Overview of the Pumping System Assessment Tool (PSAT)

Date: December 15, 2008
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Motor-driven equipment is a dominant electricity consumer

Industrial motor systems:
- are the *single largest electrical end use* category in the American economy
- account for 25% of all U.S. electrical sales
Pumps are the largest industrial user of motor-driven electrical energy.

Fluid handling equipment, including pumps, fans, and compressors, account for over 60% of industrial motor-driven energy.
BestPractices encourages a three-tiered prescreening and assessment approach

- Initial prescreening based on size, run time, and pump type
- Secondary prescreening to narrow the focus to systems where significant energy reduction opportunities are more likely
- Opportunity assessment and quantification of potential savings
The bulk of motor-driven energy is used by a relatively small part of the population. 10% of the population uses 80% of the energy.
Primary prescreening

All plant motor systems

Filter 1

Seldom used, small loads

Policies and practices

Filter 2

Big loads that run a lot

Non-centrifugal, ASD loads

Moderate priority

Big centrifugal loads that run a lot
Pump energy basics are fundamental to secondary prescreening

\[ E = \frac{Q \cdot H \cdot T \cdot sg}{5308 \cdot \eta_{pump} \cdot \eta_{motor} \cdot \eta_{drive}} \]

- **E**: energy, kilowatt-hours
- **Q**: flow rate, gpm
- **H**: head, ft
- **T**: time, hours
- **sg**: specific gravity, dimensionless
- **5308**: Units conversion constant
- **\( \eta_{pump} \)**: pump efficiency, fraction
- **\( \eta_{motor} \)**: motor efficiency, fraction
- **\( \eta_{drive} \)**: drive efficiency, fraction
Five basic causes of less than optimal pumping system operation

- Installed *components* are inherently inefficient at the normal operating conditions
- The installed *components* have degraded in service
- More flow is being provided than the *system* requires
- More head is being provided than the *system* requires
- The equipment is being run when not required by the *system*
Secondary prescreening

- All plant motor systems
  - Filter 1: Seldom used, small loads
  - Filter 2: Non-centrifugal, ASD loads
- Big loads that run a lot
- Big centrifugal loads that run a lot
  - Symptom or experienced-based segregation
  - Policies and practices
  - Highest Priority
  - Moderate priority
Some symptoms of interest

- Throttle valve-controlled systems
- Bypass (recirculation) line normally open
- Multiple parallel pump system with same number of pumps always operating
- Constant pump operation in a batch environment or frequent cycle batch operation in a continuous process
- Cavitation noise (at pump or elsewhere in the system)
- High system maintenance
- Systems that have undergone change in function
Pumping System Assessment Tool (PSAT)

- An opportunity quantification tool
- Relies on field measured (or estimated) fluid and electrical performance data
- Uses achievable pump efficiency algorithms from the Hydraulic Institute
- Motor performance (efficiency, current, power factor) curves developed from average motor data available in MotorMaster+ (supplemented by manufacturer data for larger size, slower speed motors)
A matter of focus

• PSAT is based on component performance
• It can be used to evaluate component-level performance
• But it can also be used to evaluate system-level conditions
An example system

Motor nameplate: 350 HP, 1185 rpm, 83 amps, 2300 V
Suction line is 20-in Schedule 10 SS
Discharge is 16-in Schedule 10 SS

Measured data
F1 = 6050 gpm
L1 = 12 ft above ground
P2 = 75.5 psig (5 ft above ground)
Fluid = paper stock at 120 deg F
Motor current = 80.5 amps
Head calculation

PSAT includes a pump head calculator to support user-measured pressure, flow data.

\[ \text{Type of measurement configuration} \]

- Suction tank elevation, gas space pressure, and discharge line pressure

- \( K_s \) represents all suction losses from the tank to the pump
- \( K_d \) represents all discharge losses from the pump to gauge \( P_d \)

- Tank to pipe entrance loss
- Check valve, SR elbow

**System of units:** gpm, ft, hp
Component-based analysis

Inputs

Results

<table>
<thead>
<tr>
<th>Condition A</th>
<th>Existing</th>
<th>Optimal</th>
<th>Units</th>
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<tbody>
<tr>
<td>Pump efficiency</td>
<td>78.2</td>
<td>87.3</td>
<td>%</td>
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<tr>
<td>Motor rated power</td>
<td>350</td>
<td>350</td>
<td>hp</td>
</tr>
<tr>
<td>Motor shaft power</td>
<td>339.0</td>
<td>303.7</td>
<td>hp</td>
</tr>
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<tr>
<td>Motor efficiency</td>
<td>94.5</td>
<td>95.6</td>
<td>%</td>
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<tr>
<td>Motor power factor</td>
<td>83.4</td>
<td>83.8</td>
<td>%</td>
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<tr>
<td>Motor current</td>
<td>80.5</td>
<td>71.0</td>
<td>amps</td>
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<tr>
<td>Motor power</td>
<td>267.5</td>
<td>237.1</td>
<td>kW</td>
</tr>
<tr>
<td>Annual energy</td>
<td>2343.7</td>
<td>2076.6</td>
<td>MWh</td>
</tr>
<tr>
<td>Annual cost</td>
<td>81.4</td>
<td>81.0</td>
<td>$1000</td>
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</table>

Annual savings potential, $1,000: 10.4
Optimization rating, %: 88.6
Input sections 1-3
Basic design, operating profile and cost inputs
Input section 4

Accurate performance data is essential

- Fluid
- Electrical
Alternate forms of electrical data input

Either motor current or power can be used to estimate the motor shaft load.

<table>
<thead>
<tr>
<th>Field data</th>
<th>Load estim. method</th>
<th>Flow rate, gpm</th>
<th>Head tool</th>
<th>Head, ft</th>
<th>Current ▼</th>
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<tr>
<td></td>
<td></td>
<td>6050</td>
<td></td>
<td>175</td>
<td>Current ▼</td>
</tr>
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Results: optimization rating

The optimization rating is akin to an exam grade of how well the existing operation compares with optimal.

\[
\frac{237.1}{267.5} \times 100 = 88.6
\]
Results: cost, savings potential

Annual energy costs for the existing and optimal cases are tabulated, and the potential cost savings is listed.

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**Annual savings potential, $1,000**: 10.4

**Optimization rating, %**: 88.6
A system-level perspective

Delivered to Tank 2

71.3 ft friction loss across control valve

F2 = 2800 gpm
F1 = 6050 gpm

Recirc flow

Required flow rate: 2800 gpm sent to Tank 2

Required head = Pump head: 175.3 ft
- valve loss 71.3 ft
104.0 ft
A system-level perspective

PSAT analysis using the **required** fluid data

Optimal equipment sized to meet the **required** conditions could save over $68,000/year.
PSAT does not identify solutions; some options

- Trimmed impeller
- Reduced speed motor
- Adjustable speed drive
- Different pump

Other factors, such as load variability, extent of system head that is static, and pump details (curve, impeller size, etc.) would be needed to evaluate alternative solutions.
Help pop-up screens provide run-time assistance

The Context Help window displays information about the control or indicator underneath the mouse pointer.

Optimization rating

This is a measure of the overall rating of the existing pumping system efficiency relative to the optimal motor, optimal pump configuration, expressed as a percentage. A value of 100 means the existing system is equal to the optimal, while a value of 50 means the existing system is half as efficient as the optimal system.

Mathematically, it is simply the Optimal Motor power divided by the Existing Motor power, expressed as a percentage.

It is possible for values of greater than 100% to exist, since the pump efficiencies used in the program reflect "generally attainable efficiency levels." There can be significant deviation in efficiency, particularly with smaller pumps (see Figure 1.63 of HI1.3-2000).

The background color for the Optimization rating varies with the rating:

- >100: Dark Blue
- 90-100: Green
- 80-90: Olive
- 70-80: Yellow
- 60-70: Orange
- <60: Red
The Background information button provides access to assessment guidance and curves used by PSAT to perform its calculations.
User's manual and other support features are included

Users of PSAT2004 can convert saved log and summary files to the 2008 version (a one-time operation)
A demo of the tool use
Example system

Suction line size: 14-inch sch. 40 CS (13.1" ID)
Discharge (except reducers at valve V1): 12-inch sch. 40 CS (11.9" ID)
Fluid: water at 70°F
Valve V1 is 8-inch v-port ball
Cost of electricity is 5 cents/kWh
Motor is 460-Volt, 250-hp, 1780 rpm, nameplate efficiency = 95.8%
All pressure gauges at 5 ft above ground
Pump is single stage end suction
Both tanks are open to atmosphere

Table 1. Measured operating data

<table>
<thead>
<tr>
<th>Condition</th>
<th>Q, gpm</th>
<th>P1, psig</th>
<th>P2, psig</th>
<th>P3, psig</th>
<th>Motor kW</th>
<th>% of time at Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2000</td>
<td>90</td>
<td>52</td>
<td>50</td>
<td>135</td>
<td>50%</td>
</tr>
<tr>
<td>B</td>
<td>3160</td>
<td>75</td>
<td>66</td>
<td>61</td>
<td>150</td>
<td>40%</td>
</tr>
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</table>
We'll do PSAT calculations for Condition A

- Calculate pump head
- Annual energy cost
- Potential savings
- Develop a system curve with artificial control valve losses eliminated
- Take a look at some of the background information and data
Other options for the side-by-side comparison

• Same pump, different operating conditions
• Same pump, different times - such as in periodic performance testing/trending
• Parallel pumps
• Old pump/new pump
• etc., etc.
A valve loss estimating tool accompanies PSAT

Based on standard valve equations (ISA 75.01)
Software download (free) and training links

www1.eere.energy.gov/industry/bestpractices/software.html

Software Tools

BestPractices has a varied and expanding software collection. Much of the software can be accessed here. A few packages must be ordered from the EERE Information Center via e-mail or by calling 1-877-EERE-INF (877-337-3463).

With the right know-how, you can use these powerful tools to help identify and analyze energy system savings opportunities in your plant. While the tools are accessible here for download, you are also encouraged to attend a training workshop to enhance your knowledge and take full advantage of opportunities identified in the software programs. For some tools, advanced training is also available to help you further increase your expertise. Find out more about training. You can get help on software installation and operation from the EERE Information Center at 1-877-EERE-INF (877-337-3463) or email to eereic@ee.doe.gov.

DOE Industry Tools

- AIRMaster+
- Chilled Water System Analysis Tool (CWSAT)
- Combined Heat and Power Application Tool (CHP)
- Fan System Assessment Tool (FSAT)
- MotorMaster+ 4.0
- MotorMaster+ International
- NOx and Energy Assessment Tool (NxEAT)
- Plant Energy Profiler for the Chemical Industry (ChemPEP Tool)
- Process Heating Assessment and Survey Tool (PHAST)
- Pumping System Assessment Tool 2004 (PSAT)
- Steam System Tool Suite
There are two PSAT workshops

End-user
Pumping Systems Field Monitoring

and Application of the
Pumping System Assessment Tool (PSAT)

A BestPractices Workshop

Software Tools

Pumping System Assessment Tool Qualification

List of Qualified PSAT Specialists

- By Last Name
- By Company
- By State

PSAT helps users assess energy savings opportunities in pumping systems, relying on field measurements of flow rate, head, and either motor power or current to perform the assessment. Using algorithms from Hydraulic Institute standards and motor performance characteristics from DOE’s NLR database, PSAT quickly estimates existing pump and motor efficiency and calculates the potential energy and cost savings of a system optimized to work at peak efficiency.

Demand is high for the software and training, and continues to grow. To meet the demand, and increase the number of PSAT experts to assist end users, DOE is working with the pumping industry, and its Allied Partner, the Hydraulic Institute, to train and qualify experts in the use of PSAT.

The qualifying workshops prepare professionals with extensive experience in pumping systems to use PSAT in their system assessments. Participants learn:

- How to accurately acquire input data for PSAT
- How to prescreen pumping systems to select the “vital” systems for further review
- How to use the PSAT software
- The difference between measurements and requirements
- The importance of a system perspective

Participants who complete the workshop and pass a qualifying exam will be recognized by DOE as Qualified Pump System Specialists, and will be listed on the BestPractices Web site. Specialists assist industrial customers in using PSAT to evaluate their pumping systems.
PSAT specialists are listed on the DOE web site

http://apps1.eere.energy.gov/industry/bestpractices/qualified_specialists/tool.cfm?software_id=2#find

Qualified BestPractices PSAT Specialists: by Last Name

| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | R | S | T | U | V | W | Y |

<table>
<thead>
<tr>
<th>Name</th>
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Become a Qualified Specialist: apps1.eere.energy.gov/industry/bestpractices/qualified_specialists/
See the “Industrial Energy Savers” Web Site

- 20 ways to save energy now
- Tools and training you can use to identify savings opportunities
- Industry expertise available
- Assessments for your plant
- Develop an Action Plan
- Learn how others have saved
- Access the National Industrial Assessment Center (IAC) Database

www.energysavers.gov/industrymanagers.html
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Web site: www1.eere.energy.gov/informationcenter
Web Site and Resources

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BestPractices Web site:
www1.eere.energy.gov/industry/bestpractices

Save Energy Now Web site:
www1.eere.energy.gov/industry/saveenergynow

- Fact Sheets
- Newsletters
- Tip Sheets
- Brochures
- Reports
- Software Tools
- Data
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