Trim Pump Impellers

Trim the pump impeller so the flow produced matches the design requirement with the discharge service valve wide open. In most cases, this will reduce the pump energy consumption as compared to the throttled operating point. Other alternatives for eliminating excess flow and/or unnecessary pumping head include throttling the pump or changing the pumps operating speed via a motor change or the installation of a variable frequency drive.

Figure 1 - Typical Pump Performance Curve: Throttling the pump with a valve on the discharge modifies the system curve and forces the pump back up its impeller curve to the design point. Changing the impeller size moves the pump operating point down the system curve to the design flow rate at the operating head required by the actual system. Both approaches will change the power requirement as can be seen from the position of the various operating points relative to the horse power lines. But, the impeller size change will generally save more. Changing the pump speed via a motor change or VFD will have similar results.
Engineering Overview:

Excessive safety factors added to the pump performance requirements during design frequently result in pumps with more head than necessary when installed. As a result, the pump operating point will shift out its performance curve until the actual flow delivered comes into balance with the pressure drop produced by that flow (see Figure 1). The technical jargon for this condition is to say the pump has “run out its curve.” Because the pump is moving more water than necessary, it is using more energy than necessary to accomplish the intended function. Many times, the pump is simply left in this state. In some instances, the balancer throttles the pump to design flow during testing and balancing phases of the project.

In older systems one may notice that a pump discharge pressure seems unnecessarily high and water flow may be low. It is not uncommon that someone has increased impeller diameter to overpower a flow problem rather than eliminate the flow restriction (fouled flow control devices are often the culprit). Of course continued fouling will further reduce flow and eventually the original flow problem returns. Resolve the flow restriction problem and then look for the original impeller, which may still be available, or the installed impeller can be trimmed.

Redundant Pumps:

Hospitals often feel the need for redundant equipment so we commonly find two pumps with excessive head capability installed and only one of those pumps is run at a time. Commonly the pumps are run in an alternating lead/lag sequence to “balance wear” (one might question why anyone would want both pumps to wear out at the same time). The real benefit for keeping both devices in frequent use is that bearings and seals become unreliable if left inactive for months at a time.

Duplicate redundant pumps (and fans for that matter) present an often unrecognized opportunity for improving efficiency and reliability. If both pumps are fitted with VFDs, they can both be run at the same time at a reduced equal flow per pump totaling the necessary system flow. Depending on system and pump specifics, this change in operation typically provides two benefits:

1. Two pumps running at 50% flow each in parallel may use half of the total energy used by one pump operating at 100% flow.

2. A pump running at 50% speed can last 4 times longer than the same pump operating at 100% speed. Therefore, two pumps running together at 50% speed will provide twice the total hours of operation that is provided by one pump run to failure and then the second pump run to failure.

Please realize that many factors will vary your own results but you will commonly come out ahead by implementing this simple change in operation. A clever designer can beneficially implement this concept anytime redundant equipment is installed.
**Opportunity Description**

A significantly throttled pump discharge valve is nearly always an indicator of significant savings potential via an impeller trim (*see Figure 2*). A lack of throttling for all of the pumps on the project can also be a clue to energy waste because even a well-selected pump will seldom exactly match the installed performance requirements of the system it serves. Thus it is unlikely that all of the pumps on a project required no adjustment to deliver design flow. Minor throttling on some or all of the pumps most likely indicates that the pump was “right sized” and only minor adjustments were required to achieve design flow. Thus there may not be much potential for additional savings via trimming the impeller in such a situation. In most cases, throttling the pump back to design flow will save some energy as compared to leaving it run wide open (*see Figure 2*). But, this approach achieves its results by putting extra resistance back into the system via the throttled valve, which shifts the system curve up the impeller curve to the original design operating point. Energy is still wasted because any pressure drop placed in a system requires energy input at the prime mover to overcome the resistance. A throttled valve at the discharge of a pump is removing energy that was just added to the system by the motor.

Trimming the pump impeller so that the design flow is delivered at the pressure drop associated with the installed system with the discharge valve wide-open system will save additional energy. Often, these savings will exceed savings achieved by simply throttling the pump by an order of magnitude or more. This is because an impeller trim shifts the system operating point down the system curve by physically modifying the flow producing capability of pump. Throttling adds resistance to the system, thereby changing the shape of the system curve, which shifts the operating point up the pump’s impeller curve.
Figure 2 - A Heavily Throttled Pump Discharge Valve For systems that are running wide open, throttling is a good first step in the impeller trimming process because it will allow energy savings to begin accruing immediately and will allow the ripple effects associated with the flow reduction to be assessed. Ripple effects include:

+ Heat transfer characteristics of the equipment and loads.
+ Loop tuning characteristics of the various control loops associated with the system and its loads.
+ Response time and characteristics of the system at start-up and under load changes.
### Advantages Over and Contrasts With Other Approaches Such as Throttling or Motor Speed Changes

#### Advantages

1. Impeller trimming will save more energy than throttling since it modifies the performance capabilities of the pump to match the wide open, unrestricted system rather than restricting the pump’s performance by adding resistance to the system.

2. Impeller trimming allows a more precise solution to flow vs. pressure requirement problem to be achieved in contrast to replacing the existing motor with a new motor operating at a lower speed. The squirrel cage motors typically used with HVAC pumps are typically available in a limited number of speeds (usually 3,750 rpm, 1,750 rpm, and 1,175 rpm). This could be important if the change is being performed on a pump that serves a chiller evaporator or condenser or circulates water through the primary heat exchanger on a high efficiency boiler.

3. Impeller trimming will generally be less expensive than installing a Variable Frequency Drive (VFD). A VFD would also allow a precise solution to the flow vs. pressure requirement problem, but adds complexity and a potential point of failure to the electrical service for the pump. The drive also will have efficiency losses of its own that will subtract from the savings that can be achieved.

4. Purchasing a new impeller of the correct size and retaining the existing impeller in stock can make reversing the modification relatively easy.

5. The life of the control valves in the system will be extended because they do not have to throttle as hard.

6. The possibility of valve “lift-off” is reduced since the differential pressure at the control valves is reduced.

7. Persistence is good since the pump must be disassembled to undo the changes that are produced by the modification.

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Continued
## Advantages Over and Contrasts With Other Approaches Such as Throttling or Motor Speed Changes (cont.)

<table>
<thead>
<tr>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>1. The approach will require a pump outage while the new impeller is installed. If the system only has one pump, then this also implies a system outage.</td>
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<tr>
<td>2. The pump will not end up operating at its best efficiency point. An approach that modifies pump speed, perhaps coupled with an impeller modification, may preserve the operating point at or near the best efficiency point where the pump was most likely selected originally. However, because of the cubic relationship between flow and pumping horsepower, the savings associated with impeller trimming can still be quite significant even though the pump efficiency is less than optimal.</td>
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## Implementation

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<tr>
<td>1. Perform a pump shut-off test and wide open flow test to determine the characteristics of the system and provide the data necessary to evaluate the pump for an impeller trim.</td>
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<tr>
<td>2. Evaluate the results of the performance test to determine if an impeller trim is the best solution for the excess flow or head condition that exists for the pump in question and, if so, what the proper impeller size should be.</td>
</tr>
<tr>
<td>3. Shut down the pump, remove the impeller, and send it out to a machine shop for trimming. An alternative that will minimize system down time and provide a quick way to return to the original condition is to order a new impeller of the correct size and simply replace the existing impeller with the new impeller.</td>
</tr>
<tr>
<td>4. Return the pump to operation and verify that performance is as anticipated and that the system served is operating satisfactorily at the new flow rate.</td>
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## Recommended Preventative Maintenance

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<th>Recommended Preventative Maintenance</th>
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<td>There is no special preventive maintenance issue associated with this modification.</td>
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Costs & Annual Savings Example

The primary benefit provided by this option is a reduction in energy consumption. *Figure 1* illustrates the effects of throttling vs. impeller trimming vs. wide open operation for a nominal 320 gpm pump that operated 24 hours per day, 7 days per week serving water cooled heat pumps in a resort. In this case the pump was originally operating wide open. Trimming the impeller saved approximately $2,050 per year in energy costs assuming $.07/kWh electricity.

Impeller trimming also reduces the electrical demand associated with the pump’s motor. In areas with significant demand charges, impeller trimming can result in a measurable reduction in demand cost, especially for larger pumps. In the example in *Figure 1*, throttling reduced the demand from approximately 9.2 kW (12.5 bhp) to 5.97 kW (8.00 bhp).

The cost of implementation will vary depending on if the impeller is removed and trimmed vs. replaced and if the work is performed in house or with union labor. Generally, the following rules will apply:

1. Most pump manufacturers will perform an impeller trim for a nominal fee in the $50 - $150 range per impeller, assuming they are also performing the modification work.
2. Installing the new impeller will typically take a crew of 1 or 2 mechanics 4 to 8 hours and require a gasket and seal set for the pump.
3. New impellers can typically be obtained for $500 for pumps of the size typically found in building HVAC systems. This assumes that the pump they are purchased for is still in production or the manufacturer has the appropriate impeller in stock. Costs are somewhat related to the size of the pump. Electing to obtain a new impeller for older pumps that are no longer in production may require that an impeller be cast. This can significantly increase the cost of the impeller, perhaps by a factor of 2 or 3.
4. Most impeller replacement will also involve replacing gaskets and seals, thus the cost of a seal kit should be included. Usually this will run less than $100.
### Costs & Annual Savings Example (cont.)

+ In most instances, the total cost for the modification will be in the $1,000 to $2,000 range for a large pump where the work is accomplished by union pipe fitters using a new impeller. Paybacks are typically less than 2 or 3 years and may be less than 6 months for large pumps with significant excess capacity.

If this fix prevents valve lift, additional savings will be realized due to:

1. Reduced potential for simultaneous heating and cooling.
2. Reduced valve seat wear and replacement costs.

### Notes and Cautions

1. This fix has been applied many times with very good results.

2. Setting up for a test and evaluating its results is much easier for a constant volume system as compared to a variable volume system. When implementing this technique on variable flow systems, additional time and analysis will be required to ensure that the system is in a true-wide open state and that the test results truly reflect that condition.

3. In most cases, trimming the impeller on one pump in a set of parallel pumps will require that a similar adjustment be made on all parallel pumps to ensure that all of the pumps work in harmony when operated simultaneously.

4. Systems with parallel pumps serving a common header where multiple pumps routinely run need to be evaluated with peak header flows rather than with only the pump in question in operation. This is because the pressure losses through the header system are influenced by the operation of all of the pumps and need to be reflected in the operating capabilities of the individual pump. If the individual pump is operated against the system by itself, it will likely run out its curve because the losses related to the operation of the other pumps are not present.

Continued
## Notes and Cautions
(cont.)

This is different than running out its curve because it has excess head capacity for the normal operating conditions and trimming the impeller based on the results of such a test could result in the inability to match the load under design conditions when all of the pumps are running.

5. Some of the effects of a system flow reduction are interactive with the other components in the system. For instance, modest excess condenser flow on a chiller may actually reduce the chiller kW per ton, and the net effect is an energy savings, even though the pump is using more than its design energy requirement. In these situations, additional assessment and/or targeted functional testing may be desirable to ensure the best over-all efficiency of the system and building.

6. In many instances, the excess pumping head addressed by this option exists as the result of safety factors added to the pump selection by the design engineer. Thus, making this modification is reducing this safety factor. However, it is quite easy to get it back simply by opening the throttling valve back up.

## Resources

1. The *Bell and Gossett Engineering Guide* provides information on impeller trimming and is a good general reference regarding pumps and hydronic systems. It can be obtained from the local Bell and Gossett representative.

2. A PowerPoint® presentation titled *Throttled Pump and Fan Discharges* can be downloaded from the PECI web site and contains information on pump curves, impeller trimming, testing steps to determine the required impellers size and case studies. It can be downloaded at [http://www.peci.org/](http://www.peci.org/).

A series of articles in *Pumps and Processes* magazine, running from January through June of 2002, discuss pump curves, pump basics and related information. They can be viewed at the magazine’s web site at [http://www.pumps-processes.com/](http://www.pumps-processes.com/). [Note: Inter-Market Publishing has decided to suspend publication of *Pumps and Processes* magazine. The last issue was November/December 2002.]