Efficient Pumping

Presented by: Mark Hemeyer
Adam Mudge
What is a Pump Curve?

- A pump curve shows the relationship between flow and pressure developed by a pump.
Pump curves also give the pump efficiency, input power and NPSHR characteristics.
What is a System Curve?

- A system curve is a function of the static head (lift) and friction losses thru the system.
  - Static Head = vertical rise in the system (relatively constant)
  - Friction loss = dependent on flow rate, pipe size and pipe material of the piping system
System Curve

- **Head (FT)**
- **Total Head**
- **Friction Loss Head**
- **Static Head**

Design Flow vs. Flow (GPM)
What is the pumps Duty Point?

- A pumps duty point is the point at which the system curve crosses the pump curve.
Duty Point

- It is always best for the duty point to be near the pumps best efficiency point (BEP)
Duty Point

- Pump curves describe how the pressure and flow that a pump delivers are related for one particular pump, at one specific impeller diameter and at one speed.

- A pump curve can only have one point of best efficiency (BEP).

- Operation very far from the left or the right of the BEP point will lead to increased bearing and mechanical seal wear.
Pump Performance with Speed Regulation

- The operating point will ALWAYS be on the system curve.
Pump Efficiency at Different Speeds

- Must consider pump efficiency and the static head as we travel down the system curve
What is the cost of pumping?

- Energy used to operate pumps
  - Dependent on flow rate, total pressure and overall pump efficiency

- Labor and parts to maintain pumps
The cost of operating pumps should always be expressed as a cost/unit volume pumped or **energy used**/unit volume pumped (specific energy).

Any other numbers (such as power consumption, shaft power etc.) do not take into account the productive work done.

Convenient units for specific energy are kWH/MG (kilowatt hours per million gallons pumped).
System Implications to Consider

- What is the flow rate? Does it/will it vary?
  - How much turn down will be required during “normal” flows? (maintain 2ft/s)

- Consider all components of a system
  - Be aware that “improving” one component can actually lower overall system performance (Running a VFD at an inefficient speed)
  - Non-clog pumps are designed for clog-free operation at their design speed

- How is the downstream process affected by the pump station output?
2 stations w/ same duty point and same pumps
- 400 GPM @ 50’ TDH (flow)
- Average flow only 200 GPM

Station #1 – 15’ static head
Station #2 – 35’ static head

Each station produces 400 GPM at nearly 282 kWh/MG at full speed. Does a VFD save money to pump only the average flow?
Station #1: VFD analysis at 200 GPM

- Connection: Single
- VFD connection: 1-VFD pump
- No of pumps: 1
- Frequency: 39 Hz
- Flow: 195.0 USgpm
- Head: 23.3 ft
- Pwr cons.: 2.1 kW
- Overall eff: 40.1%
- Spec. energy: 182.4 kWh/Mg
Station #2: VFD analysis at 200 GPM

- Note running full speed: 282 kW/H/MG
- Running at reduced speed Costs you energy!
Example Recap

- Running Station #1 (low static head) would **SAVE** nearly 35% in energy cost by using a VFD for 200 GPM.

- Running Station #2 (high static head) would **COST** over 13% more and setting minimum speed below 45 Hz could cause pump cavitation and failure.

- Always pay close attention to maintaining 2 ft/s when reducing flow thru force main.
Other potential problems

Minimum speed set to low
(This station was running at 1 ft/s)

Ramp up time is too long
(Not enough centrifugal force to push solids and rags through)
Case Studies

- Case #1
  - Single phase pumps constantly clogged and required increased maintenance

- Case #2
  - Partially clogged pump dramatically increases energy use and cost

- Case #3
  - Analysis completed to prove savings of replacing existing, 15 year old pumps
South County – Problems

- Ongoing clogging of pumps required frequent, unscheduled service calls, 2–3 times a month

- Employees were being exposed to hazardous waste and blood borne pathogens when cleaning

- Excessive overtime hours were increasing costs and were not budgeted for

- Clogged pumps were decreasing efficiency and increasing operating costs
South County – Solution

- Installed VFD’s to convert incoming 1/230V power to 3/230V
- Replaced old vortex style pumps with new, self-cleaning and high efficiency pumps
South County – Benefits

- No emergency service calls
- No overtime hours
- Improved safety for workers
- Reduced maintenance costs
- Owner has reported a 26% reduction in kilowatt hour usage
New Pumps Help Utility Resolve Lift Station Problems

South County Sewer & Water Authority, incorporated in 1994 as the administrative agency to manage the new sanitary sewer utility formed by four government centers—three townships and one village—in southern Kalamares County, MI. The utility’s service area, encompassed by Pickard and Indian Lakes, now serves approximately 400 residents and a church campus with 160+ residents and additional church use facilities. The 15 miles of sewer collection pipelines range from 8” to 14” in diameter, have 10 duplex pump stations, with individual pumps ranging from 5’‘ up to 80’‘, along the collection grid that interfaces with another system whose three main delivers the wastewater flow to the regional treatment plant in Kalamares. The agency has historically been operated by one full-time and one part-time administrative staff, while outsourcing all maintenance to the Village of Valdelsburg that maintains the lift stations and collection system at large.

The lift stations served a relatively simple gravity flow system. The lift stations are served by two electric utilities and in some areas, three-phase power was used in many areas. Therefore, six smaller stations served a single-phase power supply. The lift stations were specified and designed using traditional non-submersible pumps when first selected in 2009.

It wasn’t long before several of the lift stations along South County’s collection lines emerged as frequent maintenance headaches and Richard E. Perrin, director of the Authority. The maintenance issue was diagnosed as pump clogging problems—perhaps attributable to Brown County’s “disposable” raw material. However, further study revealed a number of other issues that led to the realization of the clogging problem itself. These contributing factors included: ungrounded transducers, recirculating water over internal (thoracic) unsecured gear sets, and foreign issues such as radiolabeling and phone transmission. All were issues that were unsecured and required during the next seven years.

For a small public sewer agency with a minimal annual operating budget of less than $1.5 million, Perrin had anticipated $2,000-$3,000 annually for lift station repairs and maintenance. In the first few years of operation, the utility installed an unexpected $67,465 in replacement, repair, and miscellaneous pieces and services, and all were less than the expected service life of those replacement pumps. The utility eventually determined that single-phase pumps were more reliable for the same services. The utility has since replaced the original single-phase, non-submersible pumps with Brown County’s “disposable” raw material.

Perrin noted that there were two months before the repair job was completed and the new pumps were installed. He described the process as seamless and efficient, with the new pumps installed and operational within a few days. The utility has since restored the lift station to its original condition, and the system is now operating at full capacity.
Case #2 – Background

- Ongoing clogging of an existing pump forced the owner to replace it with the latest Flygt non-clog pump
- During installation, Kennedy performed an energy audit on all pumps in the station
- It was discovered that another existing pump was partially clogged
Case #2

- The partially clogged pump was producing less than 60% flow relative to the other pump and was using 186% more energy.

<table>
<thead>
<tr>
<th>PUMP #</th>
<th>GPM</th>
<th>KW*H/MG</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>#3</td>
<td>1,055 GPM</td>
<td>652.4</td>
<td>OPERATING</td>
</tr>
<tr>
<td>#4</td>
<td>620 GPM</td>
<td>1215.1</td>
<td>PARTIALLY CLOGGED</td>
</tr>
</tbody>
</table>

- Without monitoring the flow, the owner would not have known about the partial clog until it became fully clogged and stopped working.

- Actual data included in Kennedy’s report.
KENNEDY ENERGY AUDIT PROVES HIGH COST OF CLOGGED PUMPS

PROBLEM: The subject pump station averages approximately 800,000 GPD and consists of four (4) 60HP pumps, two of which have VFD’s. The biggest issue with the existing pumps was clogging. When a pump becomes clogged, the pump loses its ability to provide the designed flow and head. Changes from the original design parameters also result in the pump operating further from best efficiency point which may lead to vibration, cavitation, and possible catastrophic failure. While most see the cost of clogging pumps in terms of overtime, personnel safety costs, and repair, high costs also lie in energy consumption. A clogged pump requires more energy to operate, resulting in higher utility bills, which can inflict 2-3 times the energy costs of a “non-clogged”, efficient pump.

Pump #3 at this station became severely clogged and the cost of repair was enough for the customer to evaluate new pumps and the latest Flygt N-Impeller non-clog technology.

SOLUTION: Flygt’s patented submersible N-Impeller design has a hardened and sharpened impeller with a recessed relief groove and guide pin which insures the pump will operate without clogging. Kennedy Industries evaluated the application and was able to propose a 60HP pump with the new N-Impeller non-clog design and a spacer block to allow for simple retrofit onto the customers existing guide rail system.

During installation, Kennedy Industries also performed an energy audit at the station. Electrical input readings were taken on all pumps and were translated into Kilowatt Hours per Million Gallons pumped. The new Flygt N-Impeller pump averaged 652.4 KWH/MG. While on-site, it was discovered that another existing pump was partially clogged. The partially clogged pump was only able to pump approximately 620 GPM and averaged 1215.1 KWH/MG! That is nearly double the Flygt N-Impeller pump!

The new Flygt N-Impeller design is non-clogging and will drastically save the customer money with decreased energy use, pump station down time, repair costs, and improve safety for the community’s workers. Kennedy Industries can perform energy audits at new or existing stations to provide information on actual pump performance. These energy audits can also be used to apply for Utility Rebates on new equipment such as VFDs and new pumps.
Case #3—Background

- Existing can type station with dry-pit pumps, services a fully developed neighborhood
- Pumps are 15+ years old and inefficient
- Owner wanted to apply for utility rebates for installing newer, high efficiency pumps with VFD’s
Case #3

- Kennedy performed an energy audit on the existing pumps
  - Pumps averaged 922 kWh/MG and did not produce the original design flow

- Kennedy proposed 2 new pumps and VFD’s that would reduce energy consumption by 52%

- If approved, the owner will receive a $2,400 rebate from Consumers Energy, in addition to having lower monthly utility bills for this station
### Mechanical Incentive Worksheet (continued)

#### Variable-Frequency Drive (VFD)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Customers' Energy Electrician(s)</th>
<th>Incentive (A)</th>
<th>Unit (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFD on HVAC Fans and HVAC Pumps Less Than 10HP</td>
<td>$6000</td>
<td>HP</td>
<td></td>
</tr>
<tr>
<td>VFD on HVAC Pumps 10HP or Greater</td>
<td>$8000</td>
<td>HP</td>
<td></td>
</tr>
<tr>
<td>VFD on Chiller Motors</td>
<td>$6000</td>
<td>HP</td>
<td></td>
</tr>
<tr>
<td>VFD on Process Pumps Up to 10HP</td>
<td>$6000</td>
<td>HP</td>
<td></td>
</tr>
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</table>

#### Advanced VFD Applications (Pre-notification Required)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Customers' Energy Electrician(s)</th>
<th>Incentive (A)</th>
<th>Unit (B)</th>
<th># of Units</th>
<th>Total Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant Volume Air/Pad Dryer for WH (electric customer)</td>
<td>$0.10</td>
<td>Square Foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant Volume Air/Pad Dryer for WH (gas customer)</td>
<td>$0.15</td>
<td>Square Foot</td>
<td></td>
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<tr>
<td>Constant Volume Air/Pad Dryer for WH (electric customer)</td>
<td>$0.20</td>
<td>Square Foot</td>
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<tr>
<td>Constant Volume Air/Pad Dryer for WH (gas customer)</td>
<td>$0.30</td>
<td>Square Foot</td>
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<tr>
<td>Constant Volume Air/Pad Dryer for WH (electric customer)</td>
<td>$0.40</td>
<td>Square Foot</td>
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<tr>
<td>Constant Volume Air/Pad Dryer for WH (gas customer)</td>
<td>$0.50</td>
<td>Square Foot</td>
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<tr>
<td>Constant Volume Air/Pad Dryer for WH (electric customer)</td>
<td>$0.60</td>
<td>Square Foot</td>
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</tbody>
</table>

* Figures based on electric or natural gas service from Consumers Energy to qualify for the larger incentive.

#### Compressed Air** (Pre-notification Required)

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Customers' Energy Electrician(s)</th>
<th>Incentive (A)</th>
<th>Unit (B)</th>
<th># of Units</th>
<th>Total Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>VFD Air Compressor</td>
<td>$70000</td>
<td>HP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigeration Condensing Unit</td>
<td>$1500</td>
<td>SCFM</td>
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<tr>
<td>Adsorption Air Dryer</td>
<td>$1000</td>
<td>Cubic Feet</td>
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<tr>
<td>Low-Pressure Dry Air Filter</td>
<td>$500</td>
<td>SCFM</td>
<td></td>
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<tr>
<td>Zero-Loss Compressors</td>
<td>$600</td>
<td>Cubic Feet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressed Air Screw-Type (Customers' Energy natural gas customer)</td>
<td>$10000</td>
<td>HP</td>
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<tr>
<td>Air Compressor Work-Head Recovery (Customers' Energy natural gas customer)</td>
<td>$3000</td>
<td>HP</td>
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</tbody>
</table>

* Figures based on electric and natural gas service from Consumers Energy to qualify for the larger incentive.

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** Figures based on electric and natural gas service from Consumers Energy to qualify for the larger incentive.
Questions?

Thank YOU!
Test
Training Test: Pump Efficiency and VFD system analysis

1. Variable speed drives will always save you money on pumps?
   True  False

2. The minimum speed on a pump is 30Hz no matter the system curve?
   True  False

3. TDH (Total Dynamic head) is the combination of static head and friction losses?
   True  False

4. Static head is the amount of vertical lift required?
   True  False

5. Friction head is calculated based on gpm being pumped, pipe length, material & size, C-factor, fittings and valves.
   True  False

6. Identify best efficiency flow and head on the attached curve

7. Identify the input HP required at best efficiency

8. What is the NPSHR (Net positive suction head required) at BEP (best efficiency point)

9. Assuming 100 gpm is 2fps (feet per second) what is the most efficient flow in gpm according to the attached curve? What is the kWh/Mg at this flow?

10. What is the gpm and kWh/Mg at full speed?

11. Look at the kWh/Mg for answer 9 and 10, will the Customer save money buying a VFD and running at a reduced speed?

12. Detroit Edison, Consumers Power and many other power companies offer rebate for high efficiency pumps and VFD's
   True  False
Project: Test curve
Created by: Mark Hemeyer

VFD-Analysis - Performance

Pump: N 3127 63-488-00-3702
PRODUCT DATA
Imp. diam.: 215 mm
Rtd. pw.: 10 hp.
Vanes: 2
Throughlet: 9 inch
Connection: Single
VFD connection: 1-VFD pull
No of pumps: 1
Frequency: 60 Hz
Flow: 904.7 USgpm
Head: 50.6 ft
Per cons.: 7.9 Kw
Overall eff: 66.6 %
Spec. energy: 282.1 kWh/ft

VFD-Analysis - Specific energy

Pump: N 3127 63-488-00-3702
PRODUCT DATA
Imp. diam.: 215 mm
Rtd. pw.: 10 hp.
Vanes: 2
Throughlet: 9 inch

1 pump VFD control
ON-OFF control
All pump VFD control

Flygt
ITI Industries