

Pumping System Assessment Tool User's Manual

PSAT2008

Don Casada, Diagnostic Solutions, LLC

About this manual

The Pumping System Assessment Tool (PSAT) is designed to allow users to evaluate the potential energy savings opportunities of pumping systems based on field-measured data. This user's guide document gives basic information about the data entry items, the calculated results, and assorted control button features. It is not intended to provide a tutorial on how to obtain field data or perform pumping system evaluations. The U.S. Department of Energy sponsors both end-user and specialist workshops on those subjects. International affiliates are also undertaking similar efforts. A listing of currently planned training sessions is available on the web at:

<http://www1.eere.energy.gov/industry/bestpractices/training.html>

Support from the U.S. Department of Energy

The U.S. Department of Energy supports the operation of the EERE Information Center at:

http://www1.eere.energy.gov/industry/bestpractices/info_center.html

Users may call (1-877-337-3463) or e-mail (eereic@ee.doe.gov) the EERE Information Center with questions about program operation or technical questions related pumping system operating efficiency.

Manual organization

This manual is organized by general section of the main and supporting panels. Following an overview, each section is covered, with descriptions of the individual control or indication items within that section. Links to the overview and sections are provided below.

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Help screens while using PSAT

Most of the descriptions covered in this manual are also available as help popups when running PSAT. To enable help windows, simply type "Ctrl-H" or click on the Help menu, and select "Show Context Help". Repeat those steps to toggle the help screens off.

Figure 1. PSAT main panel layout

Condition A

End suction ANSI/API

Pump rpm: 1780
 Drive: Direct drive
 Units: gpm, ft, hp
 Kinematic viscosity (cS): 1.00
 Specific gravity: 1.000
 # stages: 1
 Fixed specific speed? **YES**

Line freq: 60 Hz
 HP: 200
 Motor rpm: 1780
 Eff. class: Energy efficient

Voltage: 460
 Estimate FLA
 Full-load amps: 225.4
 Size margin, %: 0

Operating fraction: 1.000
 \$/kwhr: 0.0500

Flow rate, gpm: 2000
 Head tool: Head, ft: 277
 Load estim. method: Power
 Motor kW: 150.0
 Voltage: 460

Retrieve defaults | Set defaults | Copy A > to B >

System curve tool: select below

Condition B

Specified optimal eff (below)

Achievable efficiency: 85.0
 Pump rpm: 1480
 Drive: Direct drive
 Units: L/s, m, kW
 Kinematic viscosity (cS): 1.00
 Specific gravity: 1.000
 # stages: 1
 Fixed specific speed? **NO**

Line freq: 50 Hz
 145.0 kW <<Spec
 Motor rpm: 1480
 Eff. class: Specified (below)

FL efficiency, %: 95.8
 Voltage: 380
 Estimate FLA
 Full-load amps: 266.0
 Size margin, %: 0

Operating fraction: 1.000
 \$/kwhr: 0.0500

Flow rate, L/s: 126
 Head tool: Head, m: 84.4
 Load estim. method: Current
 Motor amps: 264.0
 Voltage: 380

Copy B < to A < | Background information

STOP

	Condition A			Condition B		
	Existing	Optimal	Units	Existing	Optimal	Units
Pump efficiency	72.6	84.8	%	72.5	85.0	%
Motor rated power	200	200	hp	145	132	kW
Motor shaft power	192.4	164.8	hp	143.9	122.7	kW
Pump shaft power	192.4	164.8	hp	143.9	122.7	kW
Motor efficiency	95.7	95.8	%	95.8	95.6	%
Motor power factor	86.7	85.7	%	86.4	86.4	%
Motor current	217.1	188.2	amps	264.0	225.7	amps
Motor power	150.0	128.4	kW	150.2	128.3	kW
Annual energy	1314.0	1125.1	MWh	1315.5	1124.1	MWh
Annual cost	65.7	56.3	\$1000	65.8	56.2	\$1000

Annual savings potential, \$1,000: 9.4
 Optimization rating, %: 85.6

9.6
85.4

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

Summary file controls:
 Create new summary file | Existing summary files: CREATE NEW

Condition A Notes | **Documentation section**

Facility: | System: | Date: | Application: | Evaluator: | General comments:

Condition B Notes

Facility: | System: | Date: | Application: | Evaluator: | General comments:

PSAT main panel general overview

A brief overview of the major sections of the PSAT main panel is provided below. More detailed information on each of the individual elements is provided in subsequent sections, organized by section as follows:

The PSAT main panel, shown in Figure 1, is the primary user interface. Calculations are performed simultaneously on two independent conditions, Condition A and Condition B, shown in Figure 2.

While most of the inputs involve simply selecting an item from a drop-down menu or typing in the numerical value, and are discussed individually later in this guide, there are three buttons that are important to highlight.

The first is the “Estimate FLA” button (FLA = Full-Load Amps). This version of PSAT requires the user to specify the FLA even if power is being used as the method to estimate motor output (shaft) power. If the motor nameplate FLA is not readily available, clicking the “Estimate FLA” button will insert a reasonable estimate for the specified motor speed, size, and efficiency class.

The second button that is important to note is the Head tool button. This button takes the user to the supporting head tool calculation panel, from which measured field data are translated into operating head. The head tool calculation panel is discussed in detail later in this guide.

The third button is the “Fixed specific speed?” selector. Generally speaking, it is more conservative to select YES. If, however, the basic pump design can be changed (such as number of stages adjusted) in an effort to improve achievable efficiency, NO may be chosen.

Figure 2. PSAT input section

Condition A	Condition B
End suction ANSI/API	Specified optimal eff (below)
Achievable efficiency: 85.0	Achievable efficiency: 85.0
Pump rpm: 1780	Pump rpm: 1480
Drive: Direct drive	Drive: Direct drive
Units: gpm, ft, hp	Units: L/s, m, kW
Kinematic viscosity (cS): 1.00	Kinematic viscosity (cS): 1.00
Specific gravity: 1.000	Specific gravity: 1.000
# stages: 1	# stages: 1
Fixed specific speed? YES	Fixed specific speed? NO
Line freq: 60 Hz	Line freq: 50 Hz
HP: 200	145.0 kW <<Spec
Motor rpm: 1780	Motor rpm: 1480
Eff. class: Energy efficient	Eff. class: Specified (below)
Voltage: 460	FL efficiency, %: 95.8
Estimate FLA	Voltage: 380
Full-load amps: 225.4	Estimate FLA
Size margin, %: 0	Full-load amps: 266.0
Operating fraction: 1.000	Size margin, %: 0
\$/kwhr: 0.0500	Operating fraction: 1.000
Flow rate, gpm: 2000	\$/kwhr: 0.0500
Head tool Head, ft: 277	Flow rate, L/s: 126
Load estim. method: Power	Head tool Head, m: 84.4
Motor kW: 150.0	Load estim. method: Current
Voltage: 460	Motor amps: 264.0
	Voltage: 380

The inputs inside the yellow (Condition A) and grey (Condition B) boxes on the left portion of the main panel are used by PSAT to compute the results which are shown in the correspondingly-labeled boxes in the upper right hand portion of the panel, as shown in Figure 3. The "Existing" column reflects PSAT's estimates of equipment (and/or system) parameters for the current operation. The "Optimal" column reflects PSAT's estimate of top of the line, commercially available equipment performance.

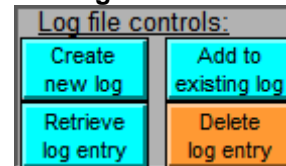
Figure 3. PSAT results section

	Condition A			Condition B		
	Existing	Optimal	Units	Existing	Optimal	Units
Pump efficiency	72.6	84.8	%	72.5	85.0	%
Motor rated power	200	200	hp	145	132	kW
Motor shaft power	192.4	164.8	hp	143.9	122.7	kW
Pump shaft power	192.4	164.8	hp	143.9	122.7	kW
Motor efficiency	95.7	95.8	%	95.8	95.6	%
Motor power factor	86.7	85.7	%	86.4	86.4	%
Motor current	217.1	188.2	amps	264.0	225.7	amps
Motor power	150.0	128.4	kW	150.2	128.3	kW
Annual energy	1314.0	1125.1	MWh	1315.5	1124.1	MWh
Annual cost	65.7	56.3	\$1000	65.8	56.2	\$1000
Annual savings potential, \$1,000		9.4		9.6		
Optimization rating, %		85.6		85.4		

The data entered under Condition A can be for the same pump as in Condition B, but measured at a different point in time, at different operating conditions, etc. Alternatively, it can be for another pump in the same system, a similar pump in a different facility, or a completely unrelated application. So there is no limitation on the selection of pump and motor combinations or the system of units. In the case of the inputs and results shown in Figures 2 and 3, different pump types, motors, and systems of units were used.

PSAT analyses may be saved for subsequent retrieval using the Log file controls buttons (Fig. 4) in the middle portion of the display. Logging is somewhat analogous to saving a file, but it provides flexibility and retrieval information that is not available through the normal Windows interface.

Figure 4. Log file controls section



PSAT analyses can also be exported to a spreadsheet format (tab-delimited file) using the Summary file controls section (Fig. 5) in the middle right hand side of the main panel display. Existing summary files may also be appended; more detailed discussion is provided in the Log and summary files control section.

Figure 5. Summary file controls section



The lower right hand portion of the main panel provides the user a means to record the facility, system, application, date, name of the individual(s) performing the evaluation, and general comments for each of the two Conditions. The Documentation section (Fig. 6) is vitally important to the overall documentation of the analysis. Furthermore, it is available for the user to read when retrieving previously logged analyses. Since in many cases, the user may have multiple sets of analyses for an individual pumping system, the documentation section is a vital portion of any saved work.

Figure 6. Documentation section

Condition A Notes

Facility System Date

Application Evaluator

General comments

Condition B Notes

Facility System Date

Application Evaluator

General comments

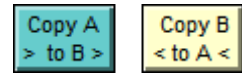
The Retrieve defaults and Set defaults buttons (Fig. 7) are at the lower left portion of the main display, beneath the Condition A input section. These Set defaults button is used to define a set of input and documentation values that will automatically be displayed when starting PSAT. The Retrieve defaults button will reset the main panel to the default values at any time (without stopping and restarting the program).

Figure 7. Retrieve, Set default buttons



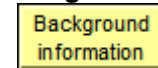
The Copy A to B and Copy B to A buttons (Fig. 8), located underneath the two Condition input sections, allow the user to quickly copy Condition A inputs to Condition B (or vice-versa). This can be especially helpful when inputting alternative conditions for the same pump, since not only will the basic nameplate type selections be the same, but also the line size, gauge location, etc. data that were used in calculating pump head for one condition (but is not displayed on the main panel) will automatically be transferred along with the visible main panel inputs.

Figure 8. Copy Condition buttons



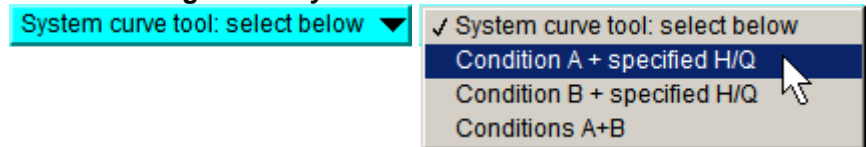
The Background information button (Fig. 9), located near the bottom center of the main panel, brings up a secondary panel from which the user can get more details about recommended methods for prescreening industrial systems and the underlying methods used by PSAT.

Figure 9. Background info button



Use of the system curve tool menu bar (Fig. 10), located at the bottom left part of the main panel, can bring up a secondary panel in which the user can develop an estimated system curve for simple systems (e.g., those with a single suction source and receiving target). The system curve panel is discussed in detail later in this guide.

Figure 10. System curve selection menu bar



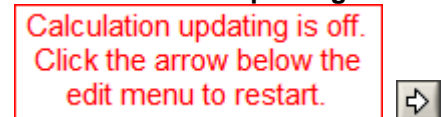
The STOP button (Fig. 11) allows the user to suspend calculation updating. Under normal conditions, PSAT is continuously updating the results on the main panel as input changes are made, the STOP button is visible at the bottom middle of the panel, and a black Run arrow (shown beside the STOP button in Figure 11) appears just below the Edit menu item.

Figure 11. STOP button



In some situations, the user may prefer to temporarily halt PSAT without closing the application. Clicking on the STOP button will halt PSAT operations and cause the Calculation updating off alert box (Fig. 12) to appear and the Run arrow to change to white (shown beside the Calculation updating box in Figure 12). To make PSAT "live" again, simply click on the white Run arrow below the Edit menu. The STOP button will once again become visible, the Calculation updating alert box will disappear, and the Run arrow will change from white to black.

Figure 12. Calculation updating off alert box



Detailed discussions of each of the input, calculated, and control elements are provided in the balance of this guide, and are organized by sections of the main display and supporting panels.

Pump, fluid section

Pump, fluid	Specified optimal eff (below) ▼
	Achievable efficiency ▲▼ 85.0
	Pump rpm ▲▼ 1780
	Drive Direct drive ▼
	Units gpm, ft, hp ▼
	Kinematic viscosity (cS) ▲▼ 1.00
	Specific gravity ▲▼ 1.000
	# stages ▲▼ 1
Fixed specific speed? NO	

Pump style

End suction ANSI/API ▼	▼ End suction slurry
	End suction sewage
	End suction stock
	API double suction
	Multistage boiler feed
	End suction ANSI/API
	Axial flow
	Double suction
	Vertical turbine
	Large end suction
	Specified optimal eff (below)

The pump style list used here is based on a listing of styles in Hydraulic Institute (HI) standard ANSI/HI 1.3-2000, American National Standard for Centrifugal Pumps for Design and Application (and also in a paper published by HI, Efficiency Prediction Method for Centrifugal Pumps).

The HI standard includes algorithms that estimate achievable pump efficiencies based on pump style and operating conditions.

Beginning with PSAT2007, the user is also provided with the ability to specify an achievable efficiency (completely independent of the HI standard methodology). This may be used, for example, to estimate potential savings associated with use of a specific pump model, or restoration of a pump to like-new conditions. It can also be helpful in assessing opportunities in systems that require special purpose pumps that are not addressed by the HI standard methods, such as recessed impeller pumps.

Achievable efficiency

Achievable efficiency ▲▼ 85.0

The pump achievable efficiency input is only displayed when the pump style is "Selected optimal eff (below)".

The input value would normally be the pump efficiency at the specified operating conditions (under the Field data section), as opposed to the best efficiency point flow rate.

Pump rpm

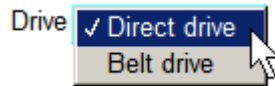
Pump rpm ▲▼ 1780

The operating or nameplate speed for the pump is used, along with the measured/required flow rate and head and number of stages, to calculate the pump specific speed. The specific speed is used to determine efficiency penalty associated with the particular pump application.

(Note that in the common use, specific speed for a particular pump applies to its best efficiency point.)

Drive

Drive **Direct drive** ▼



This drop-down selection menu allows the user to define whether the pump is direct driven by the motor or belt-driven.

The average losses used are based on curves from Appendix L of AMCA Publication 203-90. Variations ranging from -1% to +2% of the average value for motor loads exceeding 10 hp are indicated by the AMCA curves.

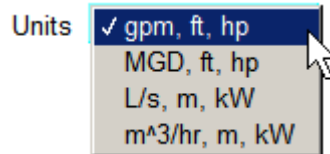
The reason that adjustable speed drives (ASDs) are not included here is twofold:

- 1) ASD efficiency is variable with speed. The user is referred to the PSAT workshop, which includes example ranges of combined motor and drive efficiencies for different drive types.
- 2) The current-based load estimation method employed by PSAT only applies to applications where the motor is driven directly across the line. Considerable variations in details associated with the drive and auxiliary component design render this method impractical.

If an adjustable speed drive is used, the user is cautioned to recognize that drive losses will inherently reduce the optimization rating, and artificially inflate the potential savings (assuming that the drive needs to remain in place).

Units

Units **gpm, ft, hp** ▼



System of units choices indicate units of flow, head, and shaft power

gpm, ft, hp....U.S. gallons/minute, feet, horsepower

MGD,ft,hp....U.S. million gallons/day, feet, horsepower

L/s, m, kW....Liters/second, meters, kilowatts

m³/hr, m, kW....cubic meters/hour, meters, kilowatts

Kinematic viscosity (cS)

Kinematic viscosity (cS) **1.00**

This is the kinematic viscosity of the fluid being pumped, in centistokes.

This is used, in conjunction with algorithms from ANSI/HI 1.3-2000 to estimate reductions in achievable efficiency associated with elevated fluid viscosity.

Specific gravity

Specific gravity **1.000**

The fluid specific gravity is the ratio of the density of the fluid to water at standard conditions. It is used in calculating the fluid power at the specified pump flow rate and head conditions.

stages

stages **1**

The number of pump stages is used to calculate pump specific speed.

Fixed specific speed?

Fixed specific speed? NO YES

The Fixed specific speed switch allows the user to specify whether a specific speed penalty that is a part of the HI achievable efficiency algorithm sequence, is actually imposed.

The basic sequence of algorithms embodied in ANSI/HI 1.3, as implemented by PSAT to estimate the upper end of commercially available pump efficiency, is as follows:

- a) select a generally attainable efficiency for a specified pump style and flow rate (from curves included in the standard),
- b) determine the specific speed that corresponds to the specified flow rate, head, number of stages and speed data in the PSAT input section (note: the industry practice for pump specific speed determination is to specify the best efficiency conditions, so PSAT's field data based implementation is not consistent with standard convention, but it also avoids the need for the user to obtain the information - which generally would mean either going to performance curves and/or contacting the supplier),
- c) using an efficiency penalty vs specific speed curve from the standard, determine the applicable efficiency penalty and deduct it from this generally attainable efficiency,
- d) multiply the achievable efficiency by a positive deviation factor, which is a function of the specified flow rate, and
- e) adjust, as needed, for viscosity effects, again using curve-based algorithms from the standard.

If the configuration must remain constant (i.e., value = "YES"), the pump specific speed will be calculated, and a penalty to the achievable efficiency based on pump style and flow rate) will be applied if the calculated specific speed is outside of the optimal range. For example, if the nature of the service conditions dictated that it was not feasible to install a pump with an impeller shape (or shapes, in the case of multistage units) that corresponded to the optimal specific speed range, one would want to specify "YES" in order to avoid overstating the achievable efficiency.

On the other hand, if the pump physical design, such as operating speed or number of stages could be changed and still provide the specified flow rate and head values, select "NO", and no specific speed penalty will be deducted (i.e., in step c above the penalty is set to 0)..An example of this might be where a low specific speed, single stage pump is currently used in an application where a multistage unit could be used instead. The inherent result of making such a change (without changing the speed, flow rate or head conditions) would be to increase the calculated impeller specific speed. If making such a change was feasible, the user might want to allow PSAT to estimate the non-penalized achievable efficiency (by selecting "NO") to get a better indication of the potential improvement possibilities.

More information about specific speed and the efficiency effect (modeled using HI standard estimates) can be accessed using the "Background information" near the bottom of the panel. This is followed in succession by clicking the "Pump efficiency curves" and "See specific speed efficiency penalty plot" selections.

Motor section

Motor	Line freq.	60 Hz	Line freq.	50 Hz
	HP	200	145.0 kW	<<Spec
	Motor rpm	1780	Motor rpm	1480
	Eff. class	Energy efficient	Eff. class	Specified (below)
	Voltage	460	FL efficiency, %	95.8
	Estimate FLA		Voltage	380
	Full-load amps	225.4	Estimate FLA	
	Size margin, %	0	Full-load amps	266.0
			Size margin, %	0

Line frequency

Line freq. 50 Hz
 60 Hz

Line freq. 50 Hz

Line frequency is the mains supply frequency; choices are 50 Hz and 60 Hz. The only use of this input is to determine the number of motor poles, based on the specified motor speed. PSAT uses algorithms based on the number of motor poles, along with efficiency class and efficiency class, to establish the characteristic motor curves (efficiency, current, power factor vs. load)

Motor rated power (HP or kW)

HP 200

145.0 kW <<Spec

<<Spec

5

7.5

10

15

20

25

30

40

50

60

75

100

125

150

✓ 200

3

3.7

4

4.5

5.5

6

7.5

9.2

11

13

15

18.5

22

26

30

✓ <<Spec

The rated power is the nameplate (shaft output) power rating for the existing motor. Depending on the Units selected in the "Pump, fluid" section, the motor power rating will be either in horsepower (HP) or kilowatts (kW).

For the HP option, standard NEMA (MG-1) sizes from 5 hp and upwards will be available for selection. For the kW option, the preferred ratings from IEC 60072 are used up to 1000 kW. Above 1000 kW, the numerical values from the NEMA standard are used, simply because they reflect a reasonable span.

If the existing motor rating is a non-standard, or custom specified size, the user can select the first entry, "<<Spec". This will cause a box to appear to the left of the input menu list. The actual nameplate value can be typed in here. It should be noted that PSAT only chooses the standard sizes (as discussed above) for optimal motors.

Spec. motor is the nominal rated power for a motor that is not in the standard HP or kW listing (in the graphic above, the input value is 145.0 kW. This entry only appears when the motor size selected from the standard box is set to "<<Spec"

Motor rpm

Motor rpm

The motor nameplate speed and the line frequency are used to determine the number of motor poles. This, in turn, is used (along with the motor class and size) to estimate motor efficiency and output shaft power for the measured electrical power or current conditions. These estimates are based on curve-fitting algorithms developed for PSAT using average performance of motors in the specified class from the MotorMaster+ database and (for larger motors) other published manufacturer data.

Motor Efficiency class

Eff. class Eff. class

There are four basic efficiency classes of motors available in this menu list item: Standard efficiency, Energy efficient, Average, and user specified. In all cases, the selection applies to the existing motor ONLY. For the optimal case, PSAT selects an energy-efficient motor (the user has no choice in the selection).

The motor classification is based on how the motor rated efficiency compares with the NEMA MG 1-2003, Table 12-11 standard. If at or above the Table 12-11 Nominal Efficiency, the Energy efficient classification applies; if below, the Standard efficiency classification should be used. If unknown, the selection of Average results in the average of Standard efficiency and Energy efficient performance being used.

A value can also be specified if nameplate or other data sources are available to better inform the user.

The classification is used in estimating the motor efficiency and output power conditions for a given input power or current. It is also used to estimate full load current using the "Estimate FLA" button.

The performance of both HP- and kW-rated motors uses the same classification scheme, even though different standards apply. In the bigger scheme of things for pumping systems, the differences are insignificant.

Full Load (FL) efficiency, %

FL efficiency, %

The Full Load efficiency input only appears if the Motor Efficiency class selection is "Specified (below)".

In many respects, this is the preferred method for evaluating the existing operation, in that if the nameplate full load efficiency is available, it should provide a better reflection of the specific motor performance than would the values in the other three Motor Efficiency classifications, which are strictly based on the motor population statistical averages.

Motor rated voltage

Voltage

The nominal motor voltage is the motor design (nameplate) voltage. The Pumping System Assessment Tool develops load and efficiency estimates based on normalized characteristics for 460 volt rating from the MotorMaster+ database, supplemented by additional published data for large and slower speed motors from several motor manufacturers.

Since the normalized performance of motors is minimally affected by rated voltage, the 460 volt characteristic motor performance curve shapes are used for all nominal voltages. Efficiency as a percent of load is held constant; average current is adjusted inversely to the ratio of voltage.

Estimate Full Load Amps (FLA)

Estimate FLA

This button can be used to provide an estimate of full load amps (FLA) when nameplate information is not available. This estimate is based on average data for motors of the specified motor hp, class, voltage, and speed; hence those parameters must be selected before clicking this button. Motor data used in the algorithms was normalized 460 volt; if another voltage is selected when the full load amps initialization button is depressed, the FLA shown will be adjusted in a linear, inverse fashion to the existing voltage. For example, the average FLA for four-pole, 460-volt, premium efficiency, 25 hp motors in the database is 30.0 amps.

If the specified Nominal motor voltage is 230 volts, clicking on the FLA initialization button will cause a value of $(460/230) * 30.0 = 60.0$ amps to be used.

If the Nameplate FLA varies by more than 5% from the average FLA for the motor rated power, speed, voltage, and class, the Estimate button and the Nameplate FLA background color will turn yellow. This is a caution to the user that the FLA value is outside the expected range.

Full-load amps

Full-load amps

The nameplate full load amps (FLA) is used as a normalizing value if Current is the selected Load estimation method (see discussion in the Measured or required conditions section below).

If the FLA is not known, an estimate can be made by using the "Estimate" button at the left. Note that the correct Nominal motor voltage, hp, and speed should be entered before the FLA initialization button is depressed.

If the Nameplate FLA varies by more than 5% from the average FLA for the motor rated power, speed, voltage, and class, the Estimate button and the Nameplate FLA background color will turn yellow. This is a caution to the user that the FLA value is outside the expected range.

Size margin, %

Size margin, %

This size margin is added to the motor selected for the optimal application. If 90 shaft hp is required for a pump operating optimally at the specified hydraulic conditions, and a 15% margin is specified, PSAT will assume that the motor rating will be the next size larger. Since $90 \times 1.15 = 103.5$, a 125 hp motor would be selected. If a 10% margin had been specified, a 100 hp motor would have been selected, since $90 \times 1.10 = 99$.

Duty, unit cost section

Duty, unit cost	Operating fraction	1.000
	\$/kwhr	0.0500

Operating fraction

Operating fraction

This is simply the fraction of the calendar hours that the equipment is operating at the specified conditions. It is used in calculating the annual cost results.

\$/kwhr (electric energy unit cost rate)

\$/kwhr

This is the per unit energy cost of electricity.

Demand charges, power factor-related penalties, and other issues can have a significant impact on the average per unit energy cost. Factors such as the time and amount of use, existing power factor, etc., would need to be considered in a detailed analysis.

For most purposes, the simplest approach is to simply divide the monthly (or preferably annual) electric energy cost by the corresponding period's energy consumption, both of which are normally included in electric bills.

Field data section

Field data	Flow rate, gpm	2000	
	Head tool	Head, ft	277
	Load estim. method	Power	
	Motor kW	150.0	
	Voltage	460	

Flow rate (gallons per minute, million gallons/day, Liters/second, or cubic meters/hour)

Flow rate, gpm Flow rate, MGD Flow rate, L/s
Flow rate, m³/h

Either the measured or the required flow rate in units that are consistent with the selection in the "Pump, fluid" section above is input here.

The flow rate value is used by the software to calculate the fluid power (which is in turn used to estimate existing pump efficiency) and to estimate the optimal pump operating efficiency.

PSAT uses curve fit algorithms which extend beyond the HI curve limits, so efficiency estimates will be made for all entries. If the specified flow rate is outside of the HI standard range limits, the background color will turn orange as a caution to the user.

Head (ft or m)

Head, ft Head, m

Either the measured or the required pump head in feet (or meters) is specified here.

Head, flow rate, and specific gravity are used to calculate fluid power for the Existing condition. When combined with the estimated shaft power for the existing condition (which is based on the measured electrical data and the specified motor nameplate information), the existing pump efficiency can be determined.

To assist in calculating measured pump head, the "Head tool" button to the left of the head input box can be clicked to bring up a head calculation panel.

Head tool button

This button is used to access a pump head calculation panel where the user specifies measured pressure, elevation, flow rate, and line size data to calculate the head developed by the pump.

The head calculated in the routine can be returned to the primary panel (for the Condition from which the head calculator was selected), or canceled, leaving the primary panel unaffected.

Load estimation method

Load estim. method Load estim. method

There are two choices of load estimation methods: Power and Current; both refer to the values at the motor input.

The preferred load estimation method is power. If input power is accurately measured, the estimate of both pump and motor efficiencies will likely be more accurate than if current alone is measured.

If a power measurement is not practical, current can be used, along with algorithms built into PSAT, to estimate input power. The power estimate from current is made based on curve fits of the average motor current vs. load profile for the specified motor size, class, and speed. Experience has shown that for motors loaded to 50% of their rating or greater, the electrical power estimated by the PSAT current-based estimates will generally agree with actual power to within a few percent. However, for lightly loaded motors (e.g., 25% load), the error can be much greater. Fortunately, the vast majority of pump applications have motors that are loaded to greater than 50% of their rating.

Motor kW or Motor amps

Motor kW

Motor amps

Either Motor kW (power) or Motor amps (current) will be displayed, depending on the Load estimation method selected. Power is the preferred measurement, but unless a permanently-installed power meter is available, is much more intrusive and challenging.

The measured current is needed if power cannot be measured. If possible, the value entered should be the average current among the three phases. Use of current to estimate input power or load is not ideal. As noted above, if current is used as the load estimation method, the measured current is compared to the average current vs. load and efficiency vs. load curves for the specified motor size, speed, and class to estimate the motor's electrical input and mechanical output powers.

The current estimating method should NOT be used if adjustable frequency drives are used. PSAT's algorithms are based on motor performance for direct, across-the-line applications. Adjustable frequency drive power may be used, but the user should recognize that losses in the drive and increased losses in the motor are not accounted for by PSAT.

Another caution relative to current measurements: If power factor correction capacitors are in use, be sure the measured current is that to the motor, not to the combination of the motor and the capacitor bank (which will be lower than the motor current).

Voltage

Voltage

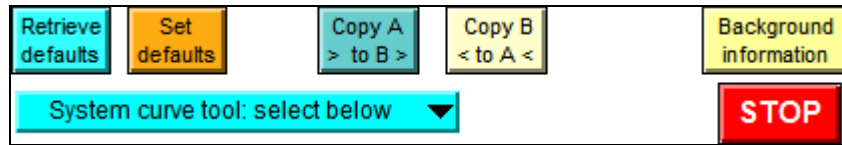
The measured bus voltage is used, along with measured current, to estimate input motor power if Current is the specified Load estimation method. If Power is the Load estimation method, the current is estimated from power and voltage.

A simple algorithm based on a combination of sources is used to adjust for over/under voltage. The algorithm assumes that at 100% of rated load, current drops 1% for every 1% increase in voltage (or vice-versa at reduced voltage). At the other end of the load scale - no load, the algorithm assumes that current increases 1% for every 1% increase in voltage (and vice-versa at reduced voltage). The relationship is assumed linear with load, so that at 50% load, current is assumed to be unaffected by voltage.

It is recognized that such a simplistic algorithm cannot accurately capture response of all motors. Nevertheless, it is believed to be reasonably representative within the normal range of voltage deviation seen in industrial applications, and has been used with good success on a number of motors in actual field service.

If there is greater than 10% between measured and nominal motor voltage, the measured voltage box background color will change to yellow as a flag to alert the user to likely input error.

Common area controls



Retrieve defaults



Clicking this button will set the entire panel back to the default values, which the user can set using the button labeled "Set defaults". This arrangement allows the user to specify standard electrical cost rate data, facility and evaluator names, etc.

Note that another way of establishing multiple default values is to simply create a dedicated log (using the Log file controls) and store different setups. This provides more flexibility, but also involves additional steps.

Set defaults



Clicking this button will make the currently displayed data the default configuration. The default configuration will automatically load each time PSAT is started. It can also be retrieved at any time by clicking the "Retrieve defaults" button to the left.

When the "Set defaults" button is clicked, the user will be prompted to verify that the default values are to be changed.

This arrangement allows the user to specify standard electrical cost rate data, units, facility and evaluator names, etc. that will be automatically loaded.

Note that another way of establishing multiple default values is to simply create a dedicated log (using the Log file controls) and store different setups. This provides more flexibility, but also involves additional steps.

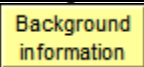
Copy A to B, Copy B to A



These buttons are used to copy all of the data from "Condition A" to the "Condition B" (or vice-versa).

This includes supporting, hidden data, including head calculation inputs and system curve data.

Background information



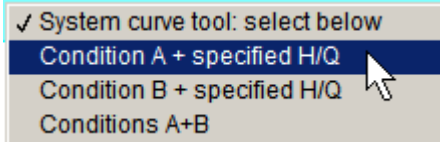
This button is used to access background information about the operation of this software, motor, pump, and system efficiency considerations, and discussions of other points of interest relative to pumping system optimization, including distinguishing between measured and required conditions.

A prescreening section provides suggestions for activities and approaches to consider before spending the time and effort to acquire the data needed by PSAT.

A link to a units-converter tool is also provided.

System curve tool menu bar

System curve tool: select below ▼



For systems which deliver flow to a single location or to multiple locations with essentially identical, parallel paths, a system curve can be estimated from any two measured flow rate/head conditions (provided that the system configuration remains unchanged).

More information about system curve development can be found on the System curve panel, which is triggered by selecting any of the three options listed in the drop-down menu. For the first selection, "Condition A + specified H/Q", the head/flow data from Condition A will be transferred to the system curve panel, where the user will need to enter another system head/flow point for the system curve to be drawn.

The same pattern applies to "Condition B + specified H/ Q."

For the third entry, "Conditions A+B", the flow and head values from both entries will be used to construct the system curve, with no additional information required from the user.

Obviously, the units will need to be consistent for proper curve development.

STOP button



The STOP button can be used to temporarily suspend program calculations and updating. This may improve processor speed when the user wants to work in another application without quitting the PSAT application. Clicking on this button will stop program updating, but not quit the application.

Note that the STOP button only appears when the program is actively updating, and will disappear after clicking, being replaced by a box alerting the user that "Calculation updating is off."

To resume calculations, click on the arrow just below the Edit menu in the upper left corner of the screen. The STOP button will reappear after clicking the arrow, reminding the user that the program is continuously updating calculated results.

The preferred method for exiting the PSAT program is to first click this STOP button and then close the program by clicking on the standard window close button at the upper right.

Calculation updating is off alert box

Calculation updating is off.
Click the arrow below the
edit menu to restart.

This is simply a status advisory, noting that PSAT's calculations have been stopped. When this box is visible, changes to inputs can be made, but the results will not be updated until updating is restarted by clicking the arrow below the Edit menu.

Run arrow



PSAT's Run arrow appears just below the Edit menu. When PSAT calculation updating is live, the STOP button will be displayed and the run arrow will be black. If the STOP button is depressed, PSAT calculation updating will halt, the "Calculation updating is off" alert box will appear, and the Run arrow will change to white. To start PSAT running again, click on the white run arrow.

Results section

	Condition A			Condition B		
	Existing	Optimal	Units	Existing	Optimal	Units
Pump efficiency	72.6	84.8	%	72.5	85.0	%
Motor rated power	200	200	hp	150	132	kW
Motor shaft power	192.4	164.8	hp	143.8	122.7	kW
Pump shaft power	192.4	164.8	hp	143.8	122.7	kW
Motor efficiency	95.7	95.8	%	95.9	95.6	%
Motor power factor	86.7	85.7	%	86.4	86.4	%
Motor current	217.1	188.2	amps	217.9	186.4	amps
Motor power	150.0	128.4	kW	150.0	128.3	kW
Annual energy	1314.0	1125.1	MWh	1314.0	1124.1	MWh
Annual cost	65.7	56.3	\$1000	65.7	56.2	\$1000
Annual savings potential, \$1,000						
	9.4			9.5		
Optimization rating, %	85.6			85.5		

Pump efficiency

	Existing	Optimal	Units
Pump efficiency	72.6	84.8	%

Existing

Existing pump efficiency is fluid power added by the pump divided by pump input shaft power.

Fluid power added by the pump is calculated from the product of the flow rate, head, and specific gravity. Shaft power is estimated using measured electrical data and PSAT's motor efficiency vs load curves.

Optimal

Optimal pump efficiency is estimated based on the efficiency estimating algorithms contained in Hydraulic Institute Standard HI 1.3-2000, Centrifugal Pump Design and Application.

The efficiency value used in PSAT includes the positive deviation from "generally attainable efficiency" shown in HI 1.3 Figures 1.76A and 1.76B.

Motor rated power

	Existing	Optimal	Units
Motor rated power	200	200	hp

Existing

Existing motor nameplate power (same as Rated power in the Motor input section)

Optimal

This is the nameplate motor rated power for an optimally sized pump.

PSAT uses the calculated fluid power and optimal pump efficiency to determine the optimal pump input shaft power. For a direct-driven pump, this is the same as the motor shaft power. If a belt drive is specified, belt losses are accounted for, so the required motor shaft power will be greater.

The size margin specified in the Motor input section is added to the required motor shaft power. Using the resultant value, PSAT selects the next largest standard motor size.

Motor shaft power

	Existing	Optimal	Units
Motor shaft power	192.4	164.8	hp

Existing

This is the estimated motor shaft power for the existing motor. The estimate is based on measured electrical data and PSAT's efficiency estimate for the specified motor size, speed, and class.

Optimal

This is the motor shaft power requirements for the optimal pump, based on the specified flow rate, head, and specific gravity values, along with the HI 1.3 achievable efficiency algorithms. If a belt drive is specified, associated losses are added to the pump shaft power to determine required motor power. For direct-driven pumps, the pump and motor shaft powers are the same.

Pump shaft power

	Existing	Optimal	Units
Pump shaft power	192.4	164.8	hp

Existing

This is the estimated pump shaft power for the existing motor. The estimate is the same as the motor shaft power (above) for direct-driven applications. For belt-driven applications, belt losses are deducted from the motor shaft power to determine pump shaft power.

Optimal

This is the shaft power requirements for the optimal pump, based on the specified flow rate, head, and specific gravity values, along with the HI 1.3 achievable efficiency algorithms.

Motor efficiency

	Existing	Optimal	Units
Motor efficiency	95.7	95.8	%

Existing

This is the estimated efficiency of the existing motor at the existing load.

Optimal

This is the estimated efficiency for an energy-efficient motor of the size indicated in the Optimal Motor rated power entry above when operating at the Optimal Motor shaft power (also indicated above).

Motor power factor

	Existing	Optimal	Units
Motor power factor	86.7	85.7	%

Existing

This is the estimated power factor for the existing motor at the existing load. It is based on the measured electrical data and the motor performance characteristic curves for the specified motor.

Optimal

This is the estimated power factor for an energy-efficient motor of the size indicated in the Optimal Motor rated power entry above when operating at the optimal motor shaft power (also indicated above).

Motor current

	Existing	Optimal	Units
Motor current	217.1	188.2	amps

Existing

This is the estimated or measured current for the existing motor at the existing load.

Optimal

This is the estimated current for an energy-efficient motor of the size indicated in the Optimal Motor rated power entry above when operating at the optimal motor shaft power (also indicated above).

Motor power

	Existing	Optimal	Units
Motor power	150.0	128.4	kW

Existing

This is the estimated or measured electric power for the existing motor at the existing load.

Optimal

This is the estimated electric power for an energy-efficient motor of the size indicated in the Optimal Motor rated power entry above when operating at the optimal motor shaft power (also indicated above).

Annual energy

	Existing	Optimal	Units
Annual energy	1314.0	1125.1	MWh

Existing

This is the annual energy consumption at the measured/estimated power level for the existing equipment when operated for the fraction of time indicated in the Operating fraction at left.

Optimal

This is the annual energy consumption for an optimized pump driven by an energy-efficient motor, based on the estimated Motor power (above) and on the fraction of time the pump is operated (see Operating fraction at left).

Annual cost

	Existing	Optimal	Units
Annual cost	65.7	56.3	\$1000

Existing

This is the existing annual energy cost based on the product of the Existing annual energy consumption (above) and the unit operating cost (cents/kwhr) input.

Optimal

This is the existing annual energy cost based on the product of the Optimal annual energy consumption (above) and the unit operating cost (cents/kwhr) input.

Annual savings potential, \$1,000

Annual savings potential, \$1,000 9.4

This is the potential annual savings, in thousands of dollars if the existing equipment was replaced with equipment that performed consistent with that indicated for the Optimal case above.

It is the difference in the Annual cost for the Existing and Optimal cases.

Optimization rating, %

Optimization rating, % 85.6

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:

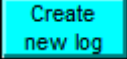
- >100: Dark Blue
- 90-100: Green
- 80-90: Olive
- 70-80: Yellow
- 60-70: Orange
- <60: Red

Log and summary files controls section

Log file controls:

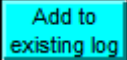
Summary file controls:
Existing summary files:

Create new log button



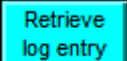
Click on this button to create a new data log with the existing information. The data will then be available for subsequent retrieval using the "Retrieve Log" button.

Add to existing log button



Click on this button to add the currently displayed data to an existing log file. You will be prompted to identify the log file to which the data will be added. Note: the file is not overwritten – it is supplemented with the currently displayed information. The data will then be available for subsequent retrieval using the "Retrieve Log" button.

Retrieve log entry

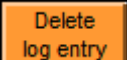


Click on this button to retrieve previously logged data. You will be prompted to locate the file that the data is stored in. If there is more than one logged data set in the file, you will then see a listing of available logs from which to select, such as shown below. Click the numbered red button to the left of the text section, which includes information entered into the Documentation section. Adequate annotation of an analysis is clearly important to the retrieval process.

Log entry

1	Condition A: Facility: AAA System: BBB Application: CCC Comments: Notes for condition A go here Date: Oct 01/2007 Evaluator: DDD Condition B: Facility: EEE System: FFF Application: GGG Comments: Notes for condition B go here Date: Oct 02/2007 Evaluator: HHH
2	Condition A: Facility: III System: JJJ Application: KKK Comments: Notes for condition A go here Date: Oct 01/2007 Evaluator: LLL Condition B: Facility: MMM System: NNN Application: OOO Comments: Notes for condition B go here Date: Oct 02/2007 Evaluator: PPP
3	Condition A: Facility: QQQ System: RRR Application: SSS Comments: Notes for condition A go here Date: Oct 01/2007 Evaluator: TTT Condition B: Facility: UUU System: VVV Application: WWW Comments: Notes for condition B go here Date: Oct 02/2007 Evaluator: XXX

Delete log entry



Click on this button to be prompted to select the log file from which a log entry will be deleted; once the file is selected, you will be shown all existing logs from which you can select one for deletion.

After deleting the log (or canceling log deletion), you'll be returned to this window, and you can then repeat the sequence to delete a different entry.

Write summary file

Create new summary file	Existing summary files CREATE NEW
Append existing summary file:	Existing summary files Example 2007 summary

The Write summary file button and Existing summary files drop down menu list are related chameleons, in that both have two different labels and colors. The label and color are dependent on the item selected in "Existing summary files".

If the Existing summary files menu selection is "CREATE NEW", the button will be labeled Create new summary file, and the background color for both will be white. If any existing summary file is selected (such as "Example 2007 summary"), the button will be labeled Append existing summary file, and the background color for both will be light blue.

If creating a new summary file, the user will be prompted to locate and name the file. The default location for summary files is in the "Summary files" folder, located in the PSAT main folder. Only summary files saved to this location will be displayed in the Existing summary files listing. Summary files can be saved elsewhere, but will not be available for appending.

A summary file is in a tab-delimited spreadsheet format. It can be opened with Excel or other spreadsheet program, and it can also be opened with any text-editing or word processing program.

Documentation section

Condition A Notes			Documentation section		
Facility	<input type="text"/>	System	<input type="text"/>	Date	<input type="text"/>
Application	<input type="text"/>			Evaluator	<input type="text"/>
General comments					
<input type="text"/>					
Condition B Notes					
Facility	<input type="text"/>	System	<input type="text"/>	Date	<input type="text"/>
Application	<input type="text"/>			Evaluator	<input type="text"/>
General comments					
<input type="text"/>					

The documentation section includes several text boxes with relatively straightforward titles. The purpose of this section is, as the name implies, to simply record information that is useful in identifying the pumping system being evaluated, when the data was acquired, assumptions made, who did the analysis, etc. There is no requirement to complete any of the boxes, but if the analysis is to be logged for subsequent retrieval, it is an excellent idea to complete this section.

Note that the General comments entry includes a scroll bar. This allows the user to provide as much information as is desired concerning assumptions, methods, circumstances, etc., as desired.

Pump head calculation panel: with suction and discharge pressure gauges

The pump head calculation panel provides two types of configurations to help the user calculate operating pump head. The configuration below is for situations where both suction and discharge pressure measurements can be made.

Type of measurement configuration

Suction and discharge line pressures ▼

K_s represents all suction losses from gauge P_s 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) ▲▼	12.000	inches	Discharge pipe diameter (ID) ▲▼	10.000	inches
Suction gauge pressure (P_s) ▲▼	5.00	psig	Discharge gauge pressure (P_d) ▲▼	124.00	psig
Suction gauge elevation (Z_s) ▲▼	5.00	ft	Discharge gauge elevation (Z_d) ▲▼	5.00	ft
Suction line loss coefficients, K_s ▲▼	0.50		Discharge line loss coefficients, K_d ▲▼	1.00	

Fluid specific gravity ▲▼

1.000

Flow rate ▲▼

2000.00

gpm

Don't update

Click to
leave the main panel
head unchanged

Accept and update

Click to
Accept and return
the calculated head

Differential elevation head	0.00	ft
Differential pressure head	274.99	ft
Differential velocity head	0.54	ft
Estimated suction friction head	0.25	ft
Estimated discharge friction head	1.04	ft
Pump head	276.81	ft

System of units: gpm, ft, hp

Important note about loss coefficients

The loss coefficients used here apply to the velocity head in the line size represented by the suction and discharge pipe diameters at the points of pressure measurement.

If the loss elements are in different size lines than the points of pressure measurement, they need to be appropriately scaled. It is generally suggested that the losses be scaled in proportion to the 4th power of the diameter ratio. For example, if the discharge pressure is measured in a 12-inch header, and there is a 6-inch check valve with a nominal loss coefficient of 2 (applied to the 6-inch valve size), the K factor to use for the valve would be $2 \times (12/6)$ to the 4th power, or 32. The reason for this 4th power scaling is that the velocity varies with the square of the pipe diameter, and the velocity head (to which the loss coefficients apply) is proportional to the velocity squared.

Pump head calculation panel: with suction tank elevation and discharge pressure

The configuration below is for situations where the suction pressure is not available, but suction tank (or well) level is.

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

Suction pipe diameter (ID)	<input type="text" value="12.000"/>	inches	Discharge pipe diameter (ID)	<input type="text" value="10.000"/>	inches																		
Suction tank gas overpressure (P_g)	<input type="text" value="0.00"/>	psig	Discharge gauge pressure (P_d)	<input type="text" value="124.00"/>	psig																		
Suction tank fluid surface elevation (Z_s)	<input type="text" value="10.00"/>	ft	Discharge gauge elevation (Z_d)	<input type="text" value="5.00"/>	ft																		
Suction line loss coefficients, K_s	<input type="text" value="0.50"/>		Discharge line loss coefficients, K_d	<input type="text" value="1.00"/>																			
Fluid specific gravity		<input type="text" value="1.000"/>	Flow rate		<input type="text" value="2000.00"/>																		
<input type="button" value="Don't update"/> <input type="button" value="Accept and update"/>		<table border="0"> <tr> <td>Differential elevation head</td> <td><input type="text" value="-5.00"/></td> <td>ft</td> </tr> <tr> <td>Differential pressure head</td> <td><input type="text" value="286.54"/></td> <td>ft</td> </tr> <tr> <td>Differential velocity head</td> <td><input type="text" value="1.04"/></td> <td>ft</td> </tr> <tr> <td>Estimated suction friction head</td> <td><input type="text" value="0.25"/></td> <td>ft</td> </tr> <tr> <td>Estimated discharge friction head</td> <td><input type="text" value="1.04"/></td> <td>ft</td> </tr> <tr> <td>Pump head</td> <td><input type="text" value="283.86"/></td> <td>ft</td> </tr> </table>				Differential elevation head	<input type="text" value="-5.00"/>	ft	Differential pressure head	<input type="text" value="286.54"/>	ft	Differential velocity head	<input type="text" value="1.04"/>	ft	Estimated suction friction head	<input type="text" value="0.25"/>	ft	Estimated discharge friction head	<input type="text" value="1.04"/>	ft	Pump head	<input type="text" value="283.86"/>	ft
Differential elevation head	<input type="text" value="-5.00"/>	ft																					
Differential pressure head	<input type="text" value="286.54"/>	ft																					
Differential velocity head	<input type="text" value="1.04"/>	ft																					
Estimated suction friction head	<input type="text" value="0.25"/>	ft																					
Estimated discharge friction head	<input type="text" value="1.04"/>	ft																					
Pump head	<input type="text" value="283.86"/>	ft																					
<input type="button" value="Click to leave the main panel head unchanged"/> <input type="button" value="Click to Accept and return the calculated head"/>																							

System of units: **gpm, ft, hp**

Important note about loss coefficients

The loss coefficients used here apply to the velocity head in the line size represented by the suction and discharge pipe diameters at the points of pressure measurement.

If the loss elements are in different size lines than the points of pressure measurement, they need to be appropriately scaled. It is generally suggested that the losses be scaled in proportion to the 4th power of the diameter ratio. For example, if the discharge pressure is measured in a 12-inch header, and there is a 6-inch check valve with a nominal loss coefficient of 2 (applied to the 6-inch valve size), the K factor to use for the valve would be $2 \times (12/6)$ to the 4th power, or 32. The reason for this 4th power scaling is that the velocity varies with the square of the pipe diameter, and the velocity head (to which the loss coefficients apply) is proportional to the velocity squared.

Descriptions of the individual controls and indicators on the head panel follow.

Type of measurement configuration

Type of measurement configuration

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

The selection of measurement configuration is made by the popup menu near the top of the panel. The graphic underneath the menu changes to provide a graphical indication of the selected configuration, as illustrated below. Shown immediately below the graphic is the list of suction side inputs which correspond to the selected configuration.

Type of measurement configuration

Suction and discharge line pressures

K_s represents all suction losses from gauge P_s to the pump
 K_d represents all discharge losses from the pump to gauge P_d

Suction pipe diameter (ID)	12.000	inches
Suction gauge pressure (P_s)	5.00	psig
Suction gauge elevation (Z_s)	5.00	ft
Suction line loss coefficients, K_s	0.50	

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

Suction pipe diameter (ID)	12.000	inches
Suction tank gas overpressure (P_g)	0.00	psig
Suction tank fluid surface elevation (Z_s)	10.00	ft
Suction line loss coefficients, K_s	0.50	

If an input only appears under one of the two types of measurement configurations, it will be so noted in italics to the right of the heading in the **Input data section** descriptions that follow.

Pump head panel input data section

Suction pipe diameter (ID)

Suction pipe diameter (ID) inches

Suction pipe inside diameter in inches or mm. This is used to calculate the fluid velocity in the suction pipe, which in turn is used to determine the suction velocity head.

Suction gauge pressure (Ps) – Suction and discharge line pressure configuration

Suction gauge pressure (Ps) psig

Suction gauge pressure in psig or kPa

Suction tank gas overpressure (Pg) – Suction tank elevation, gas space pressure, and discharge line pressure configuration

Suction tank gas overpressure (Pg) psig

This is the gas overpressure in the suction tank in psig or kPa. If the tank (or well, lake, etc.) is open to atmosphere, the gauge pressure should be set to 0.

Suction gauge elevation (Zs) – Suction and discharge line pressure configuration

Suction gauge elevation (Zs) ft

Suction gauge elevation in feet or meters, relative to a common reference point elevation.

This reference can be absolute (e.g., sea level), or relative (e.g., floor level). However, the same reference elevation must be used in defining the discharge gauge elevation.

Suction tank fluid surface elevation (Zs) – Suction tank elevation, gas space pressure, and discharge line pressure configuration

Suction tank fluid surface elevation (Zs) ft

This is the elevation of the tank (or well, lake, etc.) relative to a common reference point elevation in either feet or meters.

This reference can be absolute (e.g., sea level), or relative (e.g., floor level). However, the same reference elevation must be used in defining the discharge pressure gauge elevation.

Suction line loss coefficients, Ks

Suction line loss coefficients, Ks

The suction line loss coefficients are used to estimate the frictional head losses between the suction reference point (tank level or suction line pressure gauge) and the pump suction flange. Note that these coefficients apply to the Darcy-Weisbach style calculation ($\text{loss} = K \times \text{velocity head}$).

These losses might come from elbows, tees, suction isolation valve, etc., and in the situation where the suction tank level is used as a reference, the entrance loss from the tank to the pipe.

IMPORTANT: All losses must be normalized to the specified suction pipe diameter, and loss coefficient adjustments are made to the 4th order of the pipe diameter ratio. For example, if there is a 12-inch isolation valve with a loss coefficient (K) of 0.4, but the suction pipe diameter at the point where pressure is measured is 16-inches - such as in a suction header - the loss coefficient for the valve would be $0.4 \times (16/12)^4$, or 1.26.

Note: the fact that the word “coefficients” is plural is intentional – it is intended to account for the sum of all suction line loss elements.

Discharge pipe diameter (ID)

Discharge pipe diameter (ID) inches

Discharge pipe inside diameter in inches or mm. This is used to calculate the fluid velocity in the discharge pipe, which in turn is used to determine the discharge velocity head.

Discharge gauge pressure (Pd)Discharge gauge pressure (Pd) psig

Discharge gauge pressure in psig or kPa

Discharge gauge elevation (Zd)Discharge gauge elevation (Zd) ft

Discharge gauge elevation in feet or meters, relative to a common reference point elevation.

This reference can be absolute (e.g., sea level), or relative (e.g., floor level). However, the same reference elevation must be used in defining the suction gauge elevation.

Discharge line loss coefficients, KdDischarge line loss coefficients, Kd

The discharge line loss coefficients value is used to estimate the frictional head losses between the pump discharge flange and the discharge pressure gauge. Note that these coefficients apply to the Darcy-Weisbach style calculation (loss = $K \times \text{velocity head}$).

These losses might come from elbows, tees, discharge isolation valve, check valve, etc., but can also come from pipe (or discharge column, in the case of vertical turbine pumps) friction, especially if the discharge pressure is measured at a considerable distance from the pump. The user should adjust the loss K to account for pipe friction. To do this, look up estimated losses from loss tables, then adjust the loss K such that the increase in friction head accounts for the pipe losses.

IMPORTANT: All losses must be normalized to the specified discharge pipe diameter, and loss coefficient adjustments are made to the 4th order of the pipe diameter ratio. For example, if there is an 8-inch swing check valve with a loss coefficient (K) of 2, but the discharge pipe diameter at the point where pressure is measured is 16-inches - such as in a discharge header - the loss coefficient for the valve would be $2 \times (16/8)^4$, or 32.

Note: the fact that the word “coefficients” is plural is intentional – it is intended to account for the sum of all discharge line loss elements.

Fluid specific gravityFluid specific gravity

Specific gravity of the fluid

Note: this value is brought over from the main PSAT panel. It can be changed here in the head calculator panel. If it is changed, the modified value will be returned along with the calculated head (if the “Click to Accept and return the calculated head” button is clicked).

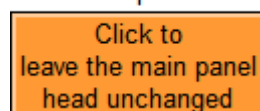
Flow rateFlow rate gpm

Pump flow rate in the indicated units (which are based on those selected on the main PSAT panel).

Note: this value is brought over from the main PSAT panel. It can be changed here in the head calculator panel. If it is changed, the modified value will be returned along with the calculated head (if the “Click to Accept and return the calculated head” button is clicked).

Don't update button

Don't update



Click this button to return to the main panel without updating the main panel flow rate, head, and specific gravity values.

Accept and update button

Accept and update

Click to
Accept and return
the calculated head

Click this button to return the above specified flow rate and specific gravity values and the calculated head (at right). The main panel will be updated to reflect these values. If the main panel is subsequently logged, all of the information on the head calculator panel (line sizes, gauge elevations, etc.) will be retained with the logged analysis.

Differential elevation head

Differential elevation head ft

This is the difference in elevation between the suction and discharge reference points.

In the case where a tank level is used, the elevation difference will be the elevation of the discharge pressure gauge minus the tank fluid surface elevation.

In the case where both suction and discharge gauges are used, the elevation difference will be the elevation of the discharge gauge minus the elevation of the suction gauge.

Differential pressure head

Differential pressure head ft

The differential pressure head is the difference between the suction and discharge pressures, converted to units of feet or meters for the specified specific gravity.

Differential velocity head

Differential velocity head ft

The differential velocity head is the discharge velocity head minus the suction velocity head.

Velocity head = $V^2/2g$

In the case where the suction tank level is used as a reference point, the differential velocity head will be identical to the discharge velocity head, since it is assumed that the tank is sufficiently large that the fluid velocity will be essentially zero.

If the suction and discharge line sizes are identical, the differential velocity head will be zero, since the velocity head in the two lines will be identical.

Estimated suction friction head

Estimated suction friction head ft

This is an estimate of the friction losses in the suction line (from the suction reference point to the pump), based upon the calculated velocity head and the specified loss coefficients. The friction loss in feet or meters is:

$$H_{fs} = K_s \times V^2/2g$$

Estimated discharge friction head

Estimated discharge friction head ft

This is an estimate of the friction losses in the discharge line (from the pump to the discharge gauge), based upon the calculated velocity head and the specified loss coefficients. The friction loss in feet or meters is:

$$H_{fd} = K_d \times V^2/2g$$

Pump head

Pump head ft

This is the total pump head, including elevation, pressure, velocity components plus the estimated suction and discharge friction losses.

System curve panel

System head curve input data

Fluid specific gravity

System loss exponent, C

	Flow rate	Head	Fluid power, hp
Point 1	<input type="text" value="2000"/>	<input type="text" value="277.2"/>	<input type="text" value="140.0"/>
Point 2	<input type="text" value="0"/>	<input type="text" value="100.0"/>	<input type="text" value="0.0"/>
Alternate	<input type="text" value="900"/>	<input type="text" value="138.9"/>	<input type="text" value="31.6"/>

Calculated static head

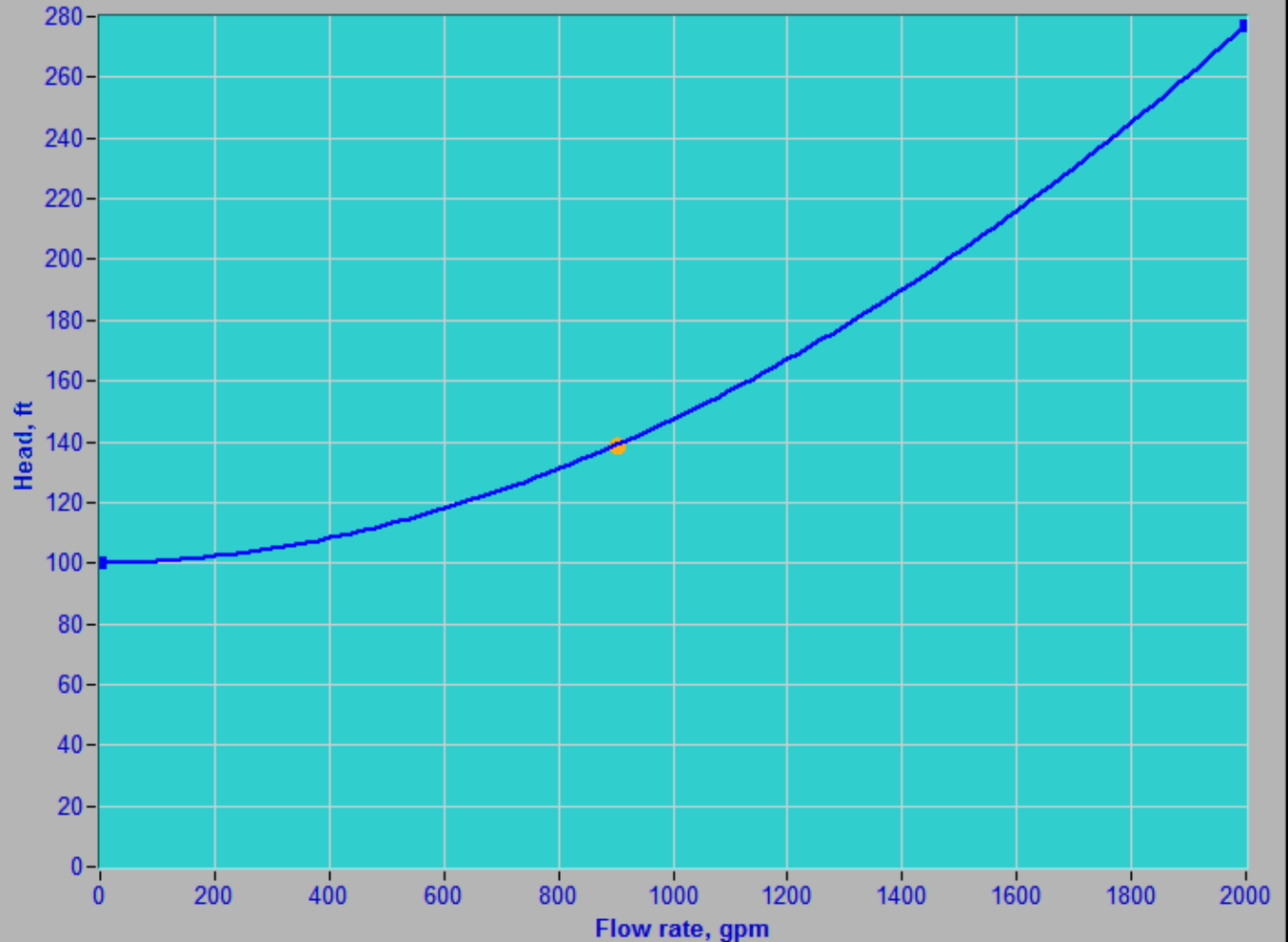
Calculated K' (loss coefficient)

Retain system curve and return to PSAT

Ignore changes, return to PSAT

Export curve info to spreadsheet

System curve source



Flow, head data

Simple system curve

Alternate duty

Curve basis

$H = H_s + K'Q^c$ where
 $H =$ Total head $H_s =$ Static head
 $K' =$ Loss coefficient $Q =$ Flow rate
 $c =$ dynamic/friction loss exponent

Note 1: K' here applies to the volumetric flow rate, not the velocity head
 Note 2: This simple system method does not apply to complex distribution systems where flow is delivered to multiple elevation or pressure zones.

System curve element descriptions

Specific gravity

Fluid specific gravity

The fluid specific gravity is initially set to the value specified on the main PSAT panel, but can be changed here.

The specific gravity does not affect the system head curve, but does affect the fluid power, which is directly proportional to the specific gravity.

System loss exponent, C

System loss exponent, C

The system friction loss exponent is the exponent to which the flow rate is raised in developing friction loss estimates. While the Darcy-Weisbach equation, as applied to both pipe and fittings, indicates an exponent of 2 proportionality, the fact that the friction factor declines slightly with increasing Reynolds number causes the net effect to be slightly less than an exponent of 2.

The difference is generally not significant. You might want to experiment with exponents ranging from 1.8 to 2.0 to see how the system head curve changes.

Point 1 conditions

	Flow rate	Head	Fluid power
Point 1	<input type="text" value="2000"/>	<input type="text" value="276.8"/>	<input type="text" value="139.8"/>

The Point 1 flow rate and head values are initially specified based on data passed from the main PSAT panel. Depending upon which system curve source is used, the initial values will be:

Condition A + user specified: Condition A flow, Condition A head
Condition B + user specified: Condition B flow, Condition B head
Condition A + Condition B: Condition A flow, Condition A head

The fluid power for point 1 is calculated from the product of the flow rate, head, and specific gravity, and is reported in either hp or kW, depending on the system of units from the main PSAT panel.

Point 2 conditions

	Flow rate	Head	Fluid power, hp
Point 2	<input type="text" value="0"/>	<input type="text" value="100.0"/>	<input type="text" value="0.0"/>

If the Condition A + Condition B selection was made on the main PSAT panel, the flow rate shown here will be the value from Condition B. Otherwise, the user can specify another flow and head data pair to develop the system curve. In many cases, this will be the system static head, with the flow rate = 0.

Alternate duty point

	Flow rate	Head	Fluid power, hp
Alternate	<input type="text" value="900"/>	<input type="text" value="138.9"/>	<input type="text" value="31.6"/>

To see the head for any flow rate on the system curve, type the flow rate value in the Alternate entry. The head for that point will be calculated from the system curve, displayed along side of it, and marked on the curve (orange circle). The associated fluid power will also be displayed.

System static head and K' loss coefficient

Calculated static head

Calculated K' (loss coefficient)

Both the system static head and the K' loss coefficient are determined from the combination of supplied Point 1 and Point 2 flow and head values, the loss exponent C, and the general curve characteristic $H(Q) = H_s + K'Q^C$

Retain system curve button

Retain system
curve and
return to PSAT

Clicking this button will return the user to the main PSAT panel. It will also result in the curve data being retained in PSAT. If the main panel is subsequently logged, the system curve information will be stored within the log.

Ignore changes button

Ignore changes,
return to PSAT

Clicking this button will return the user to the main PSAT panel, but without modifying the system curve information.

Export to spreadsheet button

Export curve info
to spreadsheet

This button is used to export the parameters needed to construct the curve (static head, the K' loss coefficient, and the System loss exponent C) to a tab-delimited text file. That will allow the user to construct a system curve in a spreadsheet or other numerical processing program.

System curve source indicator

System curve source

Condition A + user specified

This is an indicator that reports the selection made by the user on the main PSAT panel that led to this system curve panel.

Inconsistent flow units warning

Mismatched units from main PSAT panel

WARNING! This panel will close in 5 seconds.

You elected to send the head and flow rate values from Condition A and Condition B to this system curve panel, but the system of units for the two conditions were different. The systems of units for both conditions must be the same in order for the system curve to be meaningful.

This warning appears when the user has called up the system curve panel with the Condition A + Condition B selection, but the systems of units used in the two conditions are different. A system curve is only valid if the pair of specified flow/head units are consistent. The entire system curve panel will automatically close, as noted, in 5 seconds after it is opened, taking the user back at the main PSAT panel.