



U. S. Department of Energy
Energy Savings Assessment (ESA)

Overview of the Pumping System Assessment Tool (PSAT)

Date: December 15, 2008

By: Don Casada

Diagnostic Solutions, LLC

doncasada@diagsol.com

865-938-0965



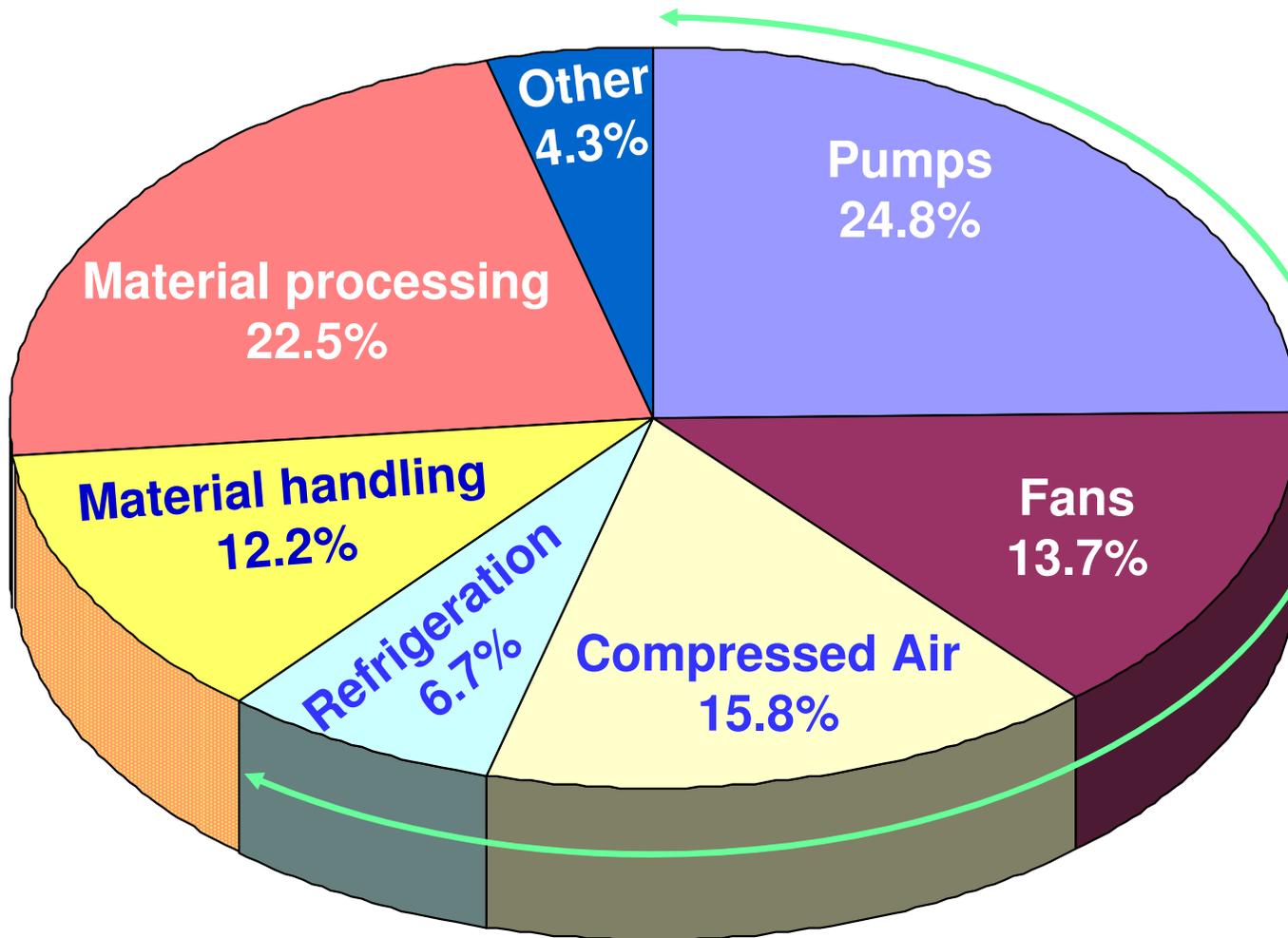
Motor-driven equipment is a dominant electricity consumer

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.

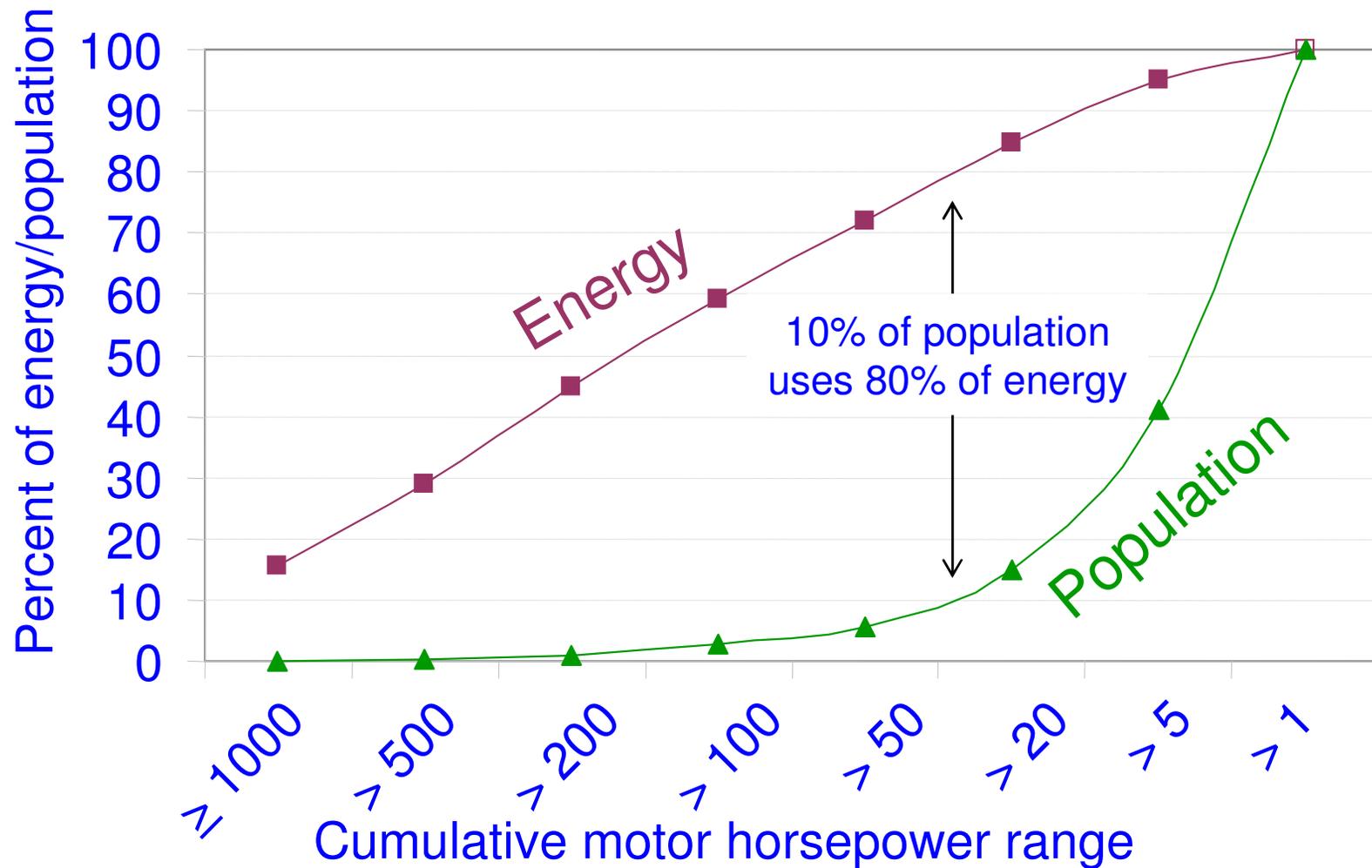


BestPractices encourages a three-tiered prescreening and assessment approach

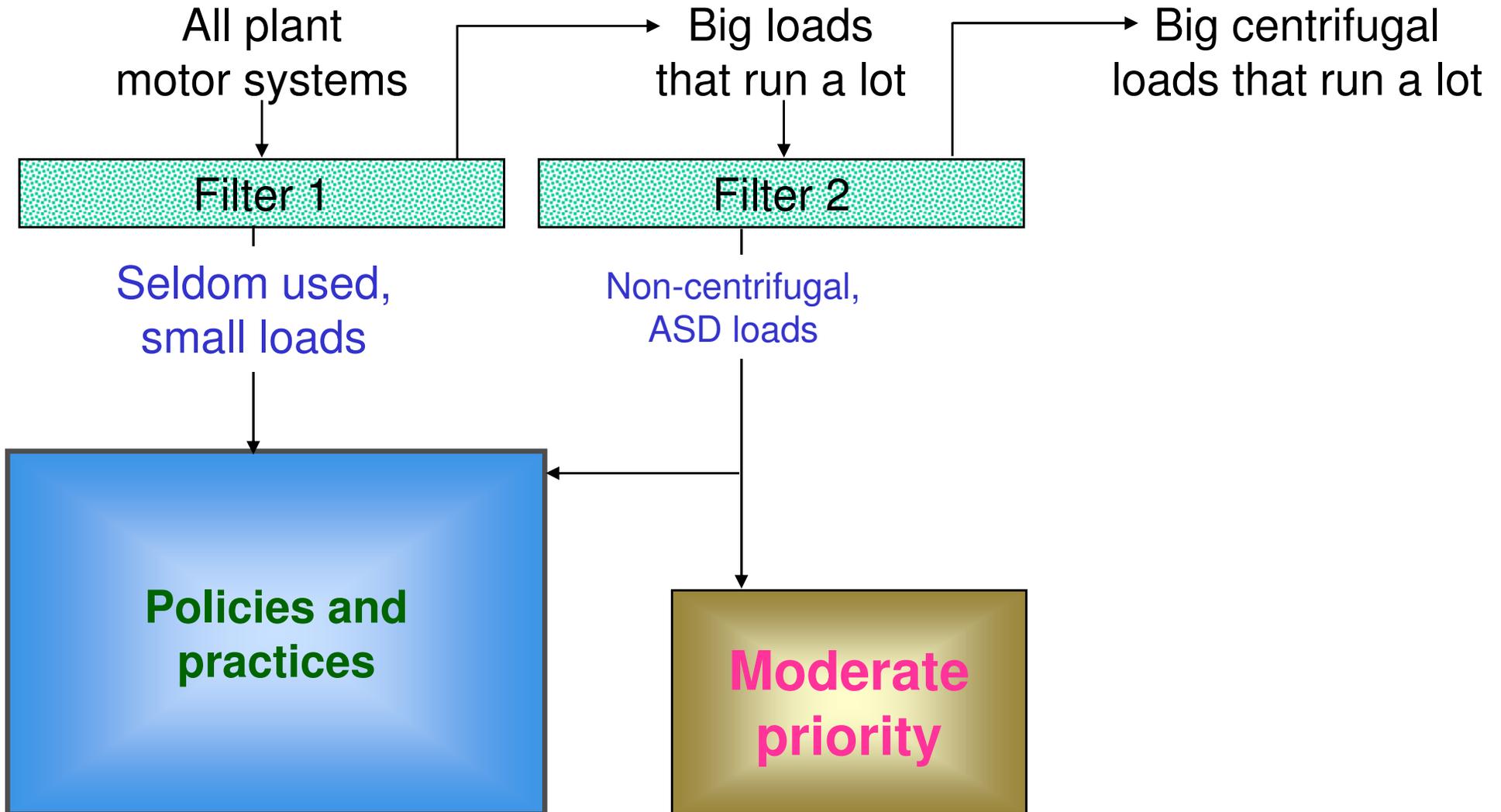
- Initial prescreening based on size, run time, and pump type
- Secondary prescreening to narrow the focus to systems where significant energy reduction opportunities are more likely
- Opportunity assessment and quantification of potential savings



The bulk of motor-driven energy is used by a relatively small part of the population



Primary prescreening



Pump energy basics are fundamental to secondary prescreening

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

E	energy, kilowatt-hours
Q	flow rate, gpm
H	head, ft
T	time, hours
sg	specific gravity, dimensionless
5308	Units conversion constant
η_{pump}	pump efficiency, fraction
η_{motor}	motor efficiency, fraction
η_{drive}	drive efficiency, fraction

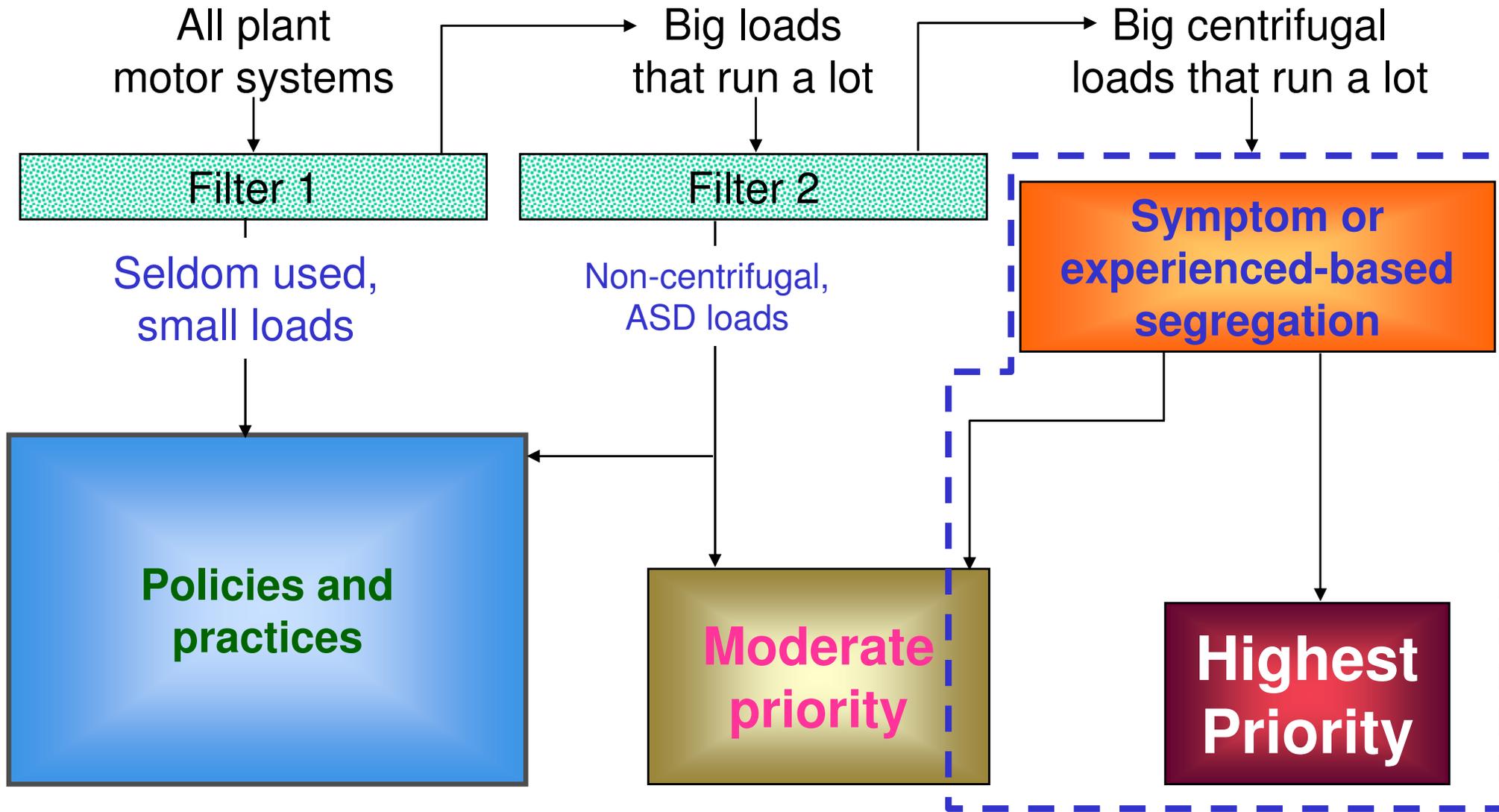


Five basic causes of less than optimal pumping system operation

- 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



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)

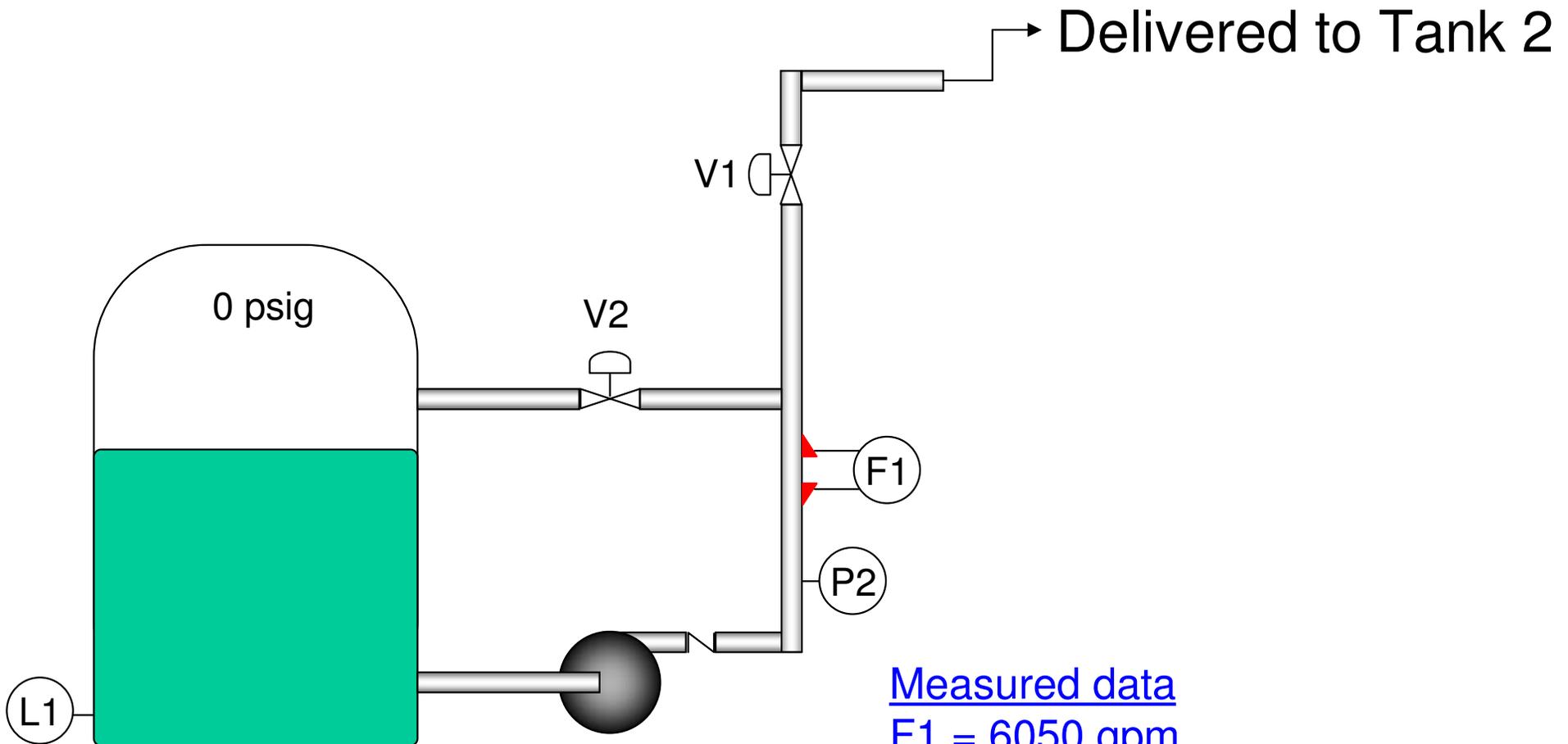


A matter of focus

- 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.

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

Click to access units converter tool

Suction pipe diameter (ID)	19.500 inches	Discharge pipe diameter (ID)	15.500 inches
Suction tank gas overpressure (P_g)	0.00 psig	Discharge gauge pressure (P_d)	75.50 psig
Suction tank fluid surface elevation (Z_s)	12.00 ft	Discharge gauge elevation (Z_d)	5.00 ft
Suction line loss coefficients, K_s	0.50	Discharge line loss coefficients, K_d	2.50
Fluid specific gravity	0.990	Flow rate	6050.00 gpm

Don't update Accept and update

Click to leave the main panel head unchanged Click to Accept and return the calculated head

System of units: gpm, ft, hp

Differential elevation head	-7.00 ft
Differential pressure head	176.23 ft
Differential velocity head	1.64 ft
Estimated suction friction head	0.33 ft
Estimated discharge friction head	4.11 ft
Pump head	175.31 ft

Tank to pipe entrance loss

Check valve, SR elbow



Component-based analysis

Inputs

Condition A

End suction stock

Pump rpm: 1185

Drive: Direct drive

Units: gpm, ft, hp

Kinematic viscosity (cS): 1.00

Specific gravity: 0.990

stages: 1

Fixed specific speed? NO

Line freq.: 60 Hz

HP: 350

Motor rpm: 1185

Eff. class: Standard efficiency

Voltage: 2300

Estimate FLA

Full-load amps: 83.0

Size margin, %: 15

Operating fraction: 1.000

\$/kwhr: 0.0390

Flow rate, gpm: 6050

Head tool: Head, ft: 175

Load estim. method: Current

Motor amps: 80.5

Voltage: 2300

Results

Condition A

	Existing	Optimal	Units
Pump efficiency	78.2	87.3	%
Motor rated power	350	350	hp
Motor shaft power	339.0	303.7	hp
Pump shaft power	339.0	303.7	hp
Motor efficiency	94.5	95.6	%
Motor power factor	83.4	83.8	%
Motor current	80.5	71.0	amps
Motor power	267.5	237.1	kW
Annual energy	2343.7	2076.6	MWh
Annual cost	91.4	81.0	\$1000
Annual savings potential, \$1,000		10.4	
Optimization rating, %		88.6	



Input sections 1-3

Basic design, operating profile and cost inputs

	End suction stock ▼
Pump, fluid	Pump rpm ▲▼ 1185
	Drive Direct drive ▼
	Units gpm, ft, hp ▼
	Kinematic viscosity (cS) ▲▼ 1.00
	Specific gravity ▲▼ 0.990
	# stages ▲▼ 1
	Fixed specific speed? NO
Motor	Line freq. 60 Hz ▼
	HP 350 ▼
	Motor rpm ▲▼ 1185
	Eff. class Standard efficiency ▼
	Voltage ▲▼ 2300
	Estimate FLA
	Full-load amps ▲▼ 83.0
	Size margin, % ▲▼ 15
Duty, unit cost	Operating fraction ▲▼ 1.000
	\$/kwhr ▲▼ 0.0390



Input section 4

Accurate performance data is essential

Field data

Flow rate, gpm	6050
Head tool Head, ft	175
Load estim. method	Current ▼
Motor amps	80.5
Voltage	2300

} fluid

} electrical



Alternate forms of electrical data input

Field data

Flow rate, gpm	6050	
Head tool	Head, ft	175
Load estim. method	Current	
Motor amps	80.5	
Voltage	2300	



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

Field data

Flow rate, gpm	6050	
Head tool	Head, ft	175
Load estim. method	Power	
Motor kW	267.5	
Voltage	2300	



Results: optimization rating

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

Condition A

	Existing	Optimal	Units
Pump efficiency	78.2	87.3	%
Motor rated power	350	350	hp
Motor shaft power	339.0	303.7	hp
Pump shaft power	339.0	303.7	hp
Motor efficiency	94.5	95.6	%
Motor power factor	83.4	83.8	%
Motor current	80.5	71.0	amps
Motor power	267.5	237.1	kW
Annual energy	2343.7	2076.6	MVWh
Annual cost	91.4	81.0	\$1000

$$\frac{237.1}{267.5} \times 100 = 88.6$$

Annual savings potential, \$1,000

Optimization rating, %

10.4
88.6



Results: cost, savings potential

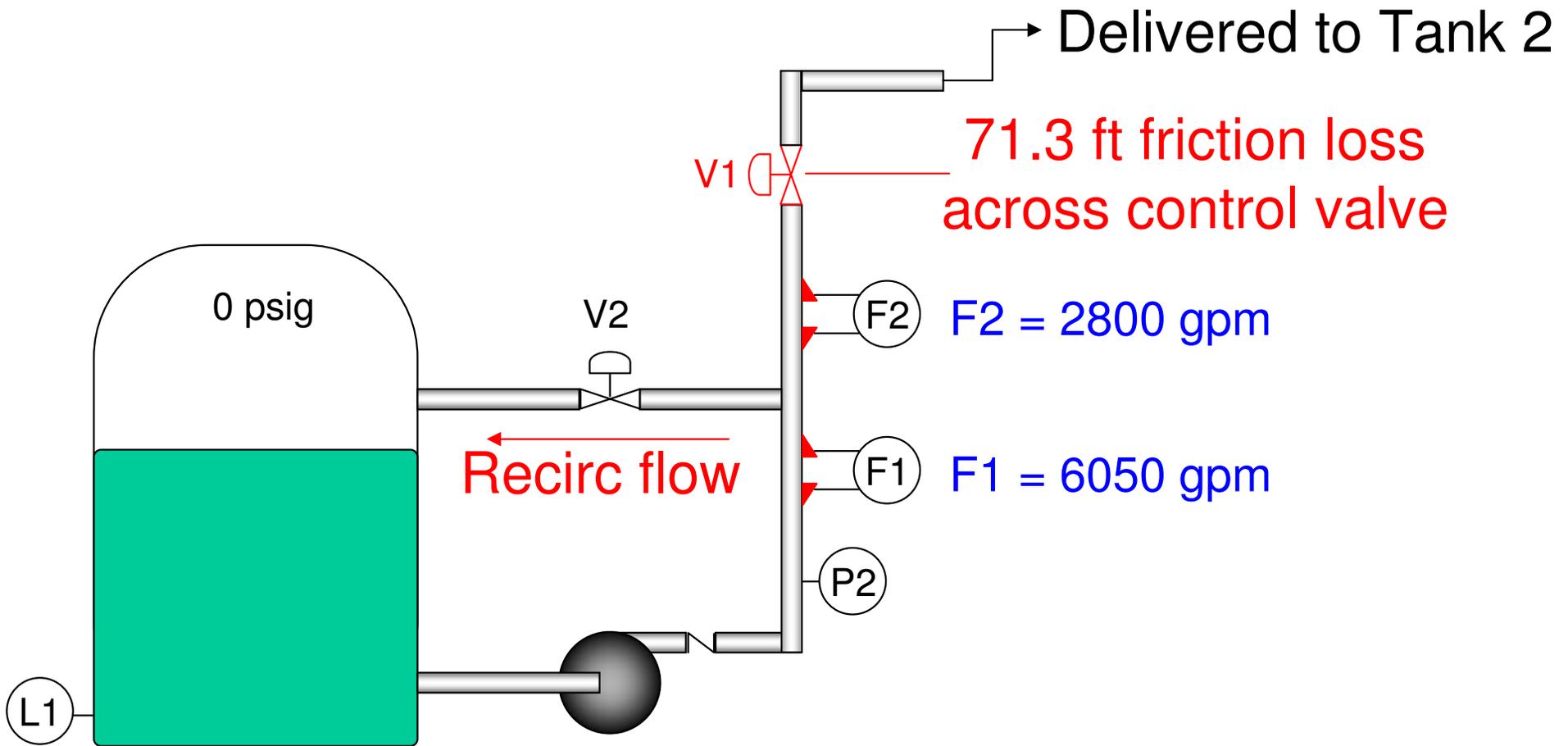
Condition A

	Existing	Optimal	Units
Pump efficiency	78.2	87.3	%
Motor rated power	350	350	hp
Motor shaft power	339.0	303.7	hp
Pump shaft power	339.0	303.7	hp
Motor efficiency	94.5	95.6	%
Motor power factor	83.4	83.8	%
Motor current	80.5	71.0	amps
Motor power	267.5	237.1	kW
Annual energy	2343.7	2076.6	MVh
Annual cost	91.4	81.0	\$1000
Annual savings potential, \$1,000		10.4	
Optimization rating, %		88.6	

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



A system-level perspective



Required flow rate: 2800 gpm sent to Tank 2

<u>Required</u> head =	Pump head:	175.3 ft
	- valve loss	71.3 ft
		<hr/>
		104.0 ft



A system-level perspective

PSAT analysis using the required fluid data

Condition B

End suction stock

Pump rpm: 1185

Drive: Direct drive

Units: gpm, ft, hp

Kinematic viscosity (cS): 1.00

Specific gravity: 0.990

stages: 1

Fixed specific speed? NO

Line freq.: 60 Hz

HP: 350

Motor rpm: 1185

Eff. class: Standard efficiency

Voltage: 2300

Estimate FLA

Full-load amps: 83.0

Size margin, %: 15

Operating fraction: 1.000

\$/kwhr: 0.0390

Flow rate, gpm: 2800

Head, ft: 104

Load estim. method: Current

Motor amps: 80.5

Voltage: 2300

	Condition B		Units
	Existing	Optimal	
Pump efficiency	21.5	84.6	%
Motor rated power	350	100	hp
Motor shaft power	339.0	86.1	hp
Pump shaft power	339.0	86.1	hp
Motor efficiency	94.5	94.8	%
Motor power factor	83.4	82.3	%
Motor current	80.5	20.6	amps
Motor power	267.5	67.7	kW
Annual energy	2343.7	593.1	MWh
Annual cost	91.4	23.1	\$1000
		68.3	
		25.3	

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

	Condition A			Condition B		
	Existing	Optimal	Units	Existing	Optimal	Units
Pump efficiency	21.5	84.6	%	21.5	84.6	%
Motor rated power	350	100	hp	350	100	hp
Motor shaft power	339.0	86.1	hp	339.0	86.1	hp
Pump shaft power	339.0	86.1	hp	339.0	86.1	hp
Motor efficiency	94.5	94.8	%	94.5	94.8	%
Motor power factor	83.4	82.3	%	83.4	82.3	%
Motor current	80.5	20.6	amps	80.5	20.6	amps
Motor power	267.5	67.7	kW	267.5	67.7	kW
Annual energy	2343.7	593.1	MWh	2343.7	593.1	MWh
Annual cost	91.4	23.1	\$1000	91.4	23.1	\$1000

Annual savings potential, \$1,000: 68.3

Optimization rating, %: 25.3

Log file controls: Create new log, Add to existing log, Retrieve log entry, Delete log entry

Summary file controls: Existing summary files

Condition A Notes: Documentation s

Facility: Mid-south Paper, System: Surge chest stock

Application: 30-0564

General comments: Net pump flow rate and required head (developed head minus t

Context Help

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).

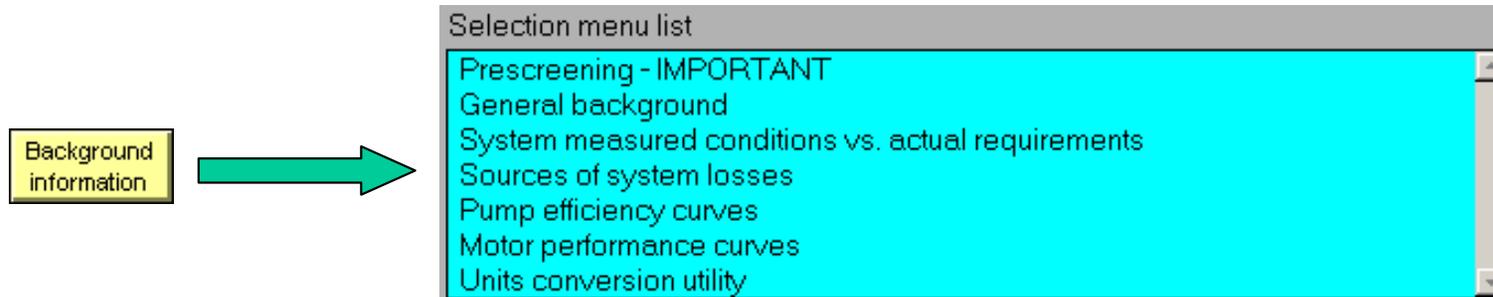
The background color for the Optimization rating varies with the rating:

- >100: Dark Blue
- 90-100: Green
- 80-90: Olive
- 70-80: Yellow
- 60-70: Orange
- <60: Red

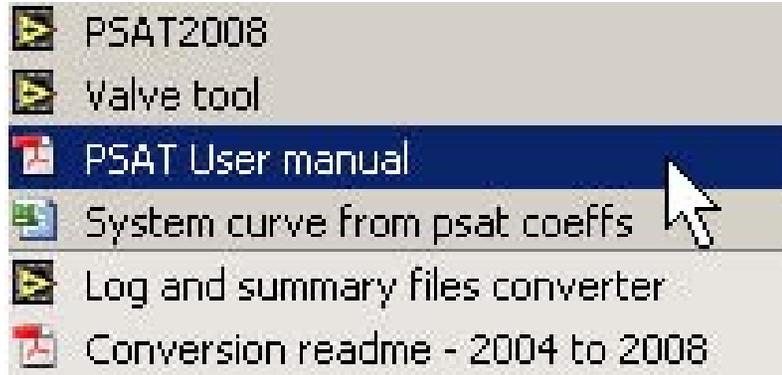
The Context Help window displays information about the control or indicator underneath the mouse pointer



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

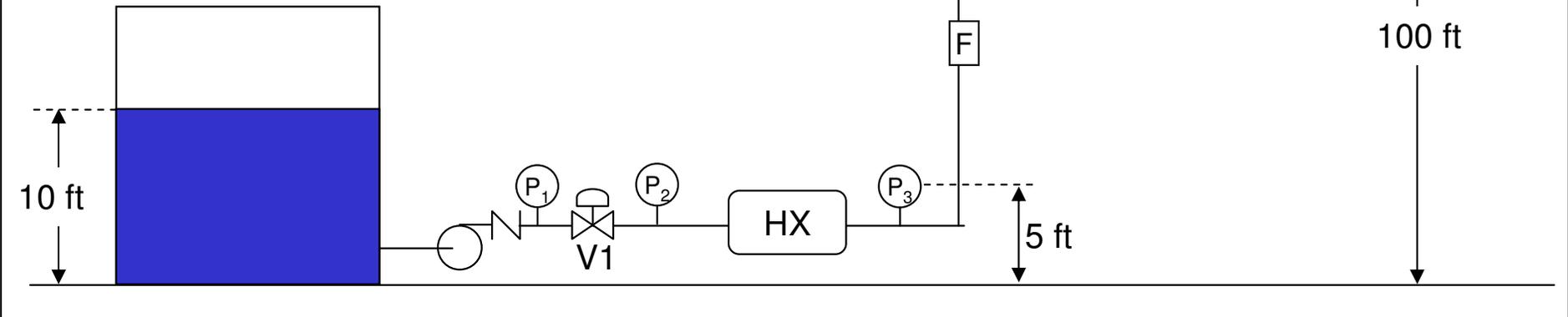


Table 1. Measured operating data

Condition	Q, gpm	P1, psig	P2, psig	P3, psig	Motor kW	% of time at Condition
A	2000	90	52	50	135	50%
B	3160	75	66	61	150	40%



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

Units

Available data selector

Specific gravity

Specified flow rate, gpm

Operating fraction

Average electrical cost rate, \$/kWh

Pump efficiency, %

Motor efficiency, %

Head loss, ft

Frictional power loss, hp

Frictional electrical power, kW

Annual cost of friction, \$



505.5
Calculated valve Cv

Upstream pressure, psig

Downstream pressure, psig

Upstream pipe ID, inches

Valve size, inches

Downstream pipe ID, inches

Upstream gauge elev, ft

Downstream gauge elev, ft

Upstream gauge velocity, ft/s

Valve velocity, ft/s

Downstream gauge velocity, ft/s

K_reducer & expander

K_valve

K_total

Based on standard valve equations (ISA 75.01)



Software download (free) and training links

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

BestPractices

 [Printable Version](#)

[BestPractices Home](#)

About BestPractices

Resources

[Software Tools](#)

[Publications](#)

[Training](#)

[Databases](#)

[Qualified Specialists](#)

[Ways to Save Energy](#)

[EERE Information Center](#)

Opportunities

[For Corporate Executive](#)

[For Plant Management](#)

[For Technical](#)

[For General Public](#)

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

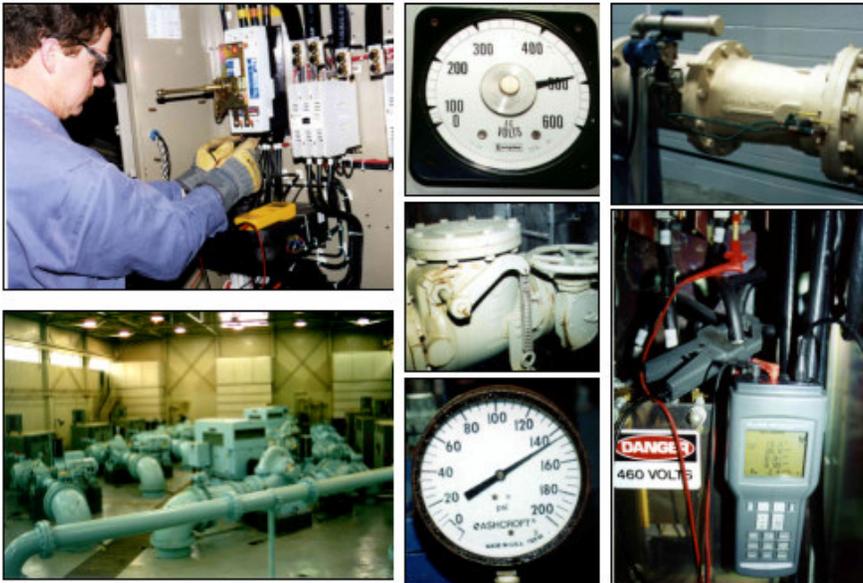
- [AIRMasteR+](#)
- [Chilled Water System Analysis Tool \(CWSAT\)](#)
- [Combined Heat and Power Application Tool \(CHP\)](#)
- [Fan System Assessment Tool \(FSAT\)](#)
- [MotorMaster+ 4.0](#)
- [MotorMaster+ International](#)
- [NOx and Energy Assessment Tool \(NxEAT\)](#)
- [Plant Energy Profiler for 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

Specialist



U.S. Department of Energy
Energy Efficiency and Renewable Energy

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable



Industrial Technologies Program

[Home](#); [BestPractices](#); [Tools and Publications](#); [Software Tools](#); [PSAT Qualification](#)

BESTPRACTICES
[Home](#)
[About BestPractices](#)
[Industrial Systems](#)
 - Compressed Air
 - Motors
 - Process Heating
 - Steam
[Plant Assessments](#)
[Training](#)
[Tools & Publications](#)
 - Software Tools
 - Databases
 - Publications Library
 - Energy Matters
[Emerging Technologies](#)
[Showcase Demonstrations](#)
[Results for Industry](#)
[Partnerships](#)
[Awards & Recognition](#)
[Solicitations](#)
[Search BestPractices](#)

Software Tools

Pumping System Assessment Tool Qualification

List of Qualified PSAT Specialists

- [By Last Name](#)
- [By Company](#)
- [By State](#)

Earn recognition as a qualified pump system specialist in the use of DOE's [Pumping System Assessment Tool \(PSAT\)](#) software by attending a qualification workshop.

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 [MotorMaster+](#) 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

‡ indicates Qualified BestPractices Instructor

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

A

Name	E-Mail	Phone
Adams, Bill	wadams@flowserve.com	269-226-6203
Ahlen, Arne	aahlen@apiweb.com	404-872-8807 ext. 205
Ahlgren, Roy ‡	roy.ahlgren@itt.com	847-966-3700
Allen, Jim	jallen@flowserve.com	757-485-8021
Anderson, Kent	andersonka@schofield.army.mil	808-656-1410 ext. 1108
Angle, Tom ‡	angle@weirsp.com	801-530-7808

[Back to Top](#)

B

Name	E-Mail	Phone
Bell, Lloyd	lbell@flowserve.com	406-240-2232
Bennington, Steven	steveb@rampump.com	513-247-5334
Bettis, Norris	nbettis@tencarva.com	423-892-8928
Bihl, Mark	mbihl@peerlesspump.com	317-924-7362
Bird, Jim	jbird@flowserve.com	410-756-3227
Biver, Paul	paul.biver@itt.com	315-568-7339
Bolles, Steve ‡	sabolles@processenergy.com	603-537-1286
Brashler, Keith	kbrash@gte.net	360-201-6066
Butts, Edward	epbpe@juno.com	503-589-1115

[Back to Top](#)



Find Additional Training

Visit the DOE BestPractices Training Web site:

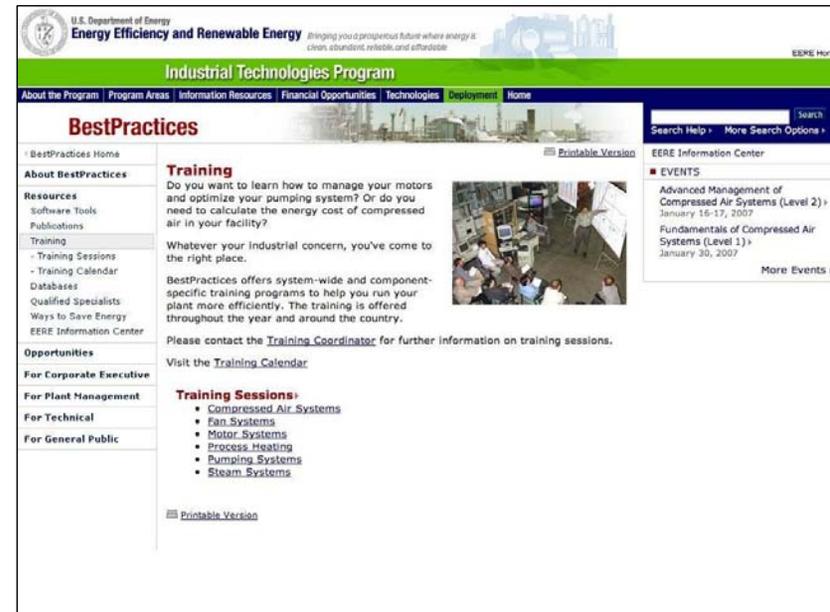
www1.eere.energy.gov/industry/bestpractices/training.html

See the Training Calendar for events in your area:

www1.eere.energy.gov/industry/bestpractices/events_calendar.asp

Become a Qualified Specialist:

apps1.eere.energy.gov/industry/bestpractices/qualified_specialists/



The screenshot shows the DOE BestPractices Training website. At the top, it features the U.S. Department of Energy logo and the text "Energy Efficiency and Renewable Energy" with the tagline "Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable". Below this is a green navigation bar for the "Industrial Technologies Program" with links for "About the Program", "Program Areas", "Information Resources", "Financial Opportunities", "Technologies", "Deployment", and "Home". The main content area is titled "BestPractices" and includes a "Training" section with the following text: "Do you want to learn how to manage your motors and optimize your pumping system? Or do you need to calculate the energy cost of compressed air in your facility? Whatever your industrial concern, you've come to the right place. BestPractices offers system-wide and component-specific training programs to help you run your plant more efficiently. The training is offered throughout the year and around the country. Please contact the Training Coordinator for further information on training sessions. Visit the Training Calendar." A "Training Sessions" list includes: Compressed Air Systems, Fan Systems, Motor Systems, Process Heating, Pumping Systems, and Steam Systems. On the right side, there is an "EVENTS" section listing "Advanced Management of Compressed Air Systems (Level 2)" for January 16-17, 2007, and "Fundamentals of Compressed Air Systems (Level 1)" for January 30, 2007. A search bar and "Printable Version" link are also visible.



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

The screenshot shows the 'Energy Savers' website page for 'Industry Plant Managers & Engineers'. The page is part of the U.S. Department of Energy's Energy Efficiency and Renewable Energy (EERE) site. The main heading is 'Industry Plant Managers & Engineers'. Below this, there is a section titled 'Boost the Bottom Line: Lower your plant energy bills'. The text states: 'Reducing energy costs can be as easy as adjusting a dial. Get started today with simple, low- or no-cost steps to energy savings:'. There are two main bullet points: '20 Ways to Save Energy Now for quick and easy cost savings' and 'Learn more about' with sub-bullets: 'How other plants have achieved big savings', 'Tools and training you can use to identify savings opportunities', 'Assessments for your facility', and 'Industry expertise available'. To the right of the text is a line graph titled 'Results of Plant Assessments'. The graph plots 'Annual Cost Savings (\$ Millions)' on the y-axis (0 to 3) against 'Natural Gas Savings (Billion Btu/year)' on the x-axis (0 to 800). A solid line shows a positive linear correlation, with data points plotted at approximately (100, 0.5), (200, 1.0), (300, 1.5), (400, 2.0), (500, 2.5), and (600, 3.0). Below the graph is a section titled 'Saving Energy' with a link to 'Learn more about energy use in U.S. industry'. The website header includes 'U.S. Department of Energy Energy Efficiency and Renewable Energy' and 'Energy Savers A consumer guide to energy efficiency and renewable energy'. Navigation links include 'Home Improvements', 'Heat & Cool', 'Buy Clean Electricity', 'Make Clean Electricity', 'Buy Vehicles', 'Information Resources', and 'Home'. There is also a search bar and a link to 'Ask an Energy Expert'.



EERE Information Center

On-call team of professional engineers, scientists, research librarians, energy specialists, and communications information staff.

Voice: [877-337-3463](tel:877-337-3463)

E-mail: eereic@ee.doe.gov

Web site: www1.eere.energy.gov/informationcenter



Web Site and Resources

Visit these DOE Web sites for the latest information and resources:

Industrial Technologies Program (ITP) Web site:

www1.eere.energy.gov/industry/

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



Acknowledgments

U.S. Department of Energy's
Industrial Technologies Program

