Test for Pumping System Efficiency

A pump’s efficiency can degrade as much as 10% to 25% before it is replaced, according to a study of industrial facilities commissioned by the U.S. Department of Energy (DOE), and efficiencies of 50% to 60% or lower are quite common. However, because these inefficiencies are not readily apparent, opportunities to save energy by repairing or replacing components and optimizing systems are often overlooked.

Define Pumping System Efficiency

System efficiency incorporates the efficiencies of the pump, motor, and other system components, as shown in the area of the illustration outlined by the dashed line.

Pumping system efficiency ($\eta_{\text{sys}}$) is defined as follows:

$$\eta_{\text{sys}} = \frac{Q_{\text{req}} \times H_{\text{req}} \times SG}{5308 \times P_{e}}$$

where

- $Q_{\text{req}}$ = required fluid flow rate, in gallons per minute
- $H_{\text{req}}$ = required pump head, in feet
- $SG$ = specific gravity
- $P_{e}$ = electrical power input.

Only the required head and flow rates are considered in calculating system efficiency. Unnecessary head losses are deducted from the pump head, and unnecessary bypass or recirculation flow is deducted from the pump flow rate.

Conduct Efficiency Tests

Efficiency tests help facilities staff identify inefficient systems, determine energy efficiency improvement measures, and estimate potential energy savings. These tests are usually conducted on larger pumps and on those that operate for long periods of time. For details, see Hydraulic Institute standards ANSI/HI 1.6-2000, Centrifugal Pump Tests, and ANSI/HI 2.6-2000, Vertical Pump Tests.

Flow rates can be obtained with reliable instruments installed in the system or preferably with stand-alone tools such as a sonic (Doppler-type) or “transit time” flow meter or a Pitot tube and manometer. Turbulence can be avoided by measuring the flow rate on a pipe section without fittings at a point where there is still a straight run of pipe ahead.

Improve System Efficiency

Internal leaks caused by excessive impeller clearances or by worn or misadjusted parts can reduce the efficiency of pumps. Corrective actions include restoring internal clearances and replacing or refurbishing worn or damaged throat bushings, wear rings, impellers, or pump bowls. Changes in process requirements and control strategies, deteriorating piping, and valve losses all affect pumping system efficiency.

Potential energy savings can be determined by using the difference between actual system operating efficiency ($\eta$) and the design (or optimal) operating efficiency ($\eta_{d}$), or by consulting published pump curves, as available, for design efficiency ratings.
Software tools like DOE’s Pumping System Assessment Tool (PSAT) also provide estimates of optimal efficiency. When the required head and flow rate, as well as actual electrical data, are input into the software, PSAT will account for artificial head and flow losses.

The equation for calculating potential energy savings is as follows:

\[
\text{Savings} = kW_{in} \times t \times \left( 1 - \frac{\eta_a}{\eta_o} \right),
\]

where

- \( \text{savings} \) = energy savings, in kilowatt-hours (kWh) per year
- \( kW_{in} \) = input electrical energy, in kilowatts (kW)
- \( t \) = annual operating hours
- \( \eta_a \) = actual system efficiency, calculated from field measurements
- \( \eta_o \) = optimal system efficiency.

**Example**

Efficiency testing and analysis indicate that a 300-horsepower centrifugal pump has an operating efficiency of 55%. However, the manufacturer’s pump curve indicates that it should operate at 78% efficiency. The pump draws 235 kW and operates 6,000 hours per year. Assuming that the pump can be restored to its original or design performance conditions, estimated energy savings are as follows:

\[
\text{Savings} = 235 \text{ kW} \times 6,000 \text{ hours/year} \times \left[ 1 - \frac{0.55}{0.78} \right] = 415,769 \text{ kWh/year}.
\]

At an energy cost of 5 cents per kWh, the estimated savings would be $20,786 per year.

**References**


*Trim or Replace Impellers on Oversized Pumps*, DOE Pumping Systems Tip Sheet, 2005.

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**About DOE’s Industrial Technologies Program**

The Industrial Technologies Program, through partnerships with industry, government, and non-governmental organizations, develops and delivers advanced energy efficiency, renewable energy, and pollution prevention technologies for industrial applications. The Industrial Technologies Program is part of the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy.

The Industrial Technologies Program encourages industry-wide efforts to boost resource productivity through a strategy called Industries of the Future (IOF). IOF focuses on the following eight energy and resource intensive industries:

- Aluminum
- Forest Products
- Metal Casting
- Petroleum
- Chemicals
- Glass
- Mining
- Steel

The Industrial Technologies Program and its BestPractices activities offer a wide variety of resources to industrial partners that cover motor, steam, compressed air, and process heating systems. For example, BestPractices software can help you decide whether to replace or rewind motors (MotorMaster+), assess the efficiency of pumping systems (PSAT), compressed air systems (AirMaster+), steam systems (Steam Scoping Tool), or determine optimal insulation thickness for pipes and pressure vessels (3E Plus). Training is available to help you or your staff learn how to use these software programs and learn more about industrial systems. Workshops are held around the country on topics such as “Capturing the Value of Steam Efficiency,” “Fundamentals and Advanced Management of Compressed Air Systems,” and “Motor System Management.” Available technical publications range from case studies and tip sheets to sourcebooks and market assessments. The Energy Matters newsletter, for example, provides timely articles and information on comprehensive energy systems for industry. You can access these resources and more by visiting the BestPractices Web site at [www.eere.energy.gov/industry/bestpractices](http://www.eere.energy.gov/industry/bestpractices) or by contacting the EERE Information Center at 877-337-3463 or via email at [www.eere.energy.gov/informationcenter](http://www.eere.energy.gov/informationcenter).