Optimize High-Energy Pumps With Improved Impeller Design

As new design and manufacturing technologies are developed, end users can affordably upgrade their systems and verify better performance.

Written by: Bob Jennings & Dr. Gary Dyson (Hydro, Inc.)
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The rising cost of electrical power has caused many industrial plants to shift their focus to energy consumption. Plants often run pumping equipment continuously, and much research has pointed to opportunities for cost savings by optimizing pumping equipment.

When evaluating the potential for energy savings, end users cannot consider a pump in isolation. The suitability of the pump for the system within which it operates is vital. Even the best designed and most efficient equipment offers power-saving potential if it is run off its best efficiency point (BEP) in a system for which it is ill-applied.

Many plants have been in operation for more than 40 years, and their operating philosophies have changed over time. Plant improvements have enabled higher throughput, often increasing production by as much as 125-150 percent. Unfortunately, little is done to improve or increase the performance of the support-service pumping equipment, such as cooling water pumps.

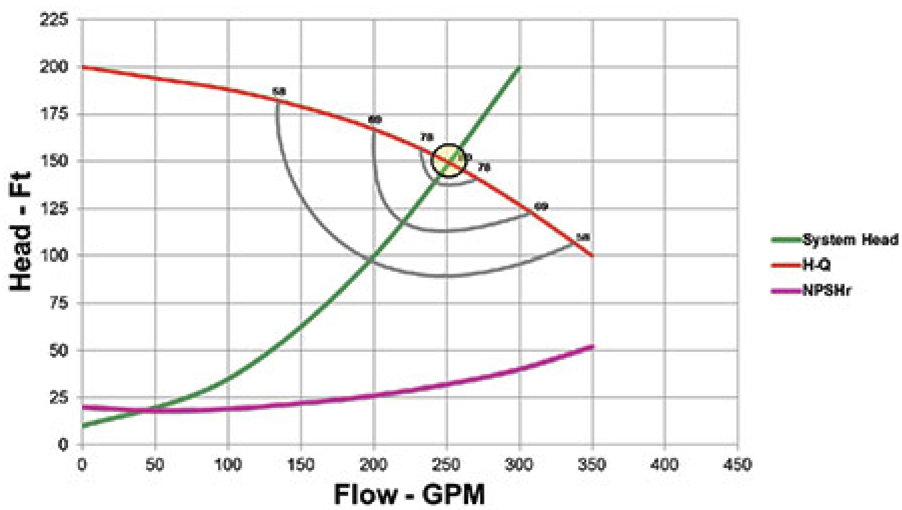
As system flow demands increase, the duty point of the pumps is forced to shift far to the right of the BEP, well outside the acceptable operating range (AOR). This causes efficiency and pump reliability to decrease dramatically.

Casting tolerances, surface finishes, and impeller/volute or impeller/diffuser geometry have all dramatically improved during the last 40 years. But because many pumps were installed when the plants were commissioned, the existing pumps were manufactured using techniques that would be considered obsolete today. The result is higher energy costs and reduced reliability and availability, which often cause production delays.

The Starting Point

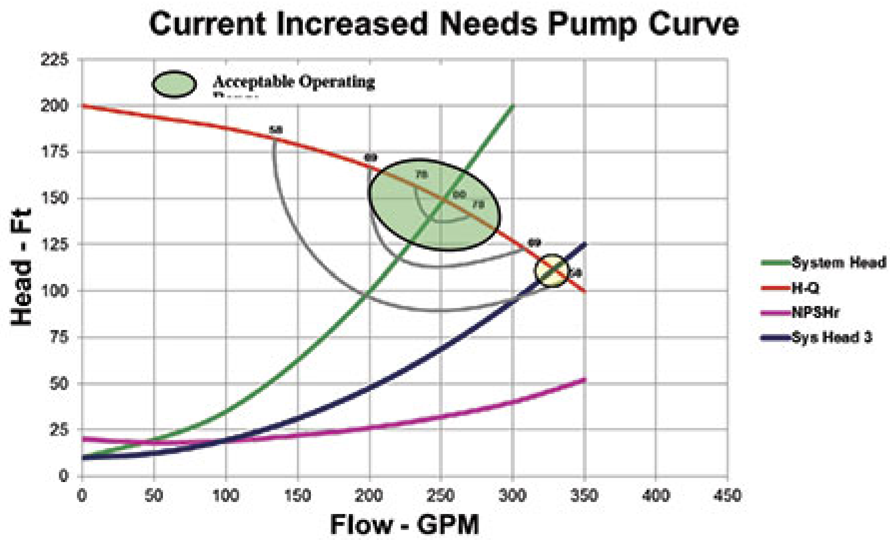
Pumps react to changing system conditions. System demand (or system resistance) determines the flow and pressure at which a pump will operate. As system flow demand increases, the flow throughput of a pump also increases, causing it to operate further on the right-hand part of the performance curve.

The system demand is graphically represented by plotting the system resistance curve as a function of flow. This curve enables the end user to quickly determine system flow for a given pump since the pressure and flow are determined by the intersection of the pump performance curve (red) with the system head curve (green). A process design engineer would ideally select a pump with an operating point that would have coincided with the BEP. This could yield a pump efficiency of 80 percent, as shown in Figure 1.



However, many support pumping systems have exceeded their original design and have much higher flows to support the higher plant production. This is particularly common in cooling water applications, condenser water pumps, descale pumps or any application where water usage is proportional to production.

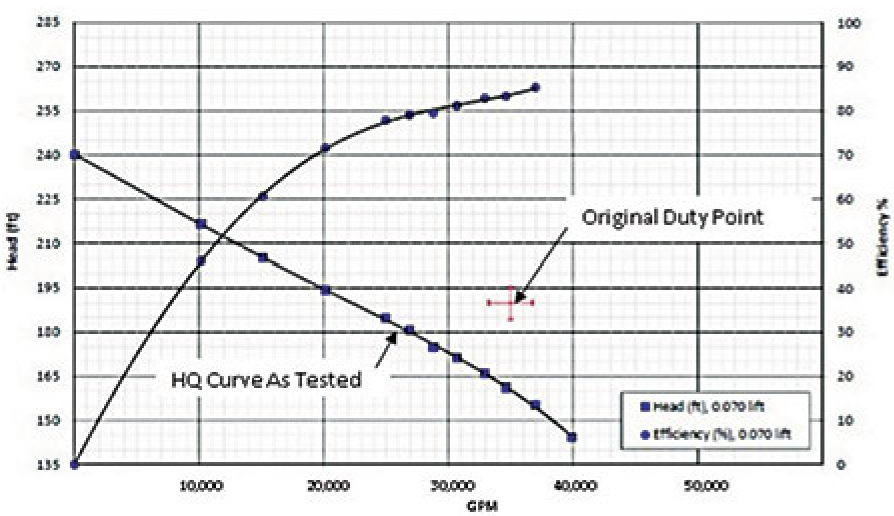
While the original design may have called for two-pump operation, present-day requirements may require 2 1/2 pumps online, with two pumps being insufficient and three pumps too many. As flows increase, the result is usually that system requirements have exceeded the AOR of the pumps (see Figure 2).



Original Duty Point

The original system design for one processing plant's service water pumps was to have three pumps operating in parallel with an installed spare as a standby. The total system requirement was 105,000 U.S. gallons per minute (GPM) (23,864 cubic meters per hour) at a pressure of 190 feet (57.9 meters) total dynamic head (TDH). Each pump was rated for 35,000 GPM (7,955 cubic meters per hour) at 190 feet (57.9 meters) TDH.

As production increased, more service water was required, causing the existing pumps to operate further out to the right of the performance curve. This caused the net positive suction head required ($NPSH_R$) to exceed the NPSH available ($NPSH_A$), leading to severe cavitation issues. To reduce cavitation problems, the plant ran four pumps in parallel and throttled each pump to keep the individual pump flows low enough to prevent cavitation.



Over time, the design of the impellers also drifted away from optimal because no testing or verification of the performance took place. Cavitation and insufficient service water continued until the pumping station could not keep up with plant demand. As Figure 3 shows, field pump assessments and subsequent individual performance tests conducted on the poorly replicated impellers showed that the pump performance had been dramatically compromised.

New Impeller Design

The technological advances made in recent years with reverse engineering, laser digitizing equipment, computation fluid dynamics (CFD) software and the ability to print 3-D foundry molds from computer-aided design/computer-aided modeling (CAD/CAM) software has revolutionized the aftermarket industry. Solutions that were cost-prohibitive five years ago are now within the realm of financial feasibility. The solution helped manufacturers and end users solve their energy optimization difficulties in three ways:

1. **Capture system resistance data and operating conditions.** The plant's pumps operated at different flow conditions. Understanding how these flow requirements matched the system's resistance enabled an optimized design flow to be derived that would ensure that head was not generated by the pump to be dissipated over a control valve, so the number of pumps running was optimized for the demand.
2. **Capture the geometry of the existing impeller using advanced laser-scanning equipment and build a CFD model of this impeller.** This allows design scenarios to be evaluated to get the optimized design for the newly established flow conditions.
3. **Use additive manufacturing in the form of 3-D foundry sand printers and casting simulation software to drastically reduce lead-time and overhead normally associated with pattern/core box sand casting processes.** The 3-D printing process directly from the design data ensures that the integrity of the design is completely captured. The high accuracy of sand printing means that vane-to-vane symmetry and vane shape is identical. Sand printing also offers improved casting surface finish. These manufacturing measures alone can lead to a 3 percent efficiency increase.

Tables 1-3 show the before and after energy usage, based on the projected energy audits.

Measurement	Per Pump	Per System
GPM	40,000*	160,000*
TDH	185	185
Efficiency	0.74	0.74
Brake horsepower	2,525	10,101
kilowatts (kW)	1,884	7,536
Hours per year	8,400	8,400
kW rate	$0.07	$0.07
Total energy cost per year	$1,107,792.00	$4,431,168.00

* Note: Four pumps online throttle to prevent cavitation

Energy Costs - Original (Present)	$ 4,431,168.00
Energy Costs - New Impeller Design	$ 2,887,668.00
Impeller Design and Manufacturing Costs for 4 impellers	$ 390,000.00*
Total Savings	**$ 1,153,500.00**

* Number excludes the regular repair cost(s) normally incurred for this equipment.

In addition to energy savings, improved reliability and availability translates to extended mean time between repairs, significantly reducing maintenance costs.

Conclusion

Significant energy savings opportunities exist in every manufacturing facility worldwide, particularly with pumping systems that:

- use pumps driven by 200 horsepower and above
- are primarily providing cooling water
- include demands proportional to the plant throughput
- are used for batch operations
- have inherent delays or production slowdown
- currently use dump valves or bypass lines
- feature fluctuating system loading

In the past, pump upgrades or rerates tended to lie strictly with the OEM because they were the only party with access to cost-effective cast parts. However, with the technology revolution that is taking place in the aftermarket, upper tier service centers with on-staff hydraulic engineering support can often provide cost-effective, newly designed impellers or volutes with solutions specifically designed for the application.

With reverse engineering, laser digitizing equipment, CFD software and rapid prototyping coupled with the ability to print 3-D foundry molds directly from CAD/CAM software, the end user is no longer required to limp along with an obsolete pumping system. Solutions are readily available and well within the realm of financial feasibility.

– See more at: http://www.pumpsandsystems.com/pumps/august-2015-optimize-high-energy-pumps-improved-impeller-design