causing the flow reduction can be categorised as internal or external. That being, an internal fault would be related to the pump, and an external fault would be the system that the pump is a part of (i.e. everything else), for example, the valves and pipes.

2.1 Pump benchmarking.

For all pump types, there are different wearing components. As the name suggests, those components are designed to be sacrificial so the pump performance can be restored through maintenance.

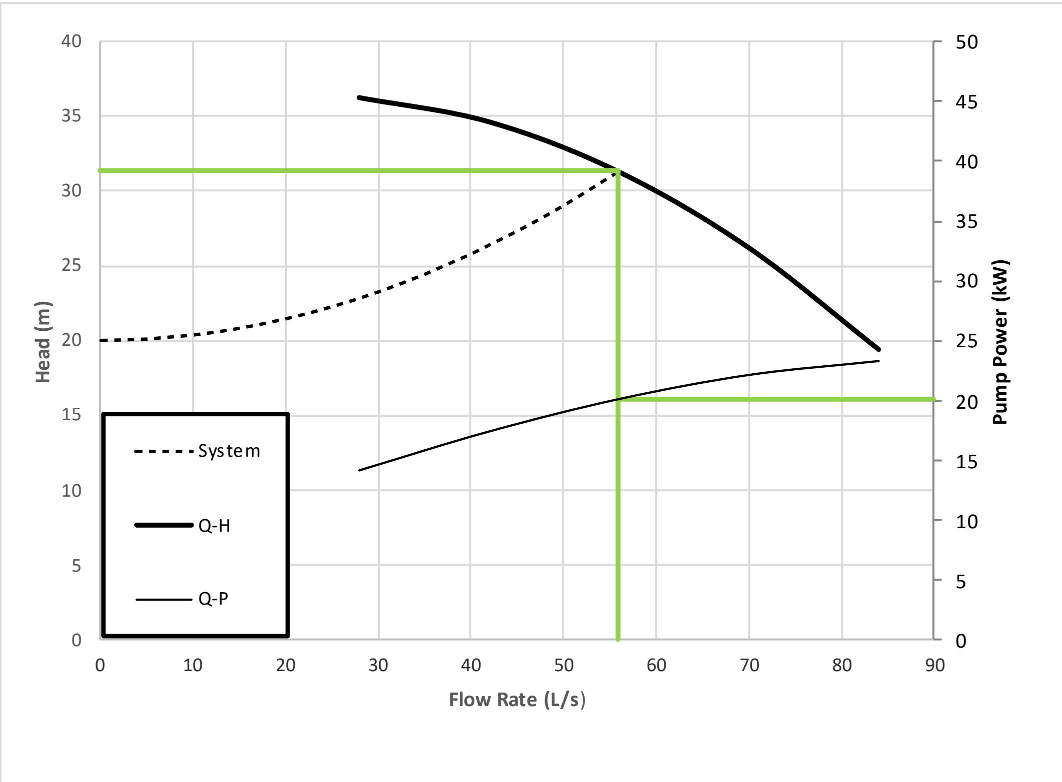
Some of the wearing parts contribute to the pressure, also known as Head, that the pump produces. As those parts wear, the flow (Q) verses pressure, also known as Head (H) characteristic curve shifts. Likewise, the flow (Q) verses Power (P) characteristic curve also shifts when compared to as-new performance.

For this reason, it is a good idea to test the performance of a pump when it is new and record the results. This test doesn't need to be done by the pump manufacturer; at its most basic a pump performance test can be a discharge pressure, the power (or amps) drawn by the motor, and the time to pump a known volume. Then, if the performance of a pump is ever questioned, there is a benchmark to refer to.

This will also be used to calculate the Specific Energy benchmark, which will be crucial for identifying the ongoing cost of both internal and external issues encountered through the life of the asset.

2.2 System Benchmarking.

Just as the pump will wear with time, so does the system that the pump is a part of. Air valves will require maintenance, as will pressure sensors and flow meters. An important point to note is that not all flow reductions are due to pump wear.



<u>Figure 1:</u> ***Pump Manufacturers Characteristic Curve with Benchmarking.***

As with benchmarking pump performance, the system is likewise benchmarked using the same information. One additional piece of information that will be required is the discharge pressure after the pump has stopped and the pressure has had time to stabilise. This can be used to determine the 'static' pressure, also know and the static lift. Essentially, it is the pressure produced by the water in the pipe from the pump to the highest point on the discharge pipe.

Once there are two known pressures, one for no flow, and the other for when the pump is running, a system curve can be generated. Figure 2 shows a pump manufacturers curve with the benchmarking and system curve marked onto it. Once the system curve has been determined, this too becomes a benchmark which will also be crucial. If the flow rate changes, the 'new' flow and pressure can be plotted against the original system curve.

2.3 External Fault (System related).

A classic system related fault is a partial blockage. The partial blockage can be caused by several mechanisms, such as a failed air valve, a growth of solids, or a valve that wasn't completely re-opened after being closed.

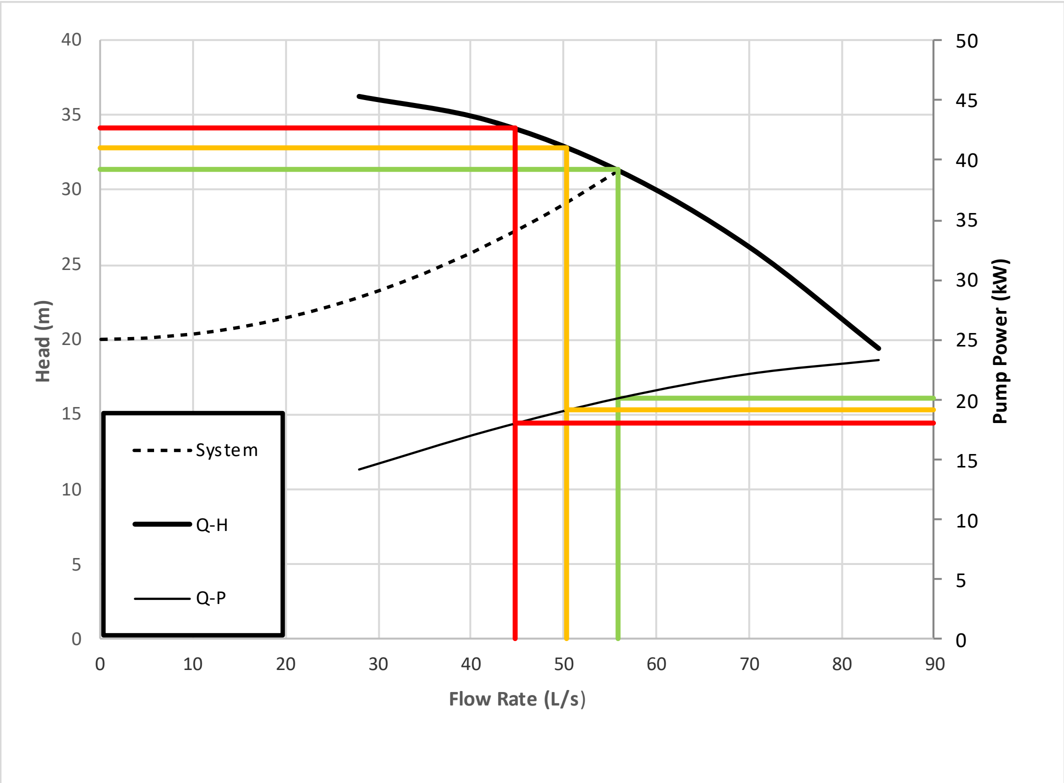


Figure 2: ***High Pressure example for 10% & 20% flow reduction.***

For this example, the pressure observed at the pump correlates with the pump curve for the flow rate instead of the system curve. It can also be seen that the power is progressively reduced with flow, this is common in this type of flow reduction. An illustration is shown in figure 2.

Therefore, it may be assumed that the pump using less power means that less energy is being used. Using the formula given for Specific Energy, the results show that as the flow is reduced through the action of increased system pressure, the Specific Energy always increases. For this example, the pump efficiency decreases as the flow reduces, but that that may not necessarily always happen. A summary of the results of the calculations for this example are shown in Table 1.

Table 1: ***Specific Energy and Pump efficiency for increased pressure example.***

Flow Reduction	Specific Energy (kWh/kL)	Percentage above benchmark.	Pump Efficiency
Original Duty	0.0998	-	85.6%
10%	0.1056	5.8%	84.8%
20%	0.1119	12.2%	83.1%

2.4 Internal Fault (Pump related).

A very normal pump related reduction in flow is caused by the wear rings. Depending on the pump design there may not be traditional wear rings, but wear rings are very common, particularly in clean-water pumps. The wear rings stop high pressure water 'leaking' internally back to the low-pressure area of the pump. As the wear ring 'gap' increases in size, more and more water is able to leak back though the gap and re-enter the impellor.

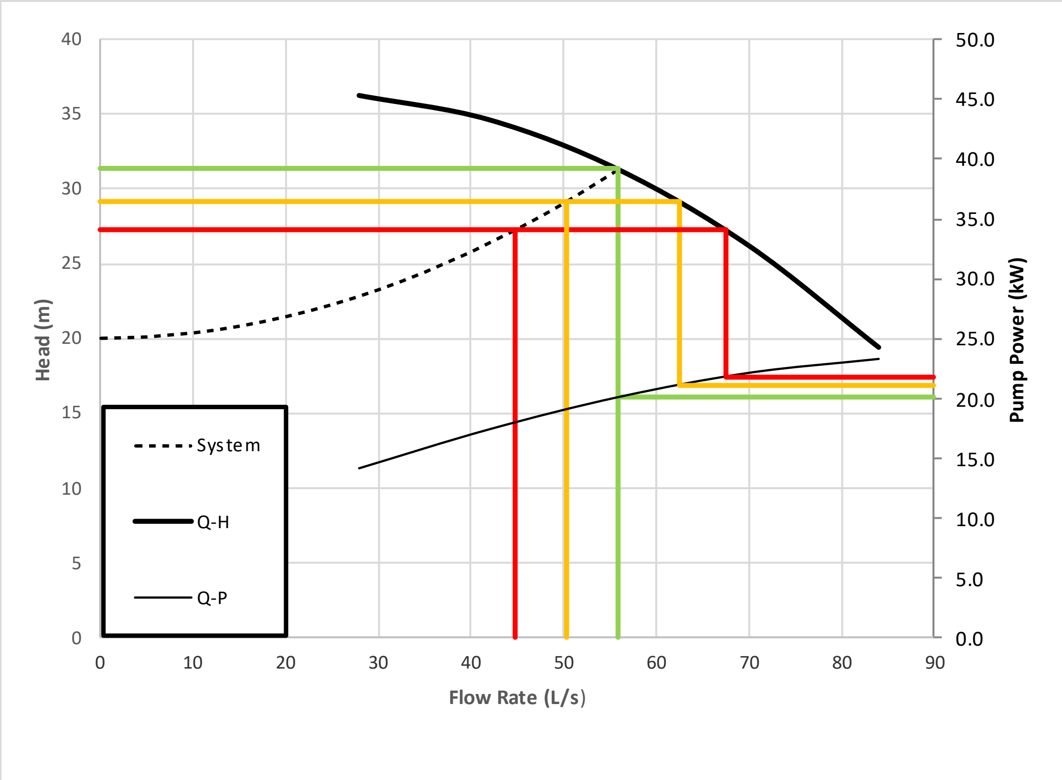


Figure 3: ***Low Pressure example for 10% & 20% flow reduction.***

Therefore, the impellor is pumping more water than is passing through the inlet and outlet of the pump. Refer to figure 3 for an illustration, it shows that the power doesn't relate to the flow rate entering and exiting the pump. Instead, the power relates to the pressure observed and is indicative the proportion of internal leakage.

For this example, the pressure observed at the pump correlates with the system curve at the flow rate instead of the pump curve. It can also be seen that the power is progressively increased. Obviously, the increase in power at reduced flow results in a far worse affect on the Specific Energy and pump efficiency, as is shown in Table 2.

Table 2: ***Specific Energy and Pump efficiency for decreased pressure example.***

Flow Reduction	Specific Energy (kWh/kL)	Percentage above benchmark	Pump Efficiency
Original Duty	0.0998	-	85.6%
10%	0.1166	16.8%	68.2%
20%	0.1352	35.5%	54.9%

2.5 Rate of wear.

The Best Efficiency Point (BEP) of a pump is the point on the Q-H characteristic curve that is the most efficient at converting the energy from the motor into hydraulic energy in the form of pressure in the water. It is the point where there is the least energy lost to heat and vibration.

Vibration is the primary mechanism that wears pumps. Therefore, the further a pump operates from the BEP, the more energy is lost to vibration, the quicker the pump wears. The rate of wear is dependent on pump design, including the materials and techniques used in pump construction. This is the reason why some pumps wear at at far quicker rate than others.

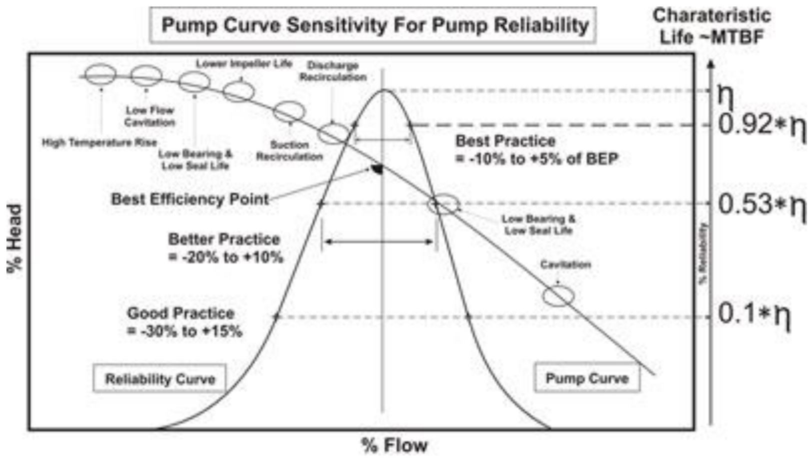


Figure 4: ***Barringer & Nelson pump reliability relationship.***

Barringer and Nelson developed a graph that illustrates the correlation between flow rate as a proportion of the flow rate at BEP and the Mean Time Between Failures (MTBF) as is shown in figure 4.

Many versions of this relationship are available on the internet, and they are mostly similar, but some have different values for the characteristic life (MTBF) of the pump. Not all pumps wear at the same rate, nor does operating away from the BEP effect the rate of wear equally.

3.0 CONCLUSION

It has been demonstrated that pumping system benchmarking is important. Even if performance data wasn't recorded when the pumping system was first commissioned it is still a valuable exercise at any point in the assets life cycle. It has also been shown that pump efficiency is an indicator of the rate of wear, and Specific Energy is an indicator of energy efficiency. An important point is that a reduction in power doesn't necessarily equate to a reduction in energy.

It is also important to note that the figures calculated for this example, and for any pumping system being analysed, is a snapshot in time. The amount of wear and rate of wear will continue to change. The results found through analysis, when applied to future costs, are the best possible case as wear over time is not constant.

The examples shown in section 2.3 may have resulted in a comparatively small change in Specific Energy and pump efficiency, but the shift in operating point away from the BEP will result in an increased rate of wear of the pump (section 2.4). Demonstrating that the two examples are inter-related.

Finally, the real cost of wear is not just the cost to have the pump refurbished back to as-new condition, or even replacing the pump if that is the preferred maintenance strategy. The real cost also includes the energy wasted because pump efficiency was not maintained.

5.0 REFERENCES

Barringer and Nelson pump reliability relationship viewed 07-06-024
https://www.efficientplantmag.com/2010/12/making-a-business-case-for-pump-improvements/