PUMPING DOWN EMISSIONS
BY REDUCING LIFE CYCLE COST

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ABSTRACT

Moving toward 'Net-Zero by 2050' includes manufacturing, operating, and maintaining assets in a manner that minimises Greenhouse Gas (GHG) emissions. The major contributors to the GHG emissions of a pumping asset are the production of the components, including parts replaced during the asset's lifecycle, and energy consumed during operation. Energy consumption and maintenance are the vast majority of a pumping asset's Life Cycle Cost (LCC), far outweighing the cost of the pump itself, and asset operation ultimately determines both expenses.

The proportion of dynamic loss within total system pressure identifies the potential to improve energy efficiency through flow reduction using a Variable Speed Drive and typically has limitations. Whereas, flow reduction using a throttling valve will use more energy regardless. In addition, pump operational efficiency relative to the best efficiency is an indicator of the expected rate of wear and determines the variable portion of the maintenance cost or the assets lifespan.

Eco-design is the third spoke in the wheel. The ability to maintain assets reduces the need for total replacement and therefore the amount of manufacturing and materials required. Additionally, well-designed pumps wear at a slower rate than pumps produced using material minimisation techniques. Together, pump efficiency, energy efficiency, and eco-design have the capacity to 'pump down' emissions, and reduce the total Life Cycle Cost and require a team effort to achieve.

1.0 INTRODUCTION

Energy efficiency makes good business sense, as does reducing the Life Cycle Cost (LCC), provided the performance is acceptable. The LCC is proportional to the Greenhouse Gas (GHG) emissions in that the major contributors to the LCC are also significant contributors to GHG emissions.

The vast majority of the LCC related to pumping asset ownership is the energy consumed followed closely by maintenance. The actual operational requirements of a pumping asset may differ significantly from those anticipated during design, and may cause the LCC to be significantly greater than anticipated. In addition, conditions change and components wear; therefore, monitoring performance and reviewing operation throughout the life cycle is essential to ensure the ongoing performance and control the LCC.

Aspects of pump construction affect the rate of wear and the maintainability of the pump. When the performance becomes unacceptable, the options are maintenance or replacement. While the LCC of a pump that requires replacement may be lower, due to the shorter lifespan, the discarded material results in significantly higher GHG emissions compared to maintenance.

Eco-design principles encompass more than just the design of an item, the operation, maintenance and even end of life is included. Eco-design done effectively is not a single consideration; it needs to occur throughout the life of the product. Aimed primarily at GHG reduction, but by association also LCC, Eco-design principles will continue to gain relevance due to the economic and environmental benefits.

2.0 DISCUSSION

The ability to operate pumping assets in a manner that minimises the LCC requires ongoing coordination between departments. That is:

- Adequate and effective performance monitoring equipment,
- Management of the data generated by that equipment including
  - Alarms,
  - Operational philosophies,
  - Additional capacities for extreme events and
  - Identify when and what maintenance is required,
- Skilled personnel monitoring the data management systems,
- The maintenance team having the capacity to act when required in terms of the availability of required skill sets and parts, plus also the capacity to perform preventative maintenance.
- Common to each of these departments should be the understanding that their actions are having on asset operation and therefore LCC.

Pump efficiency and energy efficiency are not interchangeable terms. Everyone involved during the life of a pumping asset needs an understanding of both and how they are inter-related to enable effective eco-design and the associated benefit of reducing LCC.

2.1 Pump efficiency

Pump efficiency is the relative ability for the pump to convert shaft power, also known as mechanical power, generated by a motor into fluid power:

$$Pump\ Efficiency = \frac{Power\ Out}{Power\ In} = \frac{Fluid\ Power}{Mechanical\ Power} = \frac{Flow\ x\ Pressure}{Mechanical\ Power}$$

Fluid power is the product of flow and pressure, which are the same metrics used on the axes of a pump characteristic curve, also known as a pump performance curve. A pump performance curve identifies the pressure a pump will produce across a range of flows for a given speed. A single graph may show several speeds, a range of speeds, or different pump configurations like different impellor sizes or multiple impellors in series.

On a centrifugal pump, which is the type most commonly encountered in water or wastewater pump stations, for every motor speed the pump has a Best Efficiency Point (BEP). The BEP is the point on the pump performance curve where the energy losses are least. It is the combination of flow and pressure that the pump was designed to operate at. The pump is capable of delivering flows other than the BEP, but the further that flow is from the BEP the more energy is lost to factors other than developing fluid power. As more energy is lost, the pump operates at a lower efficiency.

The energy losses in a centrifugal pump are predominantly vibration and / or cavitation. Vibration within a pump is the major cause of wear in the wear rings, shaft bearings and seals. Cavitation erodes the internal components of the pump and permanently reduces the efficiency the pump can achieve. Additionally, as shown in figure 1, flow greater than the BEP, also known as ‘operating to the right of BEP’ causes a significantly greater rate of wear than a flow rate the same proportion less than the BEP. If the pump is operated too far from the BEP there is even the potential for catastrophic failure, such as breaking the shaft.

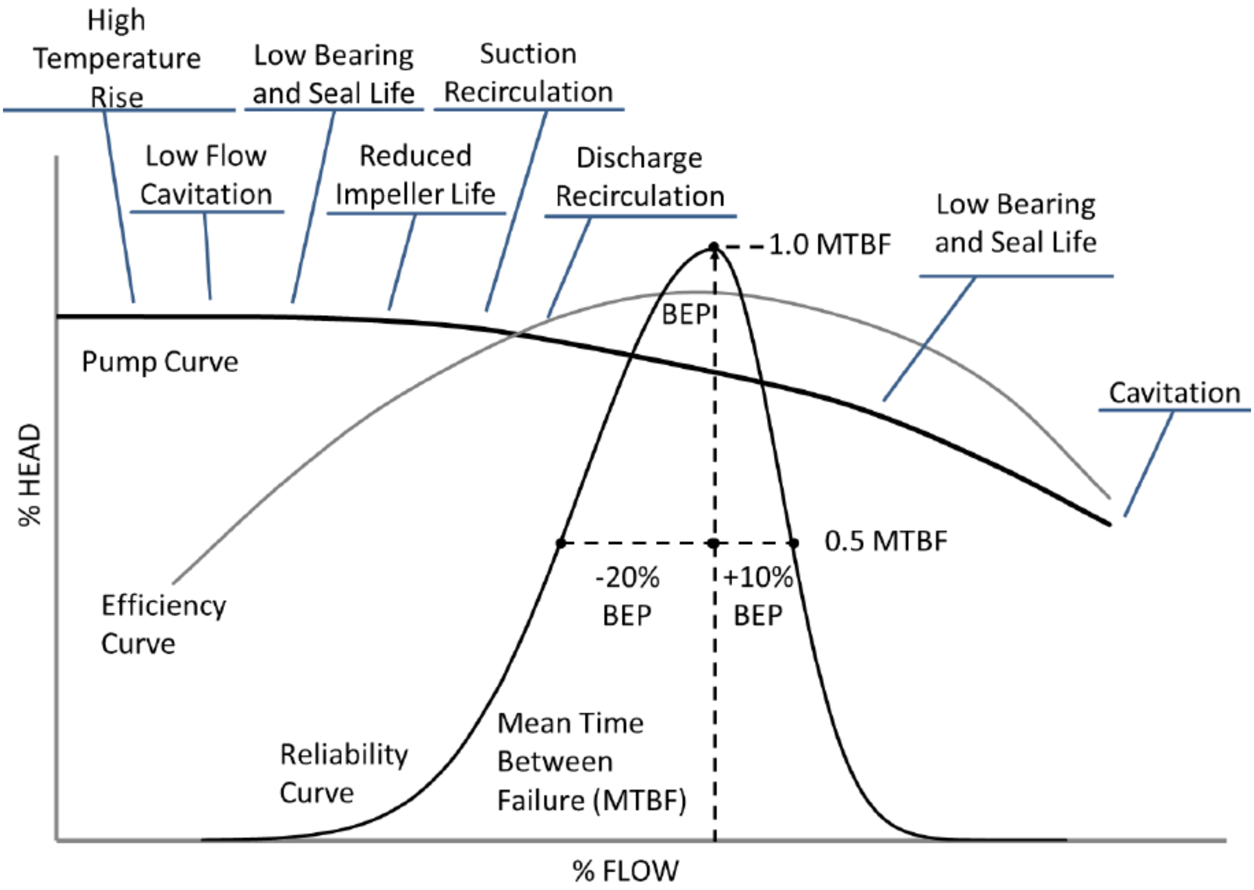

Figure 1: *Efficiency and reliability are related (Barringer Curve)*

Pump performance curves have limits. Where the curve ends is the flow rate that the manufacturer has nominated as causing the greatest 'acceptable' rate of wear. Often, the pump performance curve will extend to zero flow, also known as shut-off head. Depending on the pump design, some pumps are able to operate at shut-off head conditions without immediate damage; but generally, a flow rate above zero will be the recommended minimum continuous flow for the reasons already outlined.

In conjunction with the quality of construction, the pump operating point will ultimately determine the variable portion of the maintenance, and therefore cost, over the lifetime of the pumping asset. The maintenance cost is generally the second greatest portion of the LCC, with energy consumption being the greatest.

2.2 Energy efficiency

Energy efficiency is the relative ability for a volume of energy to perform a desired function. When viewed in a pumping context, the metric used is specific energy.

$$Specific\ Energy = \frac{Energy}{Volume\ Pumped} = \frac{Mechanical\ Power}{Flow}$$

Re-arranging the relationship for pump efficiency gives:

$$Mechanical\ Power = \frac{Flow\ x\ Pressure}{Pump\ Efficiency}$$

Inserting this into the Specific Energy relationship gives:

$$Specific\ Energy = \frac{Pressure}{Pump\ Efficiency}$$

This relationship reveals that reducing the pressure or increasing the pump efficiency will decrease the amount of energy required to pump a volume of fluid. This is important information for the energy efficient operation of pumping assets. It is also important to note that mechanical power is not a direct influence on energy efficiency. The pump affinity laws cause a pump to use less power at a lower speed, but they do not cause the pump to use less energy.

The fluid power produced by a pump when operating, is the point on the pump performance curve where it intersects the system curve. The system curve the physical difference in elevation between the source and destination, known as the static lift, and the friction in the network, known as dynamic loss.

If the proportion of dynamic loss is small in comparison to the static lift, reducing the pump speed will affect the efficiency more than the pressure. This can cause the specific energy to increase, despite the power reducing. Therefore, the saving potential of incorporating a Variable Speed Drive (VSD) is variable and site specific.

An example of a system with a small dynamic loss component follows in figures 2 & 3. Both figures contain pump and system curves, which are the same for both. Additionally, figure 2 shows pump power and pump efficiency. These figures are an illustration of the difference between flow control using a throttling valve and a VSD.

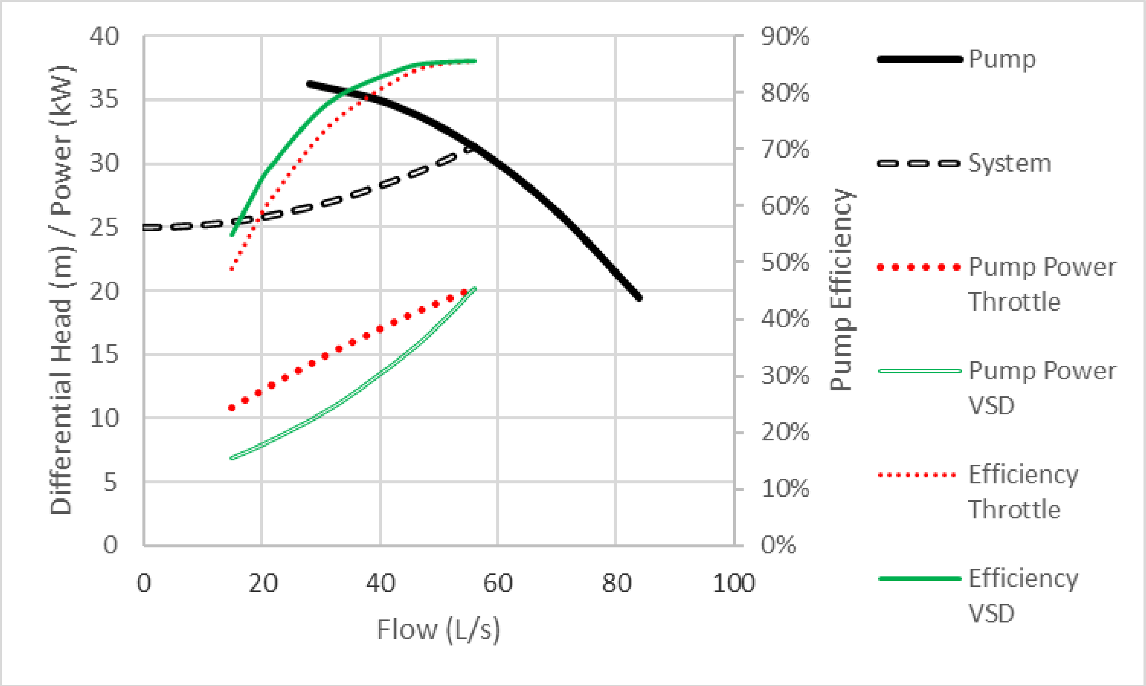

Figure 2: *Pump power and efficiency – Low dynamic loss system*

For either method of flow control, as the flow rate is reduced from what would be the unrestricted, full speed, intersection of the pump and system curves, both the efficiency and pump power decrease. For the throttling valve flow control technique the efficiency is less than the VSD equivalent for every flow except the unrestricted, full speed flow. Likewise, as would be expected given the worse efficiency, the pump power is greater when using the throttling valve flow control compared to the VSD.

Using the information provided in figure 2 it might seem safe to presume that flow control using a throttling valve has a similar energy efficiency to using a VSD. Figure 3 includes the specific energy and illustrates why that presumption would be incorrect.

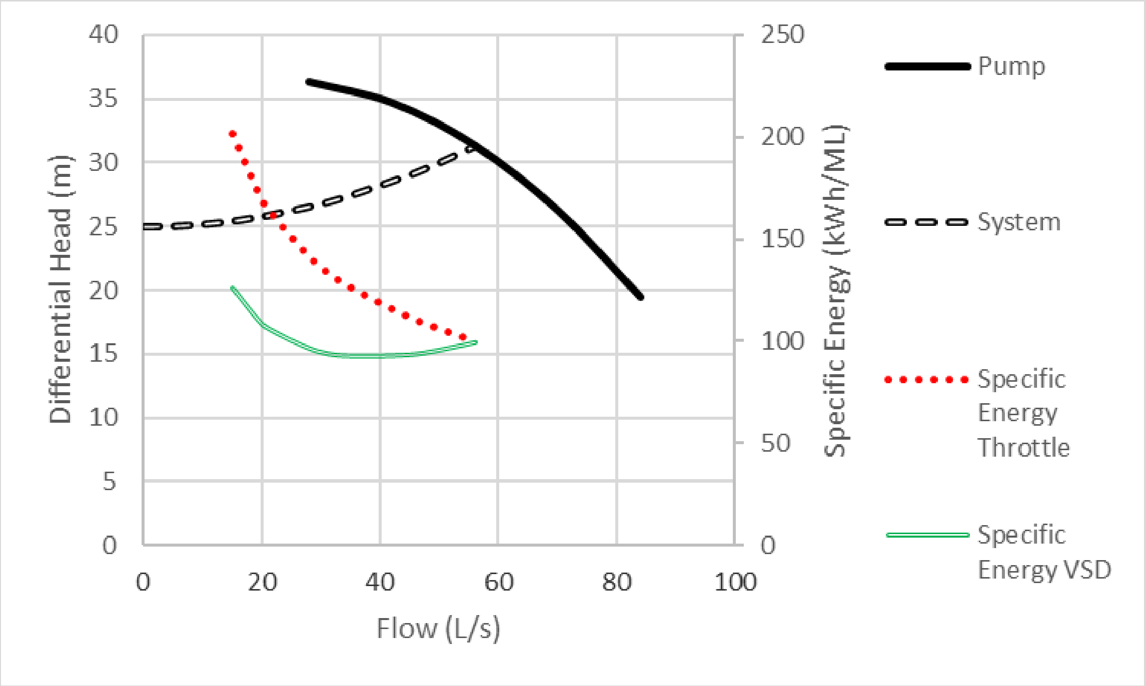

Figure 3: *Pump specific energy – Low dynamic loss system*

Reducing the flow using a throttling valve may improve pump efficiency, but always increases specific energy regardless of the proportion of dynamic loss in the system. Furthermore, as previously discussed in section 2.1 Pump Efficiency, the fact that flow control using a throttling valve has lower efficiency than VSD flow control, the pump will wear quicker leading to increased maintenance costs.

However, reducing the flow rate using a VSD does not necessarily reduce the specific energy. For the example shown in figure 3, there is only a minor reduction in specific energy as the flow is reduced, and if the flow is reduced further, more energy is used than if the pump were operated at full-speed. Therefore, there is the potential to cause greater wear and increase energy consumption by reducing flow using a VSD or throttling valve.

The energy consumption and maintenance costs are the predominant portions of the LCC, and the quality of construction plus the ability to maintain, or eco-design practices of the pump manufacturer will affect both expenses.

2.3 Eco-design

Eco-design is not new; Henry Ford practiced good eco-design, which is in part responsible for his ultimate success. Likewise, Ikea has incorporated eco-design into their business model since their inception some 50 years ago. The European Union have recently identified that sustainability is not achievable through energy efficiency alone, and are in consultation to determine the most effective way to regulate good eco-design. The eco-design goals are:

1. **Design and manufacture out of waste and pollution:**
   - Products are environmentally conscious designed:
     - Durable / robust construction and components
     - Constructed of materials that are readily available
     - Avoid the use of hazardous materials
   - Use less energy:
     - Efficient pumping system (VSD, Motor, Pump, and flow control)
     - Maintain, repair, reuse, update, and upgrade
2. **Keep materials, products, and systems in use:**
   - Operate and maintain assets to maximise life at optimum efficiency
   - Limit operation outside recommended range
   - Identify when reactive or planned maintenance required
3. **Regenerate natural systems:**
   - Remanufacturing
   - Material recovery (i.e. Recycling)

As can be seen, not all eco-design goals are controllable by the manufacturer. Operators play a vital role in the second goal, as do the maintenance team. Supervisory Control And Data Acquisition (SCADA) systems allow operators to remotely identify when maintenance is required in almost real-time. Recently, SCADA systems are being referred to as Digitalisation and/or IoT (Industrial Internet of Things) and a range of systems are available that are pre-configured using machine learning, also known as artificial intelligence or AI to provide greater insight into performance and predictive maintenance.

SCADA systems need to be sufficiently flexible to allow unusual operation during an emergency, but intelligent enough to identify wear, failure modes, and operation that is inefficient or detrimental to the longevity of the asset. SCADA systems are developed and implemented as assets are constructed or refurbished so that the operator is not required to be an expert in every asset they control. Through the SCADA system, operators can be confident that they have the resources available to help make decisions that minimise both LCC and GHG emissions.

3.0 CONCLUSION

The LCC of a pumping asset is beyond the control of anyone person or department. Therefore, all departments that play a role in the life of a pumping asset need to be aware of the consequences of their actions, which can result in unnecessary expense and emissions. Working as a team with a common goal will pump down emissions and reduce the LCC.

4.0 REFERENCES

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