FSAT

The Fan System Assessment Tool

User Manual

Version 1.0

This document was created by Productive Energy Solutions for the U.S. Department of Energy.

Published September 2004

Table of Contents

Introduction

About FSAT

The Fan System Assessment Tool (FSAT) is a software program that helps quantify the potential benefit of using a more optimized fan system to serve industrial processes. It was developed by the U.S. Department of Energy to help people who are optimizing their fan systems.

FSAT needs only basic information about your fans and the motors driving them. It is a simple but powerful tool that won't take a long time to learn or use. Most users who have a basic familiarity with fan systems can learn how to use the program in a few hours.

FSAT performs three main functions that can help you during the process of upgrading your fan system:

1. Calculating how much energy your fan system is using
2. Determining how efficiently your system is operating
3. Quantifying savings from upgrading your system

Tips for effectively using FSAT

FSAT is a helpful optimization tool, but it requires that you have a basic understanding of fan systems. Keep the following points in mind to get the most benefit from using FSAT:

- **FSAT requires that the user have a basic understanding of fan systems**.
- **The best use of FSAT is to look at the big picture to see if there is an optimization opportunity**. Although the simplest use of FSAT is as a component-based tool for analyzing fan efficiency, usually the greatest savings come from looking at your entire fan system. The most efficient fans are sometimes installed with other components that severely reduce the overall system efficiency.
- **FSAT requires good input data in order to quantitatively evaluate the fan system**. Since collecting the data requires time and resources, you should first prioritize the fan optimization opportunities in your plant qualitatively. Then use FSAT on the top three to five opportunities in your plant.
- **FSAT needs accurate measurement of the power used by the fan system**. If you don't have qualified electricians or the equipment needed to safely measure power, ask your utility for help, or contract with an expert.

- **Input all data into FSAT before looking at results**.

- **FSAT does not choose which fan type or size is best suited to your load.** You will need to consult with a fan expert to choose the best equipment.

- **The software analyzes fans that operate at one speed, or at one load point**. If your fan varies the airflow to serve changing process needs, you may need to run the software several times to represent different operating scenarios.

- **FSAT will tell you optimization and savings potential, but it will not tell you what to do to improve the system**. System inefficiency could be the result of an improperly selected fan, a poor inlet or outlet condition, or substantial loss across a damper. You may need to consult with a fan expert to pinpoint the problem and engineer a solution.

- **To optimize the fan system, you need a good grasp of the process requirements**. In many plants, flow requirements are not precisely known. You may need the assistance of a fan expert to accurately assess process requirements such as flow and pressure.

Computer requirements

- IBM PC compatible computer
- CD-ROM drive
- 8 MB of RAM
- Minimum of 15 MB of free hard disk space
- Windows 95, 98, NT, 2000, or XP

Getting Started

Starting and stopping FSAT calculations

FSAT performs calculations continuously, even when the input data has not been changed. This may cause other applications to slow down. The black arrow under the Edit menu (➔) indicates that FSAT is performing calculations.

To stop FSAT calculations, click the STOP button located about half way down on the right side of the screen. The black arrow will turn to a white arrow (⇨).

To restart FSAT calculations, click the white arrow (⇨). The white arrow turns black (➔), indicating that calculations have resumed.

Collecting fan system information

In order to provide information about the potential benefits of optimization, FSAT requires some basic data about your fan system:

- Type of fan and motor
- Fan speed or diameter
- Motor horsepower, speed, voltage, and efficiency (standard or energy efficient)
- Duty cycle (how often the fan operates)
- Electric rate
- Power or current draw
- Bus voltage
- Drive type
- Process flow rate
- Fan static pressure
- Gas density and compressibility

Use the FSAT Data Collection Worksheet (Appendix A) to help you collect this information.

Understanding the FSAT screen

The FSAT screen is divided in half. The left side of the screen is used for inputting data. The right side of the screen is used for outputting and storing calculated results.

Input panels

- **Fan and motor inputs**. Fundamental data about the fan, drive, and motor.
- **Operating parameters.** Data about the fan's duty cycle and electricity costs.
- **Electrical power or current and drive inputs**. Information about the power supplied to the motor and the type of motor drive.

- **System inputs**. Flow rate and static pressure are entered here.
- **Gas property inputs**. The density and compressibility of the gas are entered here. A calculator is available to estimate these values if they are not known.

Output panel

- **Calculated results**. This section shows the results of FSAT calculations. A three-column table provides information on the efficiency of the existing system, the existing system outfitted with an energy efficient motor, and a fully optimized system.
- **Log file controls**. This feature allows you to store and retrieve screen data from different FSAT runs.
- **Summary file controls**. This feature lets you store screen data from an FSAT run in a text file that can be read by database or spreadsheet software. You can also append data to an existing file.

Getting help

To activate FSAT's help feature, select Show Help under the Help menu. Help text will appear that describes the FSAT panel that the cursor is on or near.

Inputting Data

Input Screens

Figure 1. Screenshot: Fan and Motor Information

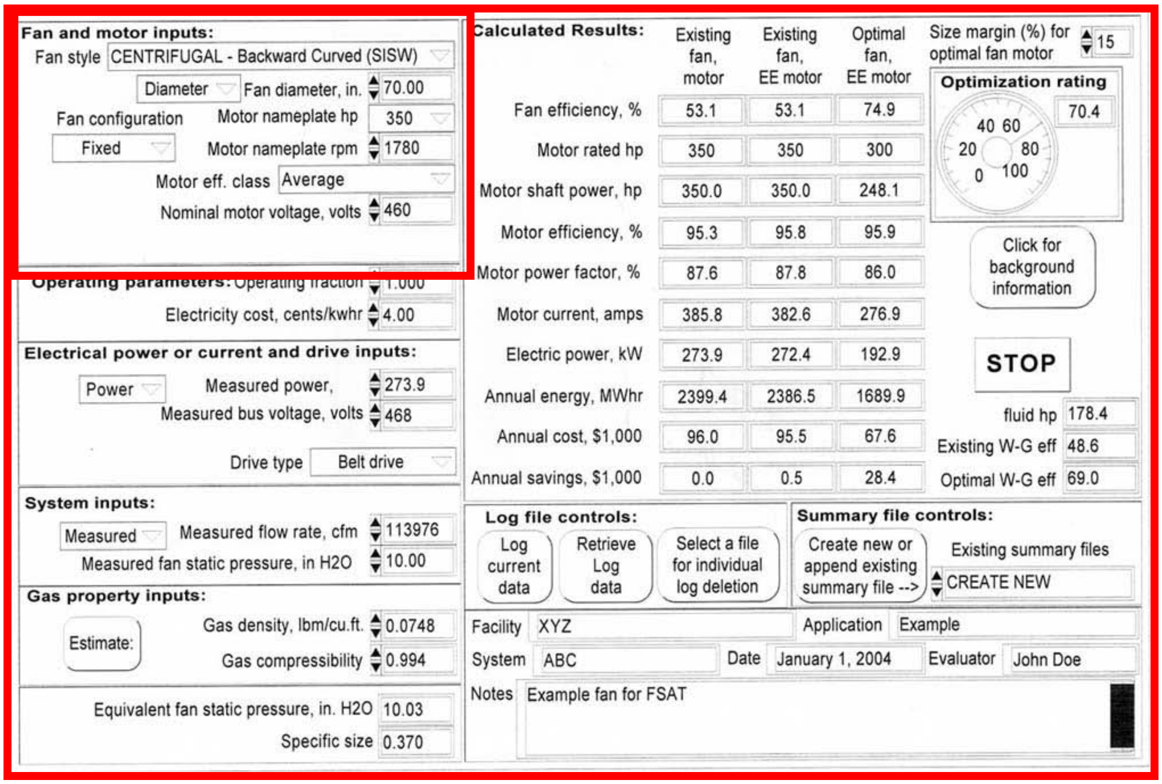
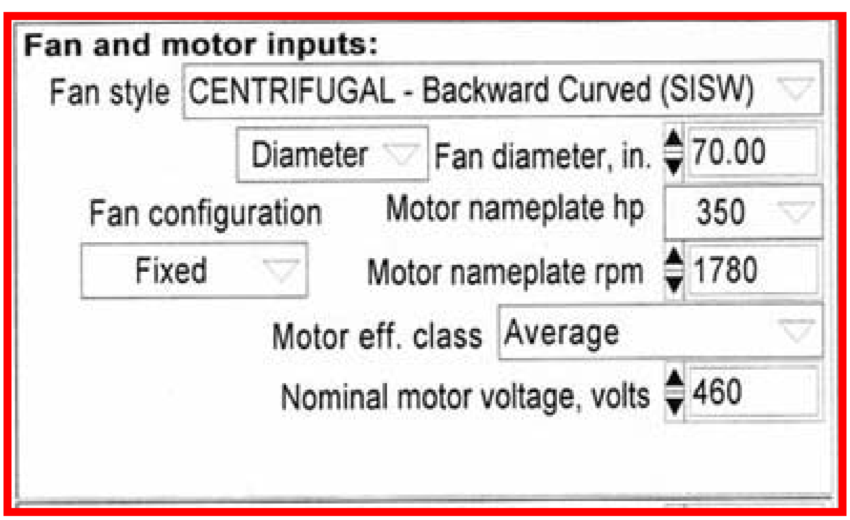


Figure 2. Screenshot Detail: Fan and Motor Information



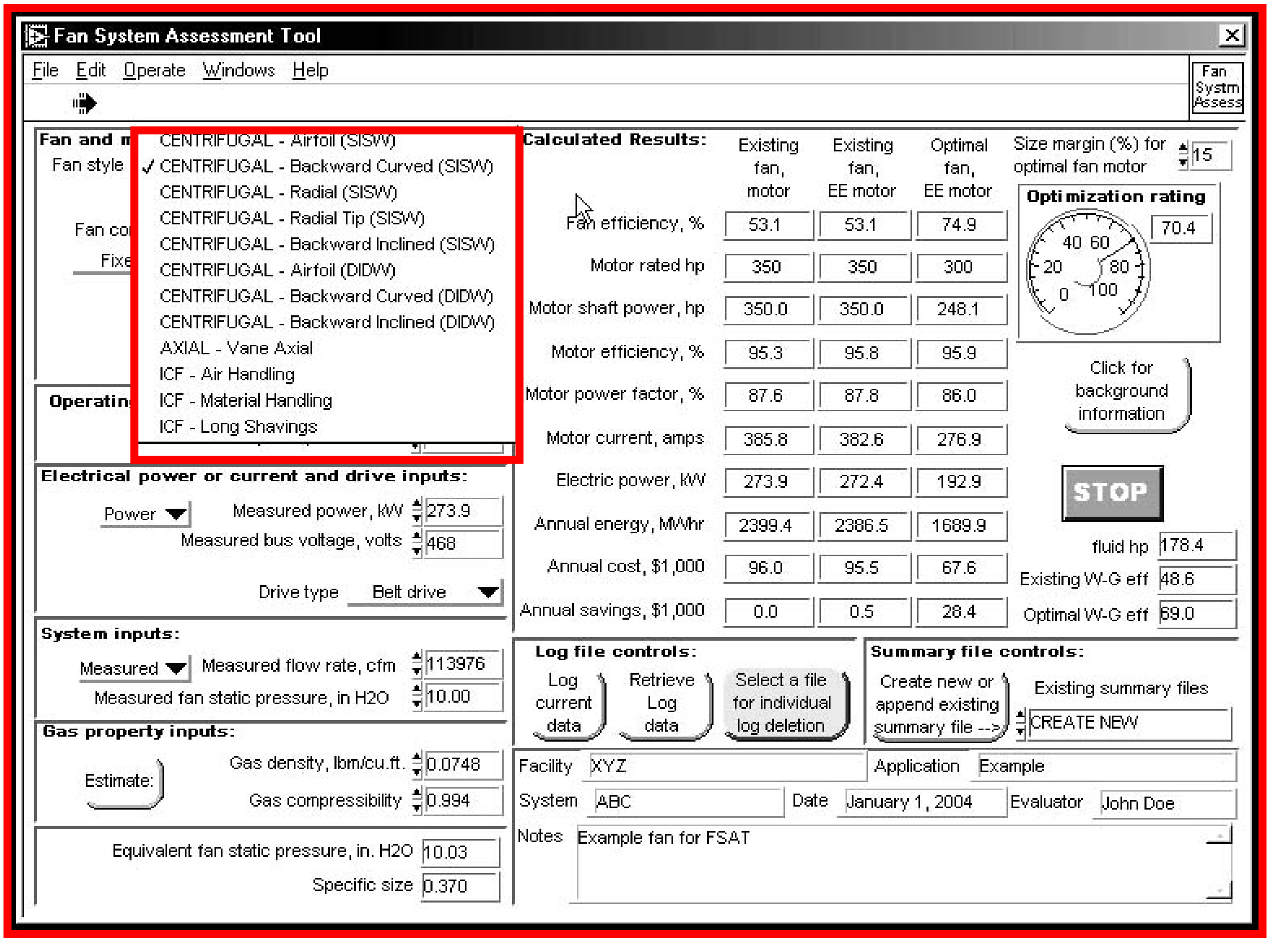
Motor Inputs

To use FSAT you will need to collect information about your motor system. Appendix B provides a convenient worksheet to help you collect this data.

Fan style

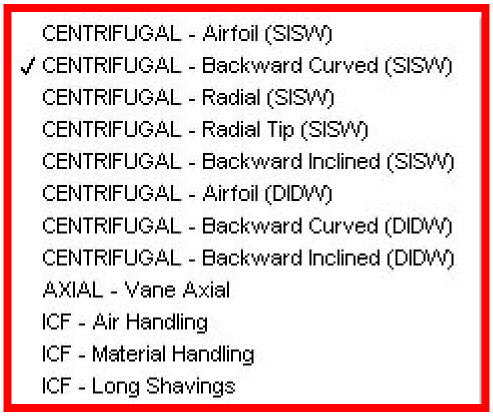
The first thing we must input is the style of fan. Usually the user would select the type of fan that is currently installed. Later, if you want to estimate the benefit of changing to a different style of fan, you could change this input to another type. For more information on fan styles see Improving Fan System Performance: A Sourcebook for Industry, p. 19-24.[1]

Figure 3. Screenshot: Fan pick list



[1] "Improving Fan System Performance", U.S. Department of Energy and Air Movement and Control Association International, Inc., 1989.

Figure 4. Screenshot Detail: Fan pick list



Speed vs. size switch

If you know either the fan rotational speed or the fan size, select the one you know. If there is a reason why only one fan size or one fan speed will work, select the parameter you need to remain constant. Once you select speed or size, enter the speed in RPM or the size in inches in the box immediately to the right.

Fan configuration

In most instances, this selection switch will remain set at "Changeable." Setting the switch to changeable allows FSAT to compare your fan to another more optimally selected fan of a different size or different rotational speed. In the rare instance that using a different fan size or speed is not possible, set the switch to "Fixed."

Motor nameplate hp

Enter the NEMA nominal size of the motor.

Motor nameplate rpm

Enter the full-load, nameplate rotational speed of the motor, such as 1780 rpm. If the precise speed is not known, then enter 900, 1200, 1800 or 3600, depending on the motor.

Motor efficiency class

For most older systems, entering "standard efficiency" is fine. If the motor has no nameplate efficiency, enter "Standard Efficiency". If the motor nameplate has an efficiency listed, use the table in Appendix C to determine if the motor is standard, average, or energy efficient.

Nominal motor volts

Enter the voltage from the motor nameplate.

Nameplate full load amps

Enter the full-load amps (designated as FLA) from the motor nameplate.

Estimate button

If the motor FLA (full-load amps) is not known, use the amperage calculator tool by clicking the Estimate button next to the nameplate FLA (see Figure 2).

Operating Parameters

Figure 5. Screenshot: Operating Fraction and Electric Rate

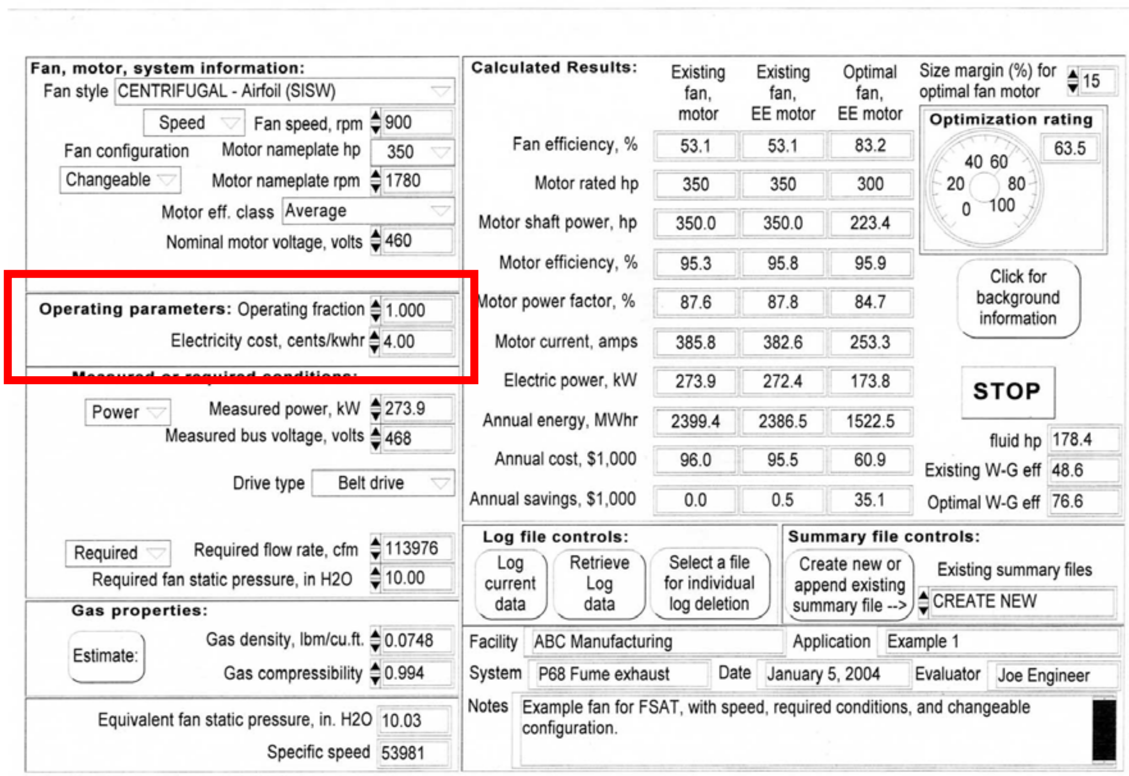
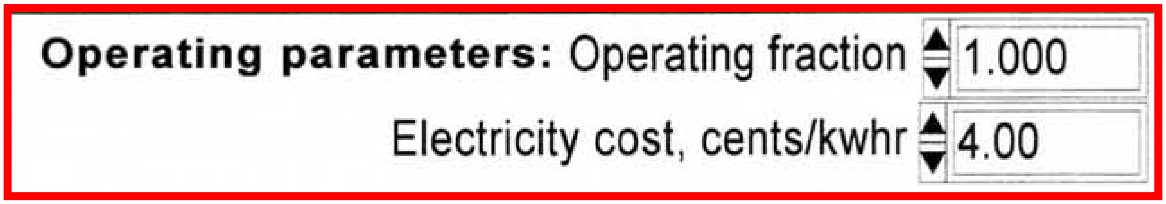


Figure 6. Screenshot Detail: Operating Fraction and Electric Rate



Operating fraction

If the motor operates 24/7/365 or 8760 hours per year, then enter 1.0 for the operating fraction. If the motor operates fewer than 8760 hours per year, then divide the actual operating hours by 8760 to get the operating fraction.

$$Operating\_Fraction = \frac{Operating\_hours}{8760}$$

For instance, if the fan operates 12 hours per day five days per week, 52 weeks per year, figure the operating fraction as follows:

$$12 \times 5 \times 52 = 3120 \text{ hours per year}$$

$$Operating\_Fraction = \frac{3120}{8760}$$

$$Operating\_Fraction = 0.36$$

Electric rate

Enter the average electric rate in cents per kilowatt-hour.

Power and Drive Inputs

Figure 7. Screenshot: Power and Drive Inputs

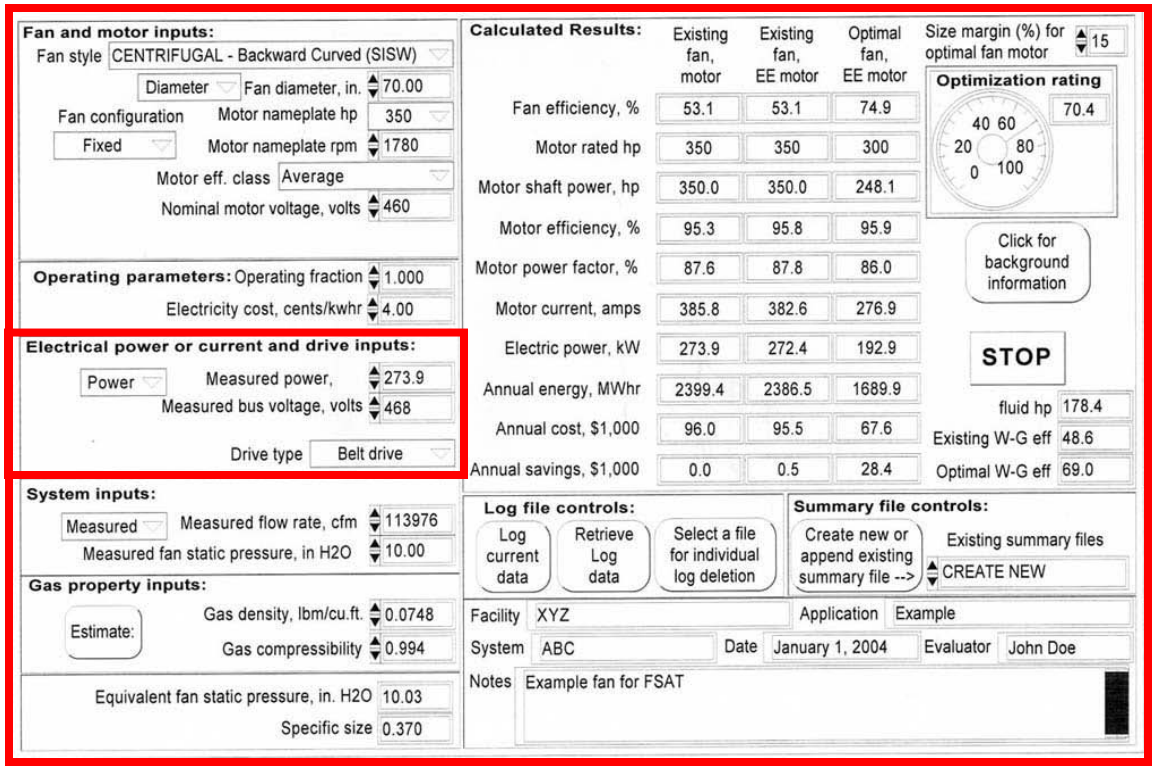
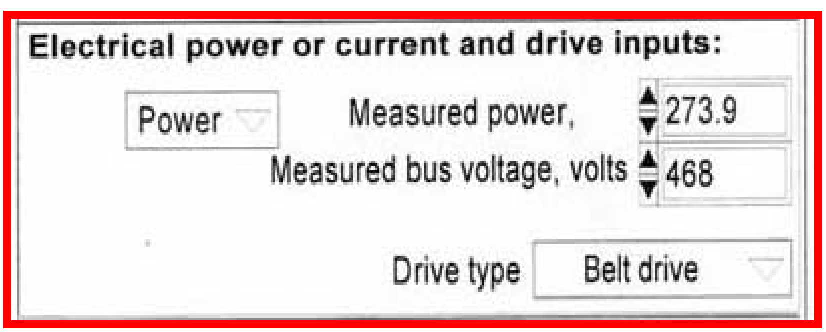


Figure 8. Screenshot Detail: Power and Drive Inputs



Current vs. power switch

Set the switch based on the type of data you have available. If a true kW power meter is available, select "Power." If all you have available is an ammeter and voltmeter, then select "Current."

Note: If you select “Current” then you must enter the Nameplate Full Load Amps, or press the Estimate button next to the FLA input.

Measured current/measured power

If the current vs. power switch is set to “Power,” then input the measured power in kW here. If the “current vs. power” switch is set to “Current,” then input the measured amps here.

Measured bus voltage

This is the voltage being supplied to the motor. This input is important if the “Current vs. Power” switch is set to “Current.” If you have chosen Power, you can either enter the voltage from the power meter reading or enter the nameplate voltage.

Drive type

Select the appropriate setting, either “Direct Drive” or “Belt Drive.”

System Inputs

Figure 9. Screenshot: System Inputs

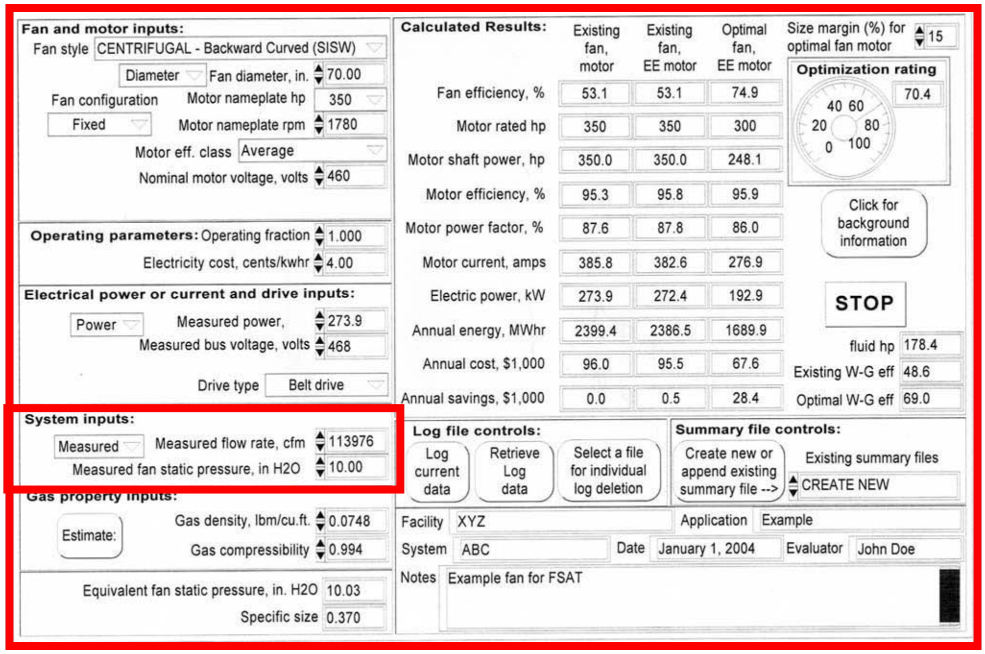
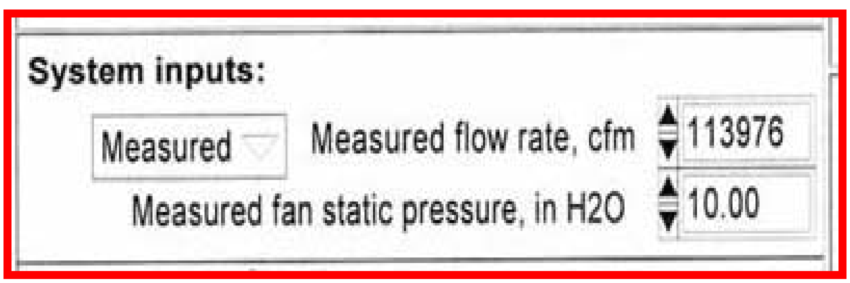


Figure 10. Screenshot Detail: System Inputs



Measured vs. required switch

The setting of this switch affects the tags on the next two input parameters, flow rate and static pressure. If "Measured" is selected, then the tags will read "Measured flow rate" and "Measured fan static pressure." Likewise, if the switch is set to "Required," the tags will read "Required flow rate" and "Required fan static pressure."

If you are doing an analysis of just the fan itself, then set this to "Measured." For instance, you would do this if you'd like to compare the efficiency of the fan to a new fan, or because you suspect the fan is deficient in some way (i.e. eroded impeller, or improper running clearance, etc.). In this case, input the measured flow rate and the measured static pressure rise across the fan in the next two fields.

If you'd like to estimate the overall system efficiency, then set this switch to "Required," and enter the process flow requirements of flow rate and pressure, rather than what the fan is developing. For instance, the system may contain dampers, unnecessary silencers, or undersized filters or coils. Any unnecessary pressure drop of this sort should not be included when entering the "required" pressure. So, instead of inputting the pressure rise across the fan, measure and input the pressure drop across the legitimate process components. See Appendix A for information about where to measure pressure drops in the system.

Note: The setting of the switch does not in any way effect the calculations that the program makes. It is there to remind the user of the philosophical shift in thinking when one is examining the fan system vs. the fan as a component.

Gas Properties Inputs

Figure 11. Screenshot – Gas Properties

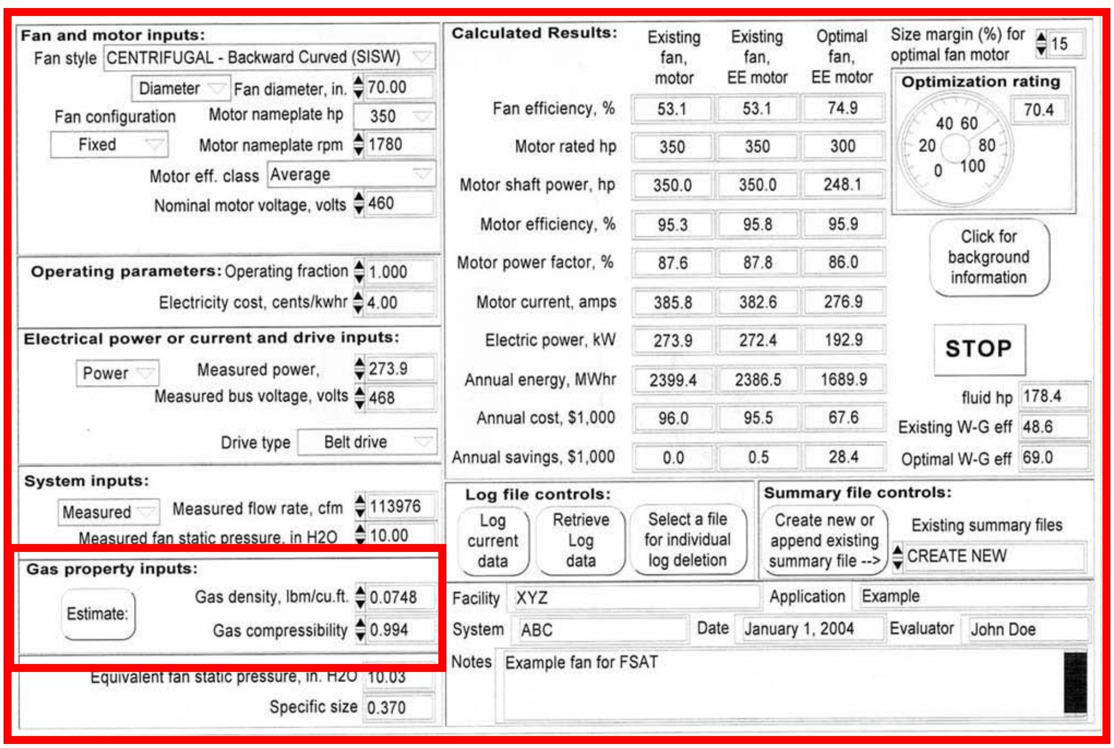
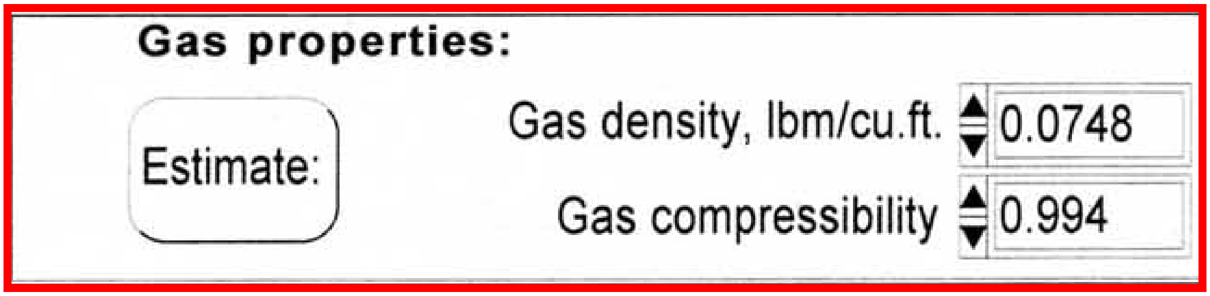


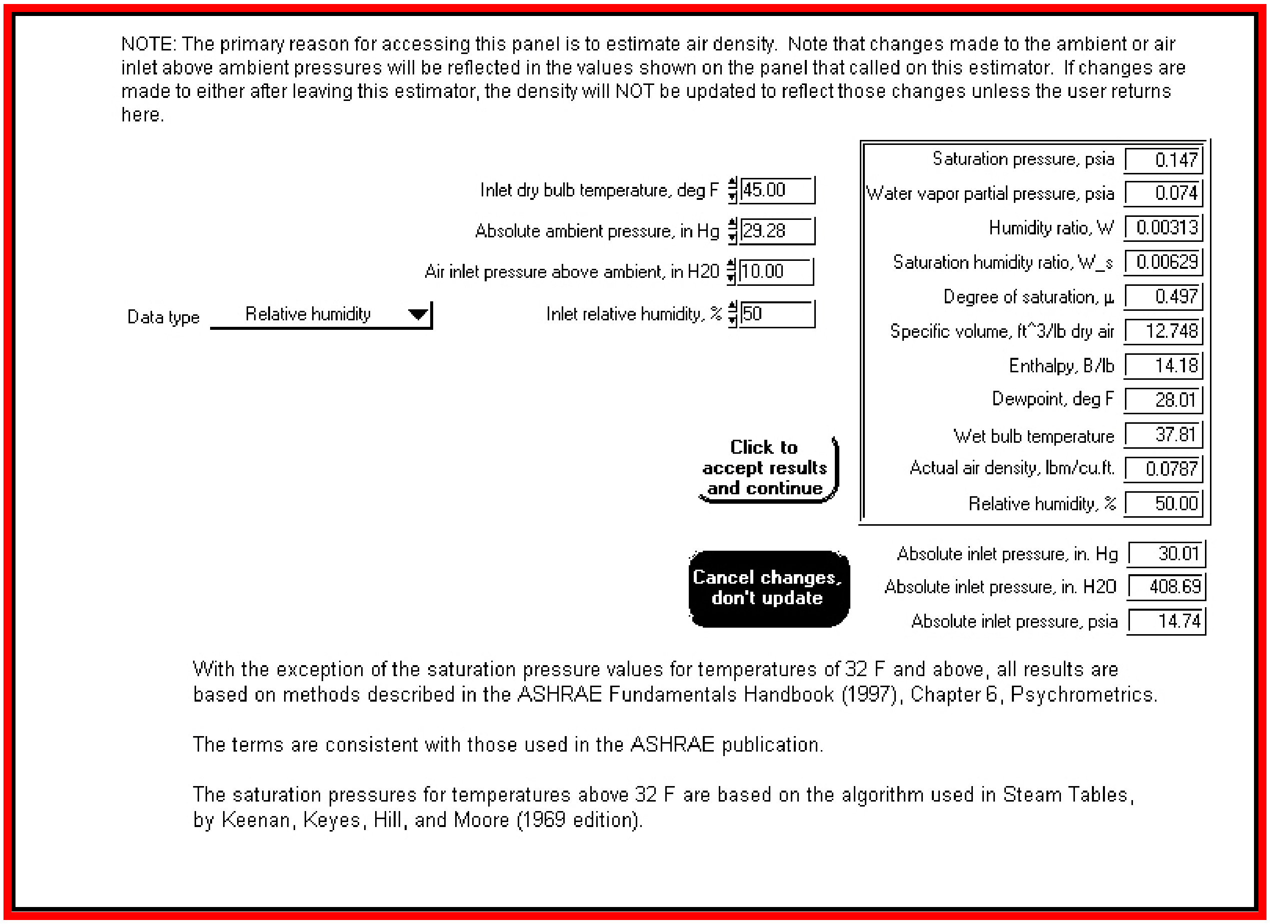
Figure 12. Screenshot Detail – Gas Properties



Estimate

The estimate button here will take you to additional screens where you can estimate the density and the compressibility of the air in case you have non-standard conditions. Some examples of fans handing air at non-standard conditions would be hot, wet air coming off a dryer, or air that is at subzero temperatures.

Figure 13. Screenshot – Psychometric Calculator Screen



Gas density

The density of standard air at 68°F, 50% RH is 0.075 lb/ft^3. If the fan is running at or close to standard room conditions, you probably don't need to worry about this for the purposes of using FSAT. If the conditions are more than 20°F different than standard conditions, input the density if you know it. If you don't know the density, use the estimate button to call up the gas properties screen. Once there, you can call up the density calculator screen and enter the information you know, making note of the conditions you enter.

Click the "accept results" button to carry your results back to the main screen. If you replace the fan or modify it, be sure to let the vendor know what the conditions are if they are non-standard.

Gas compressibility

Enter the gas compressibility factor if you know it, or use the "Estimate" button. The Estimate button will take you to the gas properties screen. Generally, you probably won't need to concern yourself with the compressibility factor unless you have very hot air or have a very large static pressure (above 30 in w.g.). In fact, up to 12 in. w.g., the compressibility factor is equal to 1. Between 12 and 30 in w.g. the compressibility factor is typically over 0.97. This type of change is only picked up with the most careful tests, using sensitive instruments.

Understanding FSAT Results

Output Screens

Figure 14: Screenshot – Outputs

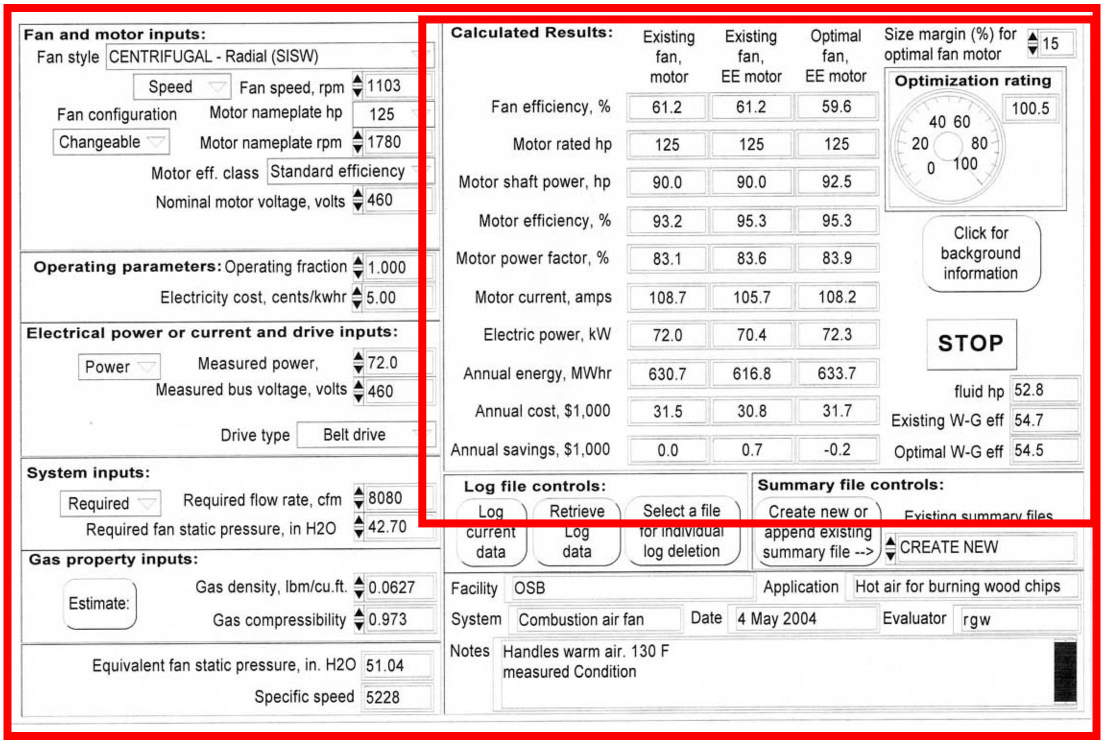
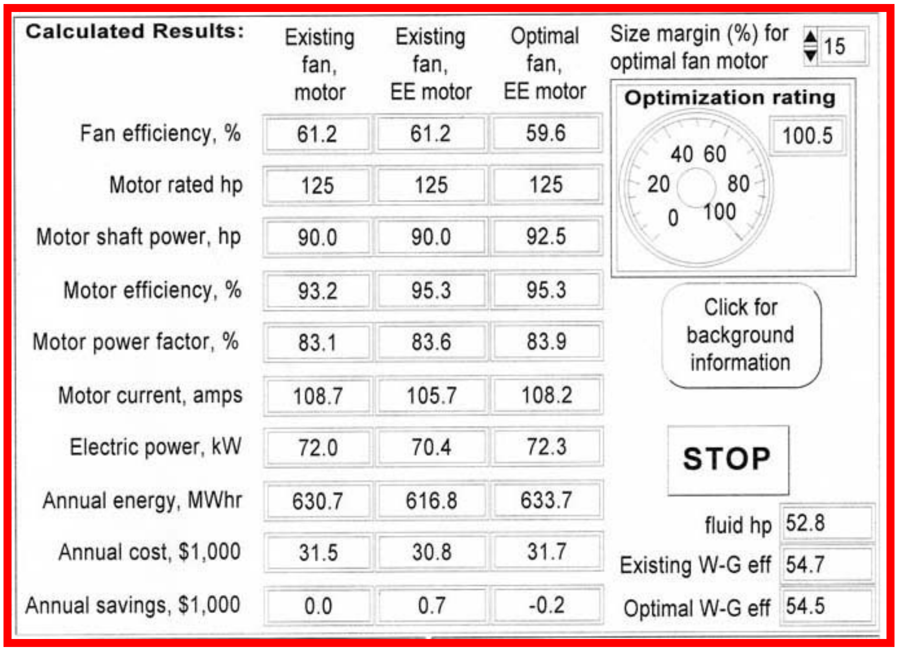


Figure 15. Screenshot Detail: Outputs



Calculated Results:	Existing fan, motor	Existing fan, EE motor	Optimal fan, EE motor
Fan efficiency, %	61.2	61.2	59.6
Motor rated hp	125	125	125
Motor shaft power, hp	90.0	90.0	92.5
Motor efficiency, %	93.2	95.3	95.3
Motor power factor, %	83.1	83.6	83.9
Motor current, amps	108.7	105.7	108.2
Electric power, kW	72.0	70.4	72.3
Annual energy, MWhr	630.7	616.8	633.7
Annual cost, $1,000	31.5	30.8	31.7
Annual savings, $1,000	0.0	0.7	-0.2

Output Columns

Most of the FSAT output is organized into three columns in a table on the right hand side of the screen. There is also the optimization gauge, which shows the optimization potential in dial format.

Existing fan, motor

The left column is a summary of the fan system output parameters as they apply to the fan or fan system as it is currently installed. The numbers in this column pertaining to the motor are echoes of inputs you made or the result of lookups from FSAT's database of information on motor performance.

Existing fan, EE motor

The middle column is a summary of the fan system output parameters as they apply to the current fan configuration driven by an energy efficient (EE) motor. This column of outputs is useful if you have a standard efficiency motor and want FSAT to calculate the savings of upgrading to an EPACT motor. If the motor type is set to "Energy Efficient," then the first two columns will be identical.

Optimal fan, EE motor

The right column is a summary of the fan system output parameters as they apply to the fan system if a new, optimally selected fan driven by an energy-efficient motor were installed.

Be careful interpreting the results of this column. If the “Fan Configuration” has been set to “fixed,” then the results in this column will actually not be the most efficient fan available, but rather the most efficient fan with the size impeller you specified, or the rotational speed you specified. Only if the “Fan Configuration” has been set to “changeable” will the results in this column reflect the most efficient fan available for the specified flow and pressure.

Output Rows

Fan efficiency

FSAT uses the input values you provided for flow, pressure, and power, and calculates the efficiency here using the fan power-law. If you input the pressure rise across the fan, then the value shown here is the efficiency of the fan itself.

If you entered the flow and pressure required by the process, and did not include any wasted pressure drop through dampers, etc., then the number in the first column is actually the system efficiency, not the fan efficiency.[2] If the efficiency is “infinite”, go back and press the “Estimate” button next to the “Motor full load amps” input, or enter the motor full-load amps directly.

Motor rated horsepower

This is an echo of the input. If this field is red, it’s most likely an indication that something is not right in the inputs. Red means FSAT thinks the existing motor is overloaded. [3]

Motor shaft power, hp

The shaft power that the motor develops to turn the fan. [4]

Motor efficiency, %

FSAT software contains detailed information on motor performance for standard efficiency and energy-efficient motors. When you enter the motor size in horsepower, the motor speed, and the “Motor eff. class,” FSAT looks up the motor efficiency based on the motor and the motor loading.[5]

---

[2] For the Optimal fan column, FSAT does a lookup of the peak efficiency achievable for the type of fan you selected, unless you have set the “Fan Configuration” to “Fixed,” in which case it looks up the peak efficiency for the size or speed of fan you selected under “Fan Diameter” or “Fan Speed.” If the background on this field is yellow or orange, FSAT is indicating that there may be a problem with using that speed or diameter fan to serve the given process requirements.

[3] For the Optimal fan column, this motor is the size FSAT thinks is appropriate based on the motor shaft power.

[4] For the Optimal fan column, the hp is calculated using the fan power-law, and the flow and pressure you input.

[5] For the Optimal fan column, this lookup is done for an EE motor of the size FSAT thinks is appropriate.

Motor power factor, %

FSAT software contains detailed information on motor performance for standard efficiency and energy efficient motors. When you enter the motor size in horsepower, the motor speed, and the "Motor eff. Class," FSAT looks up the motor power factor based on the motor and the motor loading.

Motor current, amps

If you entered the motor current, then it is repeated in the first column of this row. If you entered power, then the current is calculated based on the voltage, motor size, and motor loading.[6]

Electric power, kW

The "Electric Power" is calculated from the shaft power, as demonstrated in discussion of the fan power-law equation.

Annual energy, MWhr

Annual energy is based on the operating fraction and the electric power as calculated above.

Annual cost, $1,000

Annual operating cost in 1,000s of dollars is based on the annual energy use and electric rate.

Annual savings, $1,000

The annual savings number in the first column is always zero because the "Existing fan, motor" is the base case to which the other two columns are compared. The annual savings for each of the other two columns is calculated by subtracting the annual energy use of that column from the annual energy use for the "Existing fan, motor" case.

[6] For the Optimal fan column, FSAT looks up the amperage for an EE motor of the size FSAT thinks is appropriate at the voltage you specified, and the shaft power loading calculated above.

Other Outputs and Controls

Size margin (%) for optimal fan motor

The size margin is the minimal shaft requirements needed for the optimal fan. This selection provides a method to force the selected motor to be larger than required based on the specified fan style and fluid data. This might be appropriate, for example, in selecting a fan motor that is not only large enough to handle the current load conditions, but also able to handle increased loads in the future.

Optimization rating dial

The "Optimization Rating" is the ratio of the existing wire-to-gas efficiency divided by the optimal wire-to-gas efficiency. Usually this rating will be a number between zero and 100. A low score indicates that a good optimization opportunity exists.

Note: It is possible to run FSAT and get a high "Optimization Rating" on poorly performing systems in certain situations. For instance, if 1) there are large losses across a damper, 2) the measured flow and pressure rise across the fan are used, and 3) the fan is in good shape with no system effect, then the score will be high even though there could be significant optimization opportunity in the system.

Click for background information

Provides detailed information about the software; motor, fan, and system efficiency; and fan optimization topics.

STOP

Temporarily stops FSAT calculations. Click the white arrow (⇨) under the Edit menu to restart calculations.

Fluid hp

The fluid horsepower is the energy that the fan is delivering to meet the flow and pressure requirements that were input. This is a theoretical number that does not include any of the losses from the fan, the motor, or the drive. It would include losses due to system effect and damper loss if those are present in the system.

Existing W-G eff

The existing wire-to-gas efficiency is based on the fan efficiency for the "Existing fan, motor," adjusted for the losses in the motor and drive.

The wire-to-gas efficiency for the existing fan system is the same as the overall system efficiency if the pressure and flow required by the process have been entered. If damper loss or system effect losses are present, then the W-G eff will be higher than the overall system efficiency.

Optimal W-G eff

The existing W-G efficiency is based on the fan efficiency for the “Optimal fan, EE motor,” adjusted for the losses in the motor and drive.

The wire-to-gas efficiency for the optimal fan system is the same as the overall system efficiency if the pressure and flow required by the process have been entered, and if little or no damper loss or system effect losses are present.

Additional FSAT Features

Log File Controls

Figure 16: Screenshot – Log File Controls

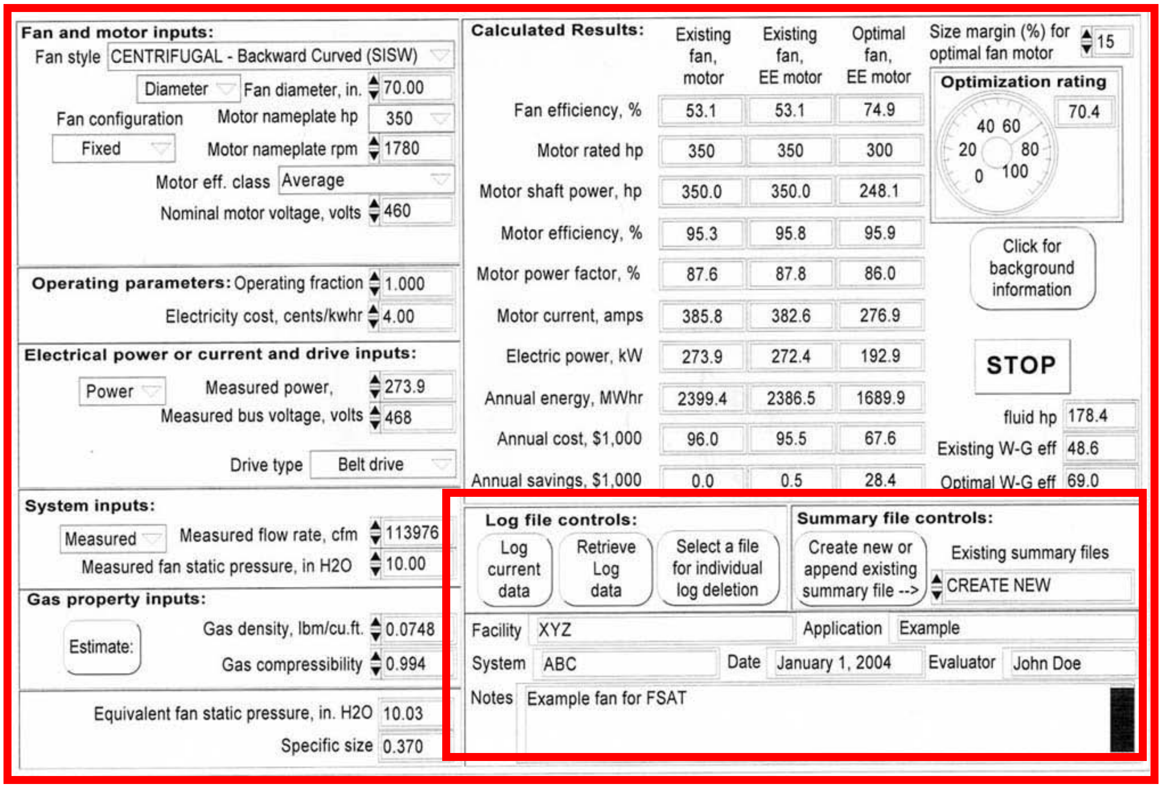
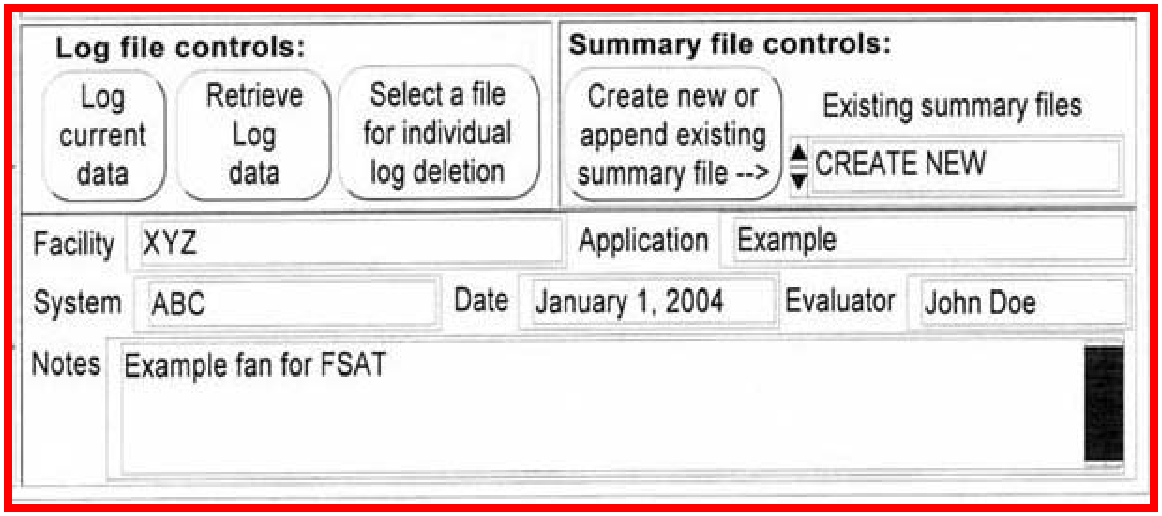


Figure 17. Screenshot - Log file controls (detail)



The Log File controls allow you to save your current results to disk and retrieve them later. The "Log current data" button saves data on screen to a log file. The button named "Retrieve log data" brings the data back to the screen. The third button is for deleting log files. Use the fields below the buttons to store information about your runs.

Summary File Controls

The summary file controls allow you to collect the results from several FSAT runs and present them in one report. The summary file is saved as a text file (ending with .txt). You can open the text file from Word or Notepad and view the results on the screen or print them out.

To use the summary file the first time, click the oval button that says "Create new or append existing summary file." Create a filename of your choice with a .txt extension. If you change the run, click the "Append" drop-down menu item. The current run will be added in a column to the right of any existing data.

Pull down & help menu

To activate FSAT's help feature, select Show Help under the Help menu. Help text will appear that describes the FSAT panel that the cursor is on or near.

Figure 18. Screenshot - Help menu

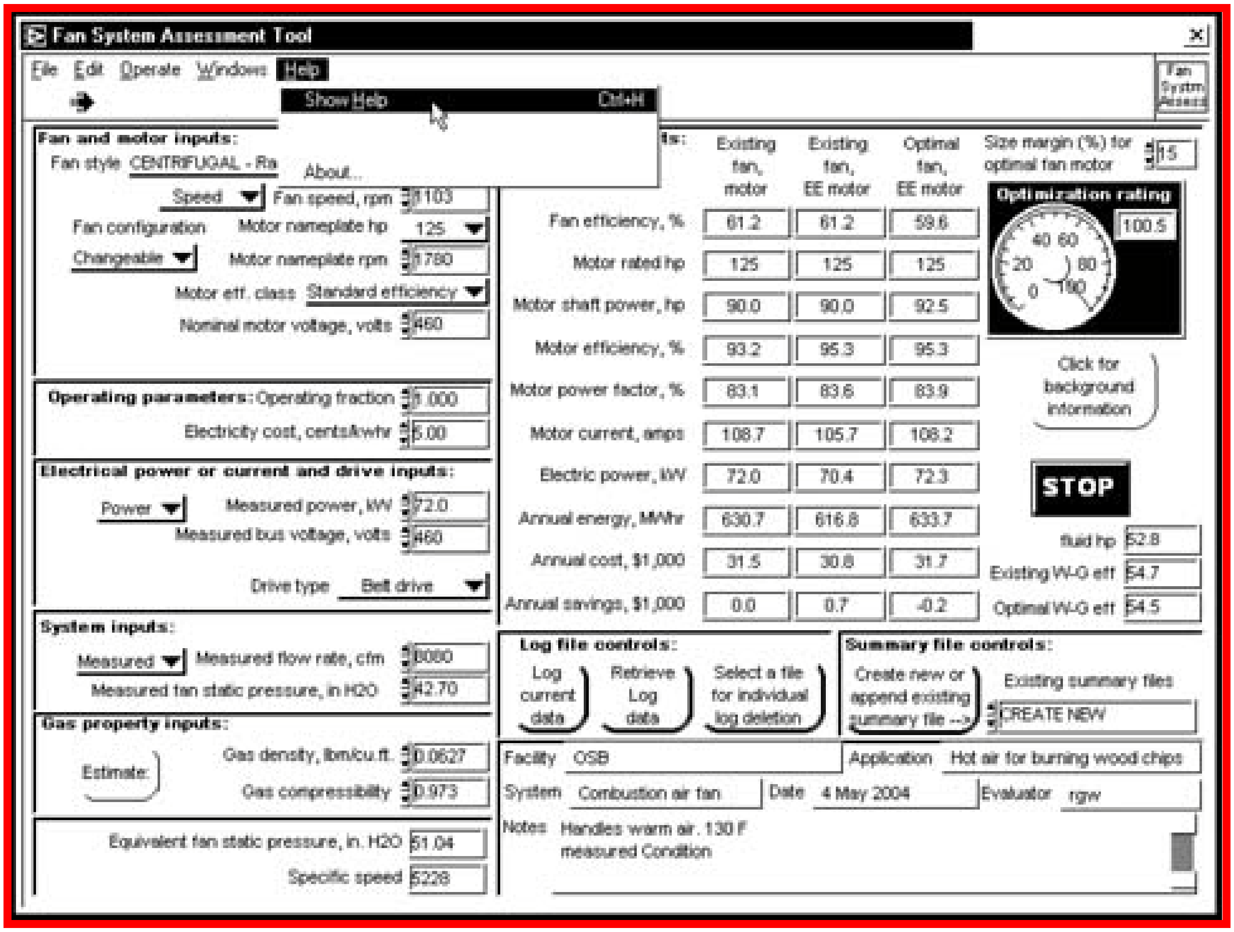
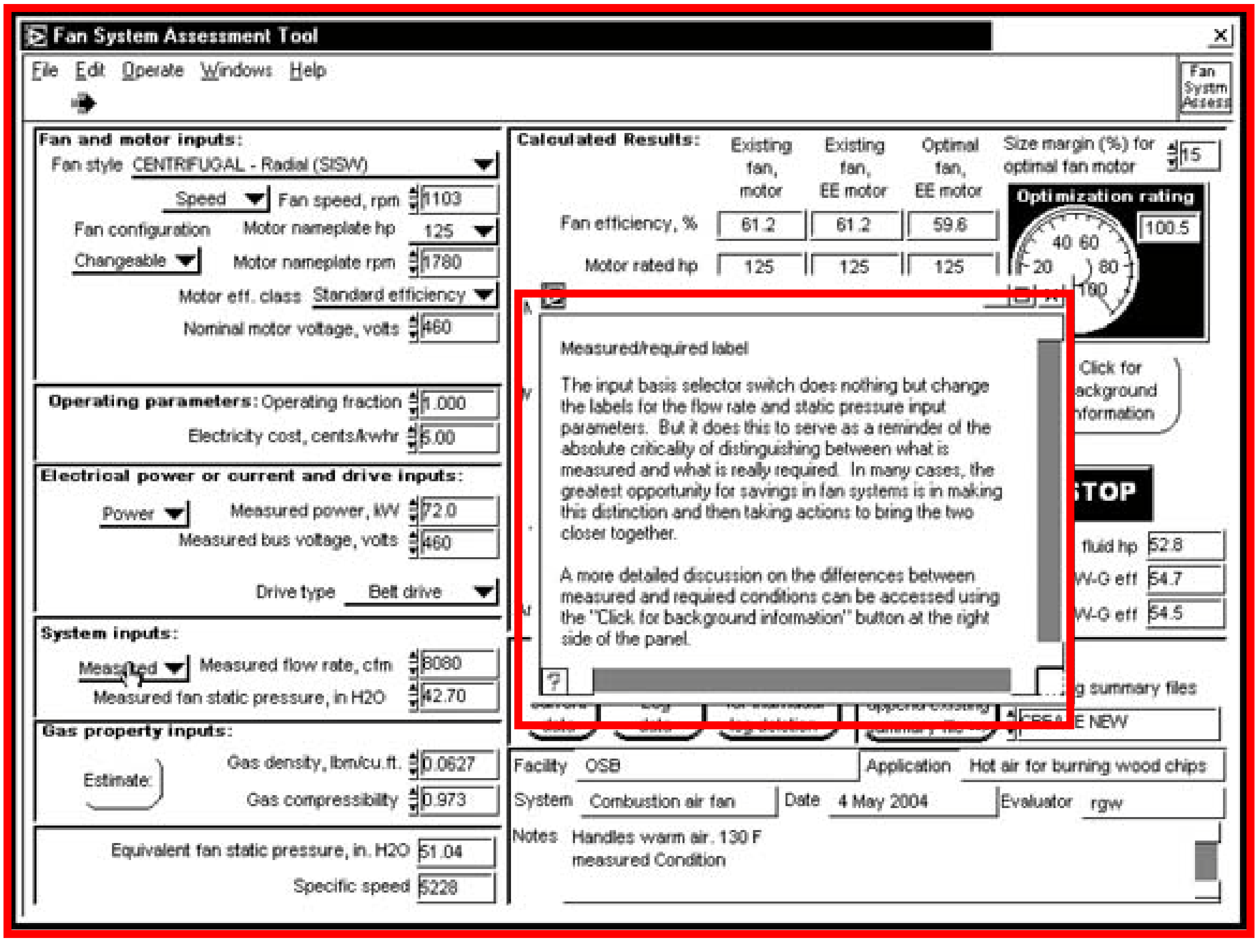


Figure 19. Screenshot: Help screen sample



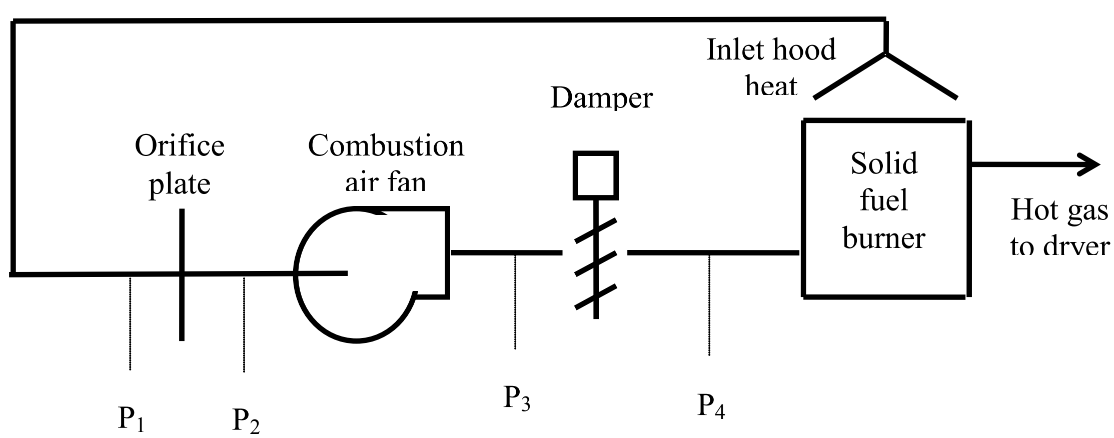
Appendix A: FSAT Sample Application

The following problem is meant to show how FSAT is actually used. This sample problem shows the measurements needed to analyze a system based both on measured data and system requirements. Both approaches are needed to assess the efficiency of an industrial system.

System description and initial assessment

In the figure below, a 125-hp radial bladed fan provides combustion air for a solid fuel biomass burner. The duct size (cross section) is the same throughout the system. The damper is used to adjust the flow to optimize combustion.

Figure A1. Solid fuel burner combustion air fan: process and instrumentation drawing (not to scale)



The following pressures were observed:

P_0	Local reference pressure in plant	= 0.0 in. w.g.
P_1	Upstream of the orifice plate	= -1.0 in. w.g.
P_2	Downstream of the orifice plate	= -4.1 in. w.g.
P_3	Fan discharge	= 38.6 in. w.g.
P_4	Downstream of damper	= 11.0 in. w.g.

The observed pressures reveal a large pressure drop across the damper and the orifice plate. Overall, the process is using only a fraction of the pressure the fan develops, and since the fan is fairly large, we suspect that this is a good optimization candidate. The consultant completed further investigations including the following flow and power measurements:

Air stream temperature	=	128 °F
Flow	=	8,080 cfm
Electrical volts and current	=	461 Volt, 107.3 Amps
Fan rotational speed	=	1,475 rpm

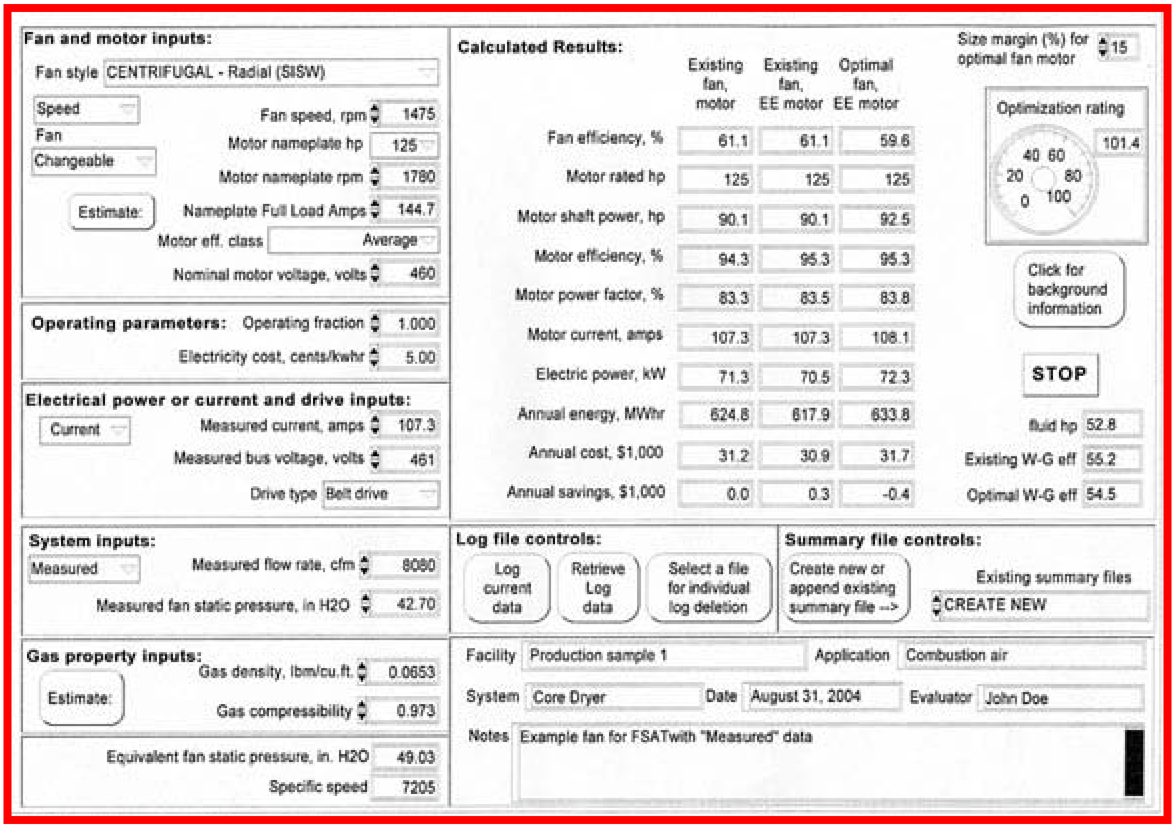
Using FSAT to analyze the system

Two steps are involved in using FSAT to fully assess the optimization opportunity. The first step is to determine the measured fan static pressure rise across the fan. The second step is to determine the pressure that the process requires, not including avoidable losses, such as the drop across the damper and the drop across the orifice plate.

Determining the "Measured fan static pressure"

The measured pressure rise across the fan is P_3-P_2 or 38.6 – (-4.1) = 42.7 in. w.g. This would be the pressure that is used for the "Measured Fan Static Pressure". When the measured pressure rise across the fan and the measured flow rate are entered into FSAT, the resulting analysis is an assessment of the performance of the fan itself. When we input the data this way, the following result is obtained from FSAT.

Figure A2. FSAT run with "measured" data.



Looking at the printout of the FSAT run with "Measured" data, we see that the system has a very high optimization rating of 101.4 %. This means the fan itself is performing well, and is efficiently producing the flow and pressure measured. This does not mean that the fan is well matched to the process, however.

Determining the "Required fan static pressure"

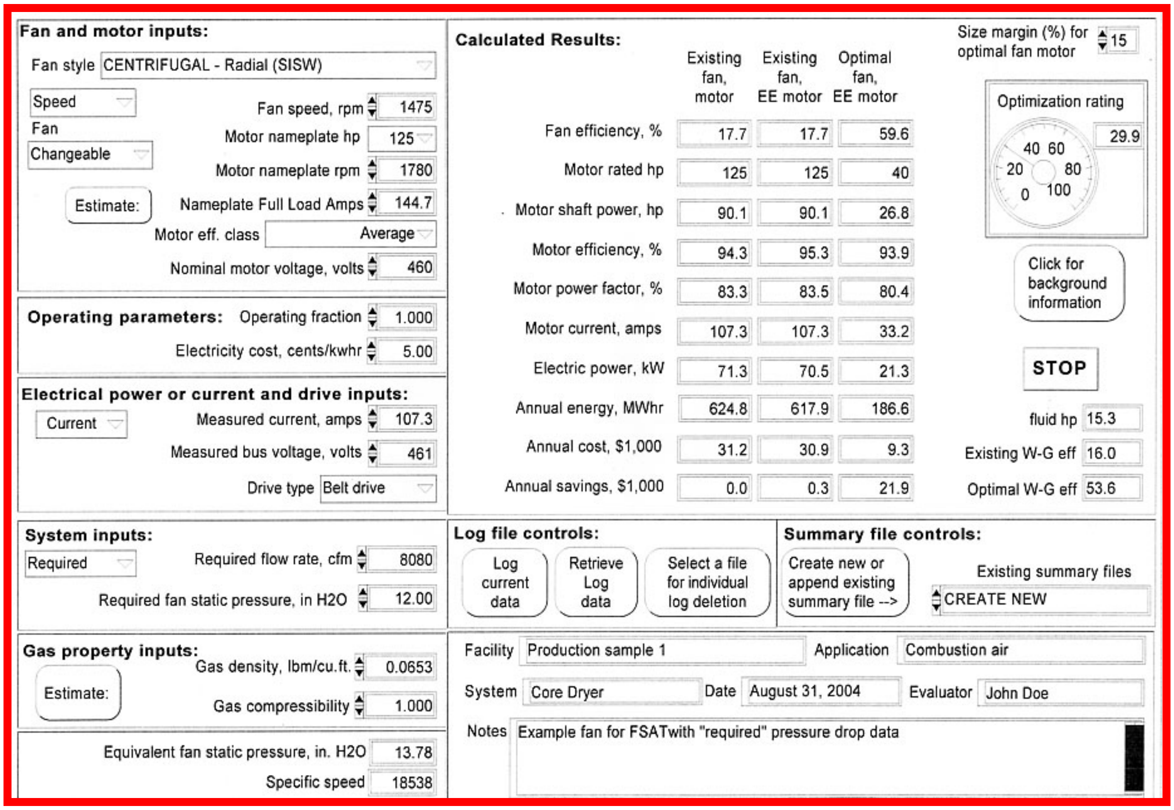
To calculate the useful pressure needed by the process requires some judgment. In this case the pressure drop across the damper and the pressure drop across the orifice plate are not useful directly to the process. Thus, the damper can be opened if the fan were matched to the process instead of being oversized, and the orifice flow meter can be replaced by a flow meter with a negligible pressure drop.

To calculate the pressure useful to the process, we have to subtract the loss across the damper and the orifice plate from the total pressure developed by the fan.

Pressure developed by the fan (P_3-P_2)	=	42.7 in w.g.
Pressure lost across the damper (P_4-P_3)	=	-27.6 in w.g.
Pressure lost across the orifice plate (P_2-P_1)	=	-3.1 in w.g.
Pressure useful for the "required" process	=	12.0 in w.g.

When we put the required conditions into FSAT, we get a very different result, as shown in Figure A3 below.

Figure A3: FSAT run with "required" data.



Putting in the requirements of the process shows the waste across the damper and the orifice flow meter. The optimization rating has now plunged to 29.9%, indicating an excellent optimization opportunity.

Summary of "measured" vs. "required" inputs

In order to accurately assess the optimization potential in a fan system requires a good knowledge of the process requirements, especially the pressure required by the process and the pressure developed by the fan. Use this information to complete two FSAT runs, one for the "measured" and one for the "required" condition, and compare the result.

FSAT Data Collection Worksheet

System Name ______________________________

FAN AND MOTOR

❑ Airfoil SISW	❑ Backward Curved SISW	❑ Backward Inclined SISW
❑ Airfoil DIDW	❑ Backward Curved DIDW	❑ Backward Inclined DIDW
❑ ICF Air Handling	❑ ICF Material Handling	❑ ICF Long Shavings
❑ Radial	❑ Radial Tip	❑ Vane Axial

Fan Speed _______ rpm OR **Fan Diameter** __________ in.

Motor HP __________ hp

Motor Speed __________ rpm

Motor Efficiency Class: ρ Energy Efficient ρ Standard Efficient ρ Unknown (Average)

Nominal Motor Voltage __________ volts

Motor Full Load __________ amps

OPERATING FRACTION AND ELECTRIC RATE

Operating Fraction ___________

Electric Rate ___________ $/kwhr

SYSTEM INFORMATION [MEASURED OR REQUIRED CONDITIONS]

Measured Power ___________ kW OR **Measured Current** ___________ amps

Measured Bus Voltage ___________ volts

Drive Type: ρ Direct ρ Belt

Required [not including avoidable pressure drop due to partially closed dampers]

Flow Rate _________ cfm **Fan Static Pressure** _________ in H_2O

Measured [Fan outlet pressure minus fan inlet pressure] – Inlet velocity pressure

Flow Rate _________ cfm **Fan Static Pressure** _________ in H_2O

GAS PROPERTIES [Optional. Complete if non-standard conditions]

Gas Density __________ lbm/cu.ft

If gas is **air**, FSAT can help estimate density:

Inlet Dry Bulb __________ °F

Inlet Wet Bulb __________°F OR **Inlet Relative Humidity** _________ %

Ambient Pressure _______in Hg OR **Elevation Above Sea Level** ______ Ft.

Air Inlet Pressure Above Ambient __________ in H_2O

Appendix C: Table of motor efficiencies

Table C-1 lists various efficiency levels for motors from 10 to 500 hp. As shown in the table, the larger motors tend to be more efficient than the smaller motors. Three of the columns correspond to motor choices found in FSAT, while the premium efficiency motors are a newer category not yet incorporated into FSAT.

Standard efficiency motors

Standard efficiency motors are longer available for purchase in the U.S., although many are still operating. If you have an older standard efficiency motor that has been repaired more than once, consider replacing it with a new premium efficiency motor the next time it fails.

If your motor is at or below the efficiency level shown in the standard efficiency column, set the FSAT motor efficiency class to “standard efficiency.”

Energy-efficient (EE) motors

This standard is adopted from the NEMA standard for energy efficient motors (NEMA MG-1 Table 12-10). These motors are known as EPACT motors. Any new general-purpose motors sold in the U.S. market must meet or exceed these full-load nominal efficiencies.

If your motor is at or above the efficiency level shown in the Energy-Efficient column, set the FSAT motor efficiency class to “Energy Efficient.”

Average efficiency motors

FSAT includes another choice for the motor efficiency class, which is the average of the Standard Efficiency and Energy Efficient. Choose “average” for the motor efficiency class if the efficiency of your motor is between Energy Efficient and Standard Efficiency, or if you don’t know the efficiency but the motor is less than 10 years old.

Premium efficiency motors

More recently, NEMA developed a new efficiency standard known as NEMA Premium. When motors fail, or when systems are upgraded, consider replacing the motor with a new premium-efficiency motor. Future releases of FSAT software may incorporate premium-efficiency motors.

Table C-1. Nominal Full Load Motor Efficiencies. For NEMA design A and B, three phase, general purpose TEFC motors (1800 RPM).

HP	Standard efficiency [1]	Average efficiency [2]	EPACT or Energy-Efficient [3]	NEMA Premium Efficiency [4]
10	86.6	88.1	89.5	91.7
15	87.9	89.5	91.0	92.4
20	88.8	89.9	91.0	93.0
25	89.5	91.0	92.4	93.6
30	90.1	91.3	92.4	93.6
40	90.9	92.0	93.0	94.1
50	91.4	92.2	93.0	94.5
60	91.8	92.7	93.6	95.0
75	92.2	93.2	94.1	95.4
100	92.8	93.7	94.5	95.4
125	93.2	93.9	94.5	95.4
150	93.5	94.3	95.0	95.8
200	94.0	94.5	95.0	96.2
250	94.4	94.7	95.0	96.2
300	94.6	95.0	95.4	96.2
350	94.8	95.1	95.4	96.2
400	94.9	95.2	95.4	96.2
450	95.0	95.2	95.4	96.2
500	95.1	95.5	95.8	96.2

Notes:

1. Typical for older motors.
2. Numerical average of Standard Efficient and Energy-Efficient.
3. Based on NEMA MG-1 Table 12-10. Formerly know as Energy-Efficient motors, this is now the federal standard for new motors. Also known as EPACT motors.
4. Newer NEMA Standard. Motors are available which meet or exceed this standard.

Appendix D: Technical supplement