US DOE Industrial Technologies BestPractices Software Tools

Fan System Assessment Tool Introduction

Presented By

Developed For Oak Ridge National Lab by
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Agenda

- Training Webcast Introduction
- Introduction of Fan Efficiency Concepts - 20 minutes
- Introduction of Tools - 20 minutes
- FSAT Demonstration - 20 minutes
- Q & A - 10 minutes
- Summary

Fan System Assessment Training Learning Objectives (one day training)

Class participants will:

1. explain the benefits of optimizing fan systems;
2. calculate the cost of operating fans in their facility;
3. explain the interaction between the fan curve and the system curve;
4. estimate the overall efficiency of a fan system;
5. analyze the optimization potential of fan systems;
6. describe how to use FSAT software;
7. create an action plan to improve fan system efficiency and reliability in their plants; and
8. report one concept or technique from the day’s program that they consider significant.

Fan System Assessment Training
Learning Objectives (Qualified Specialist training)

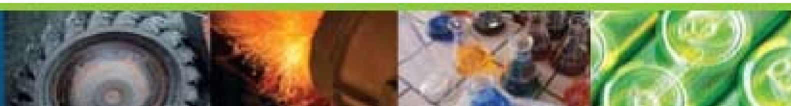
- Estimate operating costs and identify optimization opportunities for a fan system case study
- Understand the use of manometers, pitot tubes and other instruments as measurement tools in a fan performance test
- Develop a measurement plan as part of a performance test
- Understand how FSAT handles gas temperature and density
- Describe how to manage files in FSAT
- Understand how to use FSAT to get the greatest benefit when modeling fan systems
- Analyze field data to establish FSAT inputs
- Input field data results and use FSAT to evaluate fan systems
- Demonstrate competence in using FSAT to pre-qualify good potential fan system optimization opportunities.

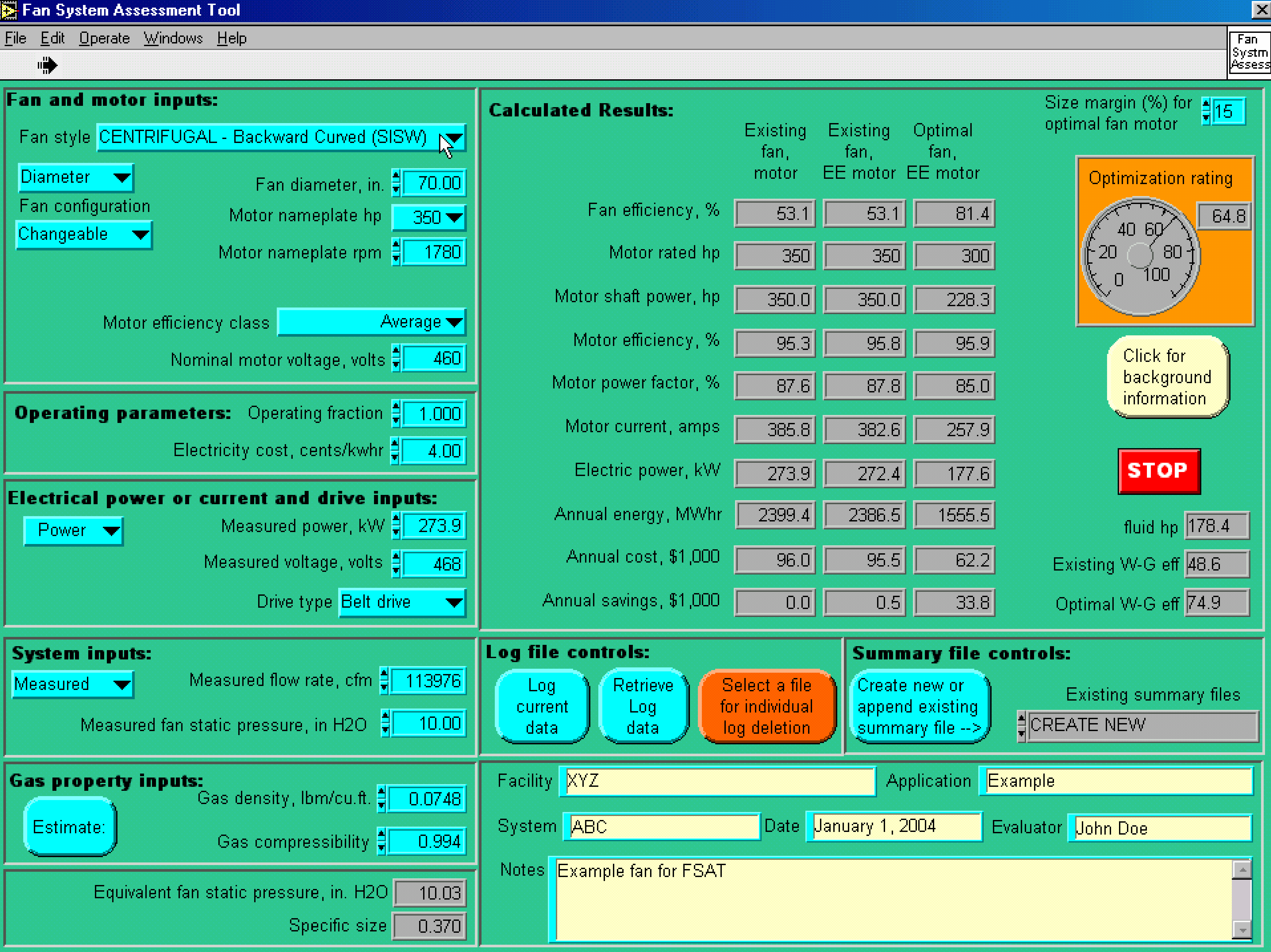
Fan System Assessment Tool

Developed by the U.S. Department of Energy (DOE)

FSAT will:

- **Calculate fan system energy use**
- **Determine system efficiency**
- **Quantify optimization savings**

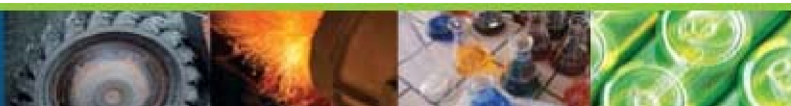




Fan System Assessment Tool
File Edit Operate Windows Help
Fan Systm Assess
Fan and motor inputs:
Fan style CENTRIFUGAL - Backward Curved (SISW)
Diameter
Fan diameter, in. 70.00
Fan configuration
Changeable
Motor nameplate hp 350
Motor nameplate rpm 1780
Motor efficiency class Average
Nominal motor voltage, volts 460
Operating parameters: Operating fraction 1.000
Electricity cost, cents/kwhr 4.00
Electrical power or current and drive inputs:
Power
Measured power, kW 273.9
Measured voltage, volts 468
Drive type Belt drive
System inputs:
Measured
Measured flow rate, cfm 113976
Measured fan static pressure, in H2O 10.00
Gas property inputs:
Gas density, lbm/cu.ft. 0.0748
Estimate:
Gas compressibility 0.994
Equivalent fan static pressure, in. H2O 10.03
Specific size 0.370
Calculated Results:
Existing fan, motor
Existing fan, EE motor
Optimal fan, EE motor
Fan efficiency, % 53.1 53.1 81.4
Motor rated hp 350 350 300
Motor shaft power, hp 350.0 350.0 228.3
Motor efficiency, % 95.3 95.8 95.9
Motor power factor, % 87.6 87.8 85.0
Motor current, amps 385.8 382.6 257.9
Electric power, kW 273.9 272.4 177.6
Annual energy, MWhr 2399.4 2386.5 1555.5
Annual cost, $1,000 96.0 95.5 62.2
Annual savings, $1,000 0.0 0.5 33.8
Size margin (%) for optimal fan motor 15
Optimization rating
64.8
0 20 40 60 80 100
Click for background information
STOP
fluid hp 178.4
Existing W-G eff 48.6
Optimal W-G eff 74.9
Log file controls:
Log current data
Retrieve Log data
Select a file for individual log deletion
Summary file controls:
Create new or append existing summary file -->
Existing summary files
CREATE NEW
Facility XYZ
Application Example
System ABC
Date January 1, 2004
Evaluator John Doe
Notes Example fan for FSAT

When using FSAT keep in mind that:

- ***FSAT is best for the big picture.***
- ***FSAT requires good input data.***
- ***FSAT requires you to know which type of fan is suited your load.***
- ***FSAT analyzes one load point.***
- ***FSAT will not tell you what to do to improve the system.***



Optimization Benefits

Financial

Corporate

Production

Maintenance

Safety

Environmental

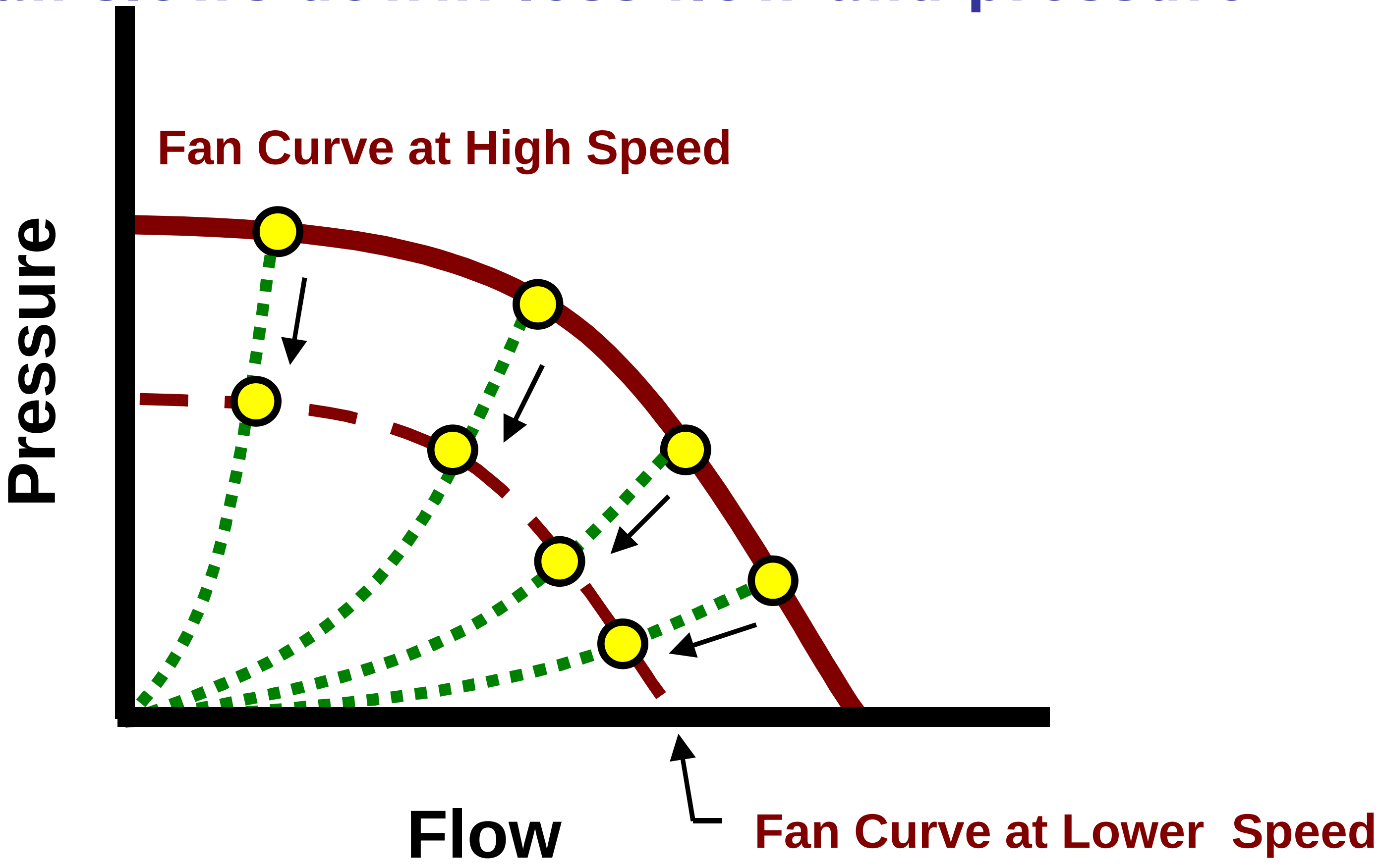
Societal

Time Magazine April 5, 2004

Fan Speed and the Fan Curve

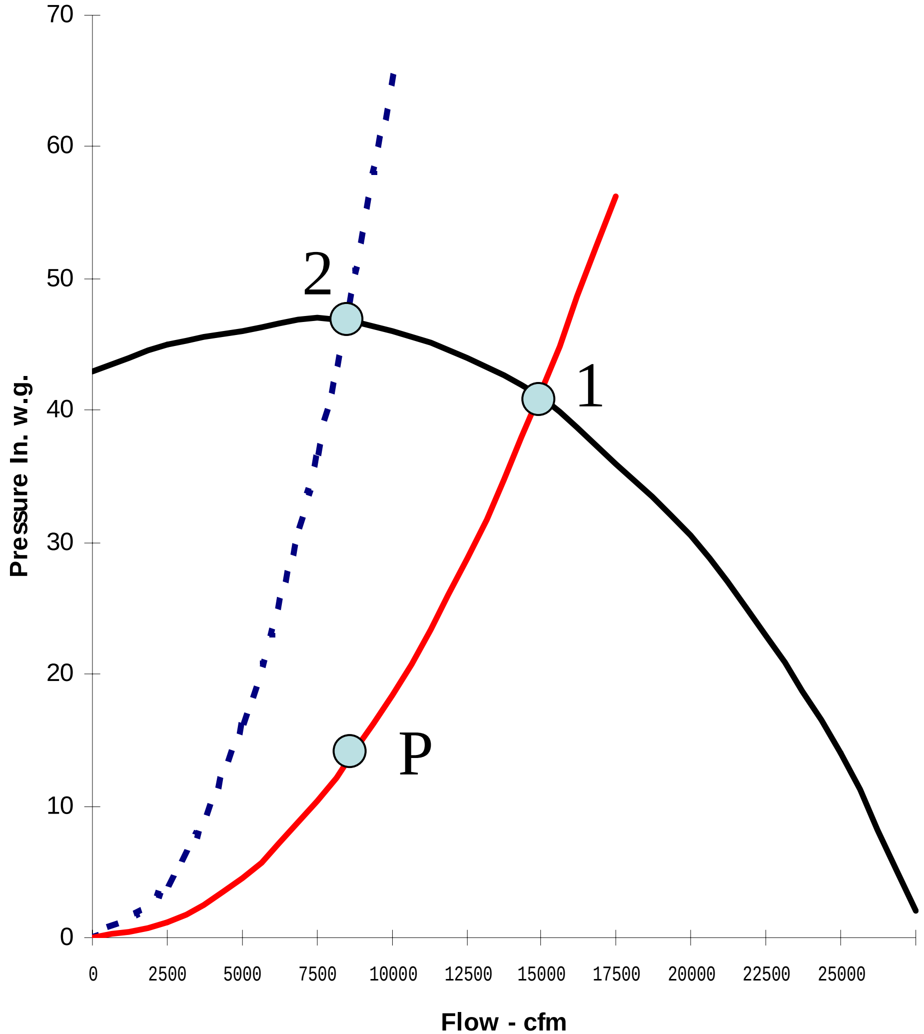
Fan speeds up: more flow and pressure

Fan slows down: less flow and pressure



Combustion Air Fan - OSB

Fan Curve and System Curve interaction



Point P:
Process requirements
(8,080 cfm and 12 in. w.g.)

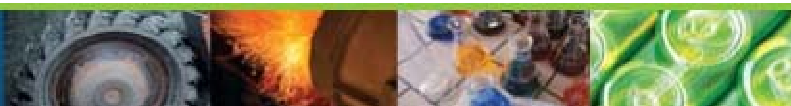
Point 1:
Flow and pressure with open damper
(16,000 cfm, 42 in. w.g.
-- assumes the motor doesn't overload)

Point 2:
Flow and pressure with damper closed
(8,080 cfm, 43 in w.g.)

Overall Fan System Efficiency

Several factors affect the overall fan system efficiency:

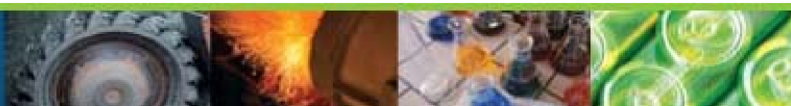
- Fan impeller shape
- Dampers and control methods
- Poor installation (System Effect)
- Drive type
- Motor type
- Fan Size



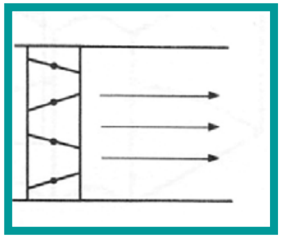
What is Efficiency?

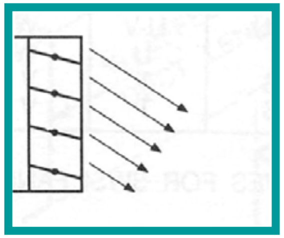
$$\eta = \frac{output}{input} \text{ or } \eta = \frac{Useful\ Output}{Energy\ Input}$$

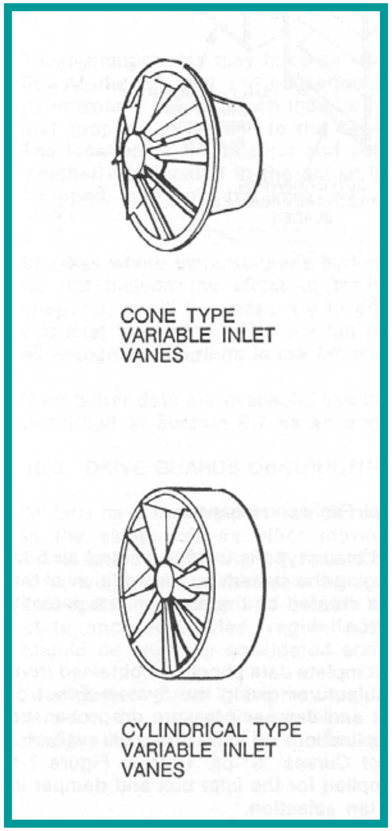
Efficiency is the portion of energy you paid for that is actually doing the work



Types of Dampers







Damper Locations:

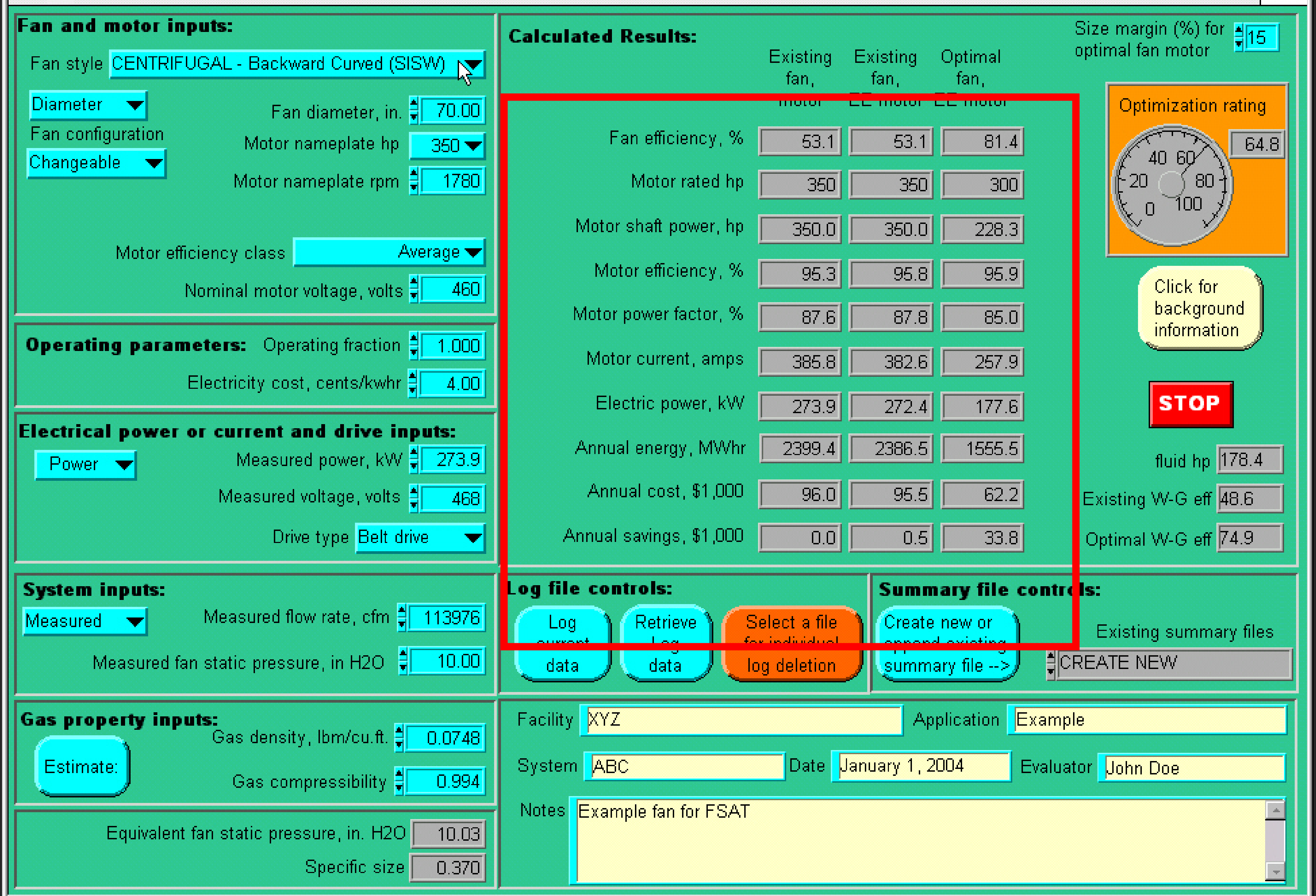
Inlet Vane - Use with Caution

Inlet Damper - Poor

System Damper - Bad

Outlet Damper - Worst

Diagram Courtesy AMCA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Fan configuration
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Changeable
Motor nameplate rpm
1780
Motor efficiency class
Average
Nominal motor voltage, volts
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Operating parameters:
Operating fraction
1.000
Electricity cost, cents/kwhr
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60
80
100
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ABC
Date
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Evaluator
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Notes
Example fan for FSAT

Fan System Optimization Checklist

Fan System Optimization Checklist

For fans over 50 hp that operate more than 4000 hours per year

Instructions: Use this checklist to qualitatively select the top optimization projects for FSAT analysis. Make a copy of this list for each of your major systems, then go through the list and add up the points for the conditions that apply. **If there are any control, production & maintenance, or system effect indicators, <u>then</u> add points for size and run hours as follows:** *If the system operates more than 6000 hours add a point. **If the system is over 100 hp add a point per 100 hp (200 hp = 2 points, 300 hp = 3 pts, etc). Also add a point or points if production or maintenance problems are severe. Two or more points can indicate a good optimization opportunity. Four or more points probably indicate a very good opportunity. ***Note***: Fans with adjustable speed drives usually are <u>not</u> good candidates for optimization.

Fan System ______________________________

Are there problems with the system?______________________________

Points** 1 ___ Motor _______ hp

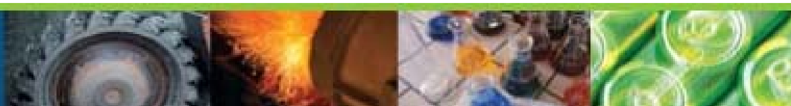
Points* 1 ___ Operating hours _____________

Tally the points _____________

Control		Production & Maintenance		System Effect	
Points		Points		Points	
2 ___	Motor overloads unless damper restricts flow	2 ___	Too much flow or pressure for production	2 ___	90° turn *right at* fan outlet or inlet
2 ___	Spill or bypass	2 ___	Unstable or hard to control system	1 ___	90° turn *near* fan outlet or inlet
2 ___	Discharge damper	2 ___	Unreliable system breaks down regularly	2 ___	Dirt leg at bottom of inlet duct
1 ___	Inlet damper	1 ___	Not enough flow or pressure for production	1 ___	No outlet duct
1 ___	Variable inlet vane	1 ___	System is excessively noisy	1 ___	Restricted or sharp inlet
1 ___	System damper	1 ___	Buildup on fan blades		
1 ___	Damper is mostly closed	1 ___	Need to weld ductwork cracks regularly		
		1 ___	Radial fan handling clean air		

Facility/Contact/ phone/fax: ______________________________

See full size handout



FSAT Data Collection Worksheet

See full size handout

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 ________ cents/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

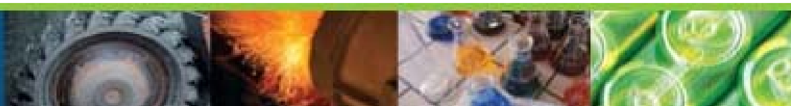
If gas is **air**, FSAT can help estimate density:

Inlet Dry Bulb ________ °F

Inlet Wet Bulb ________ °F OR **Inlet Relative Humidity** ________ %

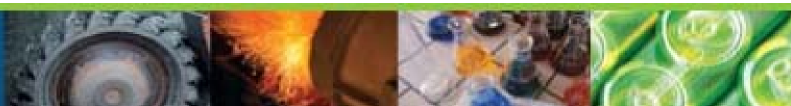
Ambient Pressure ______ in Hg OR **Elevation Above Sea Level** ______ Ft.

Air Inlet Pressure Above Ambient ________ in H_2O

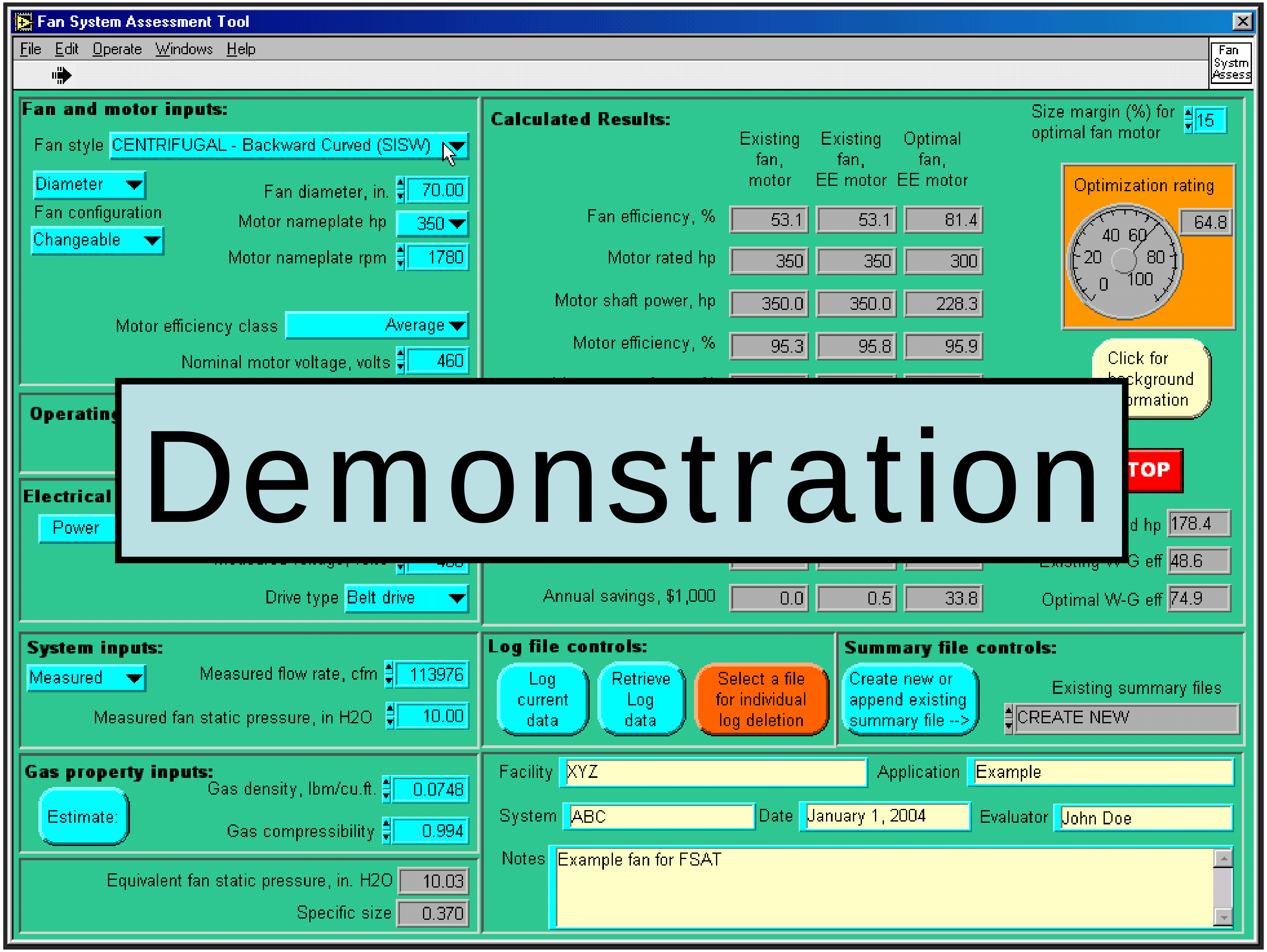


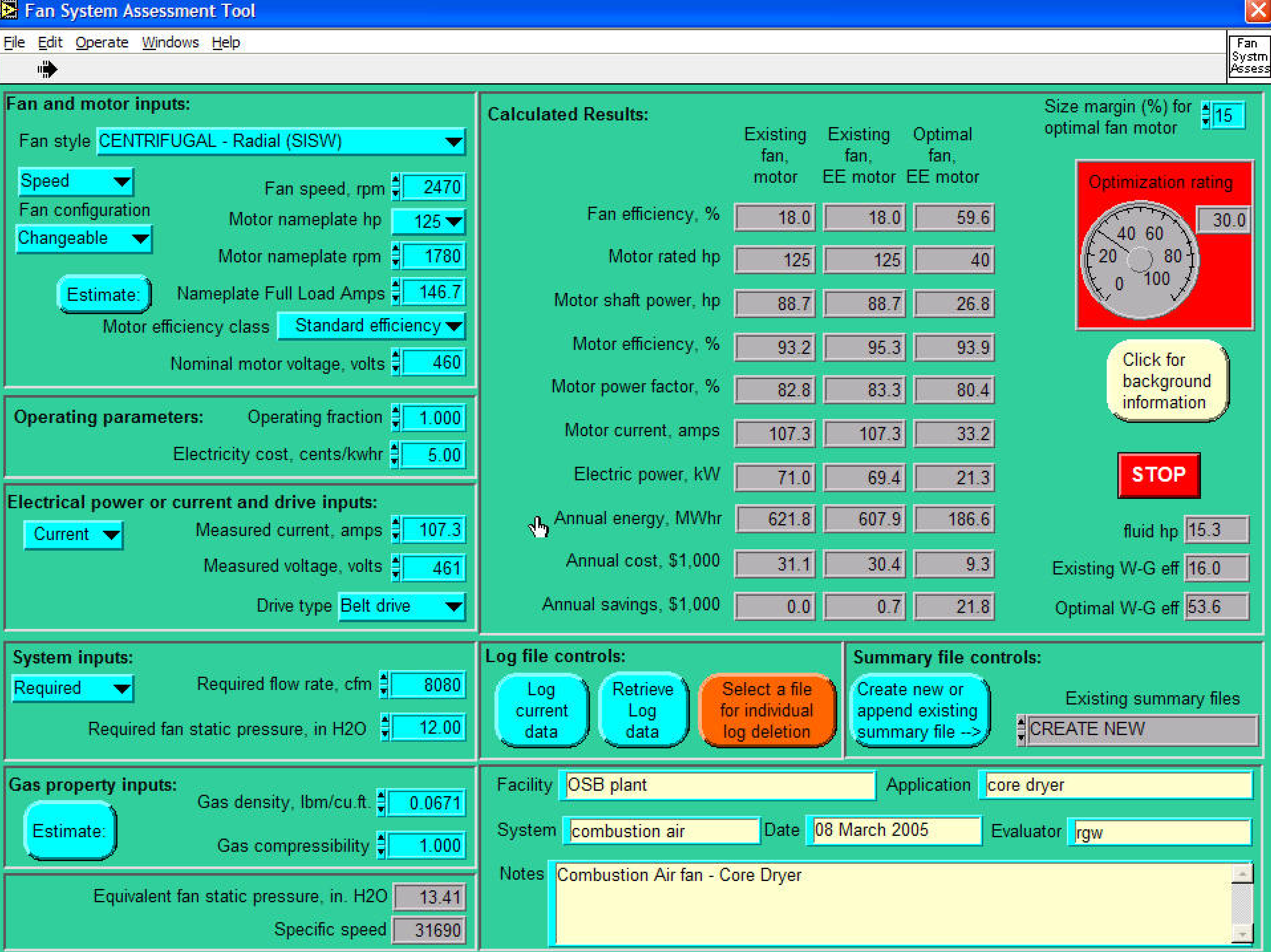
FSAT Inputs - Key Points

- **Fill in the <u>FSAT Data Collection Worksheet</u> for your fan.**
- **Make note of how much pressure is being developed vs. what is needed.**
- **Enter the information in FSAT.**
- **If you do not know density, use the calculator.**
- **Wait until all data is entered to look at results**



Demonstration




Fan System Assessment Tool
File Edit Operate Windows Help
Fan Systm Assess
Fan and motor inputs:
Fan style CENTRIFUGAL - Radial (SISW)
Speed
Fan speed, rpm 2470
Fan configuration
Changeable
Motor nameplate hp 125
Motor nameplate rpm 1780
Estimate:
Nameplate Full Load Amps 146.7
Motor efficiency class Standard efficiency
Nominal motor voltage, volts 460
Operating parameters:
Operating fraction 1.000
Electricity cost, cents/kwhr 5.00
Electrical power or current and drive inputs:
Current
Measured current, amps 107.3
Measured voltage, volts 461
Drive type Belt drive
System inputs:
Required
Required flow rate, cfm 8080
Required fan static pressure, in H2O 12.00
Gas property inputs:
Gas density, lbm/cu.ft. 0.0671
Estimate:
Gas compressibility 1.000
Equivalent fan static pressure, in. H2O 13.41
Specific speed 31690
Calculated Results:
Existing fan, motor
Existing fan, EE motor
Optimal fan, EE motor
Fan efficiency, % 18.0 18.0 59.6
Motor rated hp 125 125 40
Motor shaft power, hp 88.7 88.7 26.8
Motor efficiency, % 93.2 95.3 93.9
Motor power factor, % 82.8 83.3 80.4
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Annual energy, MWhr 621.8 607.9 186.6
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Optimization rating
30.0
0 20 40 60 80 100
Click for background information
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Log file controls:
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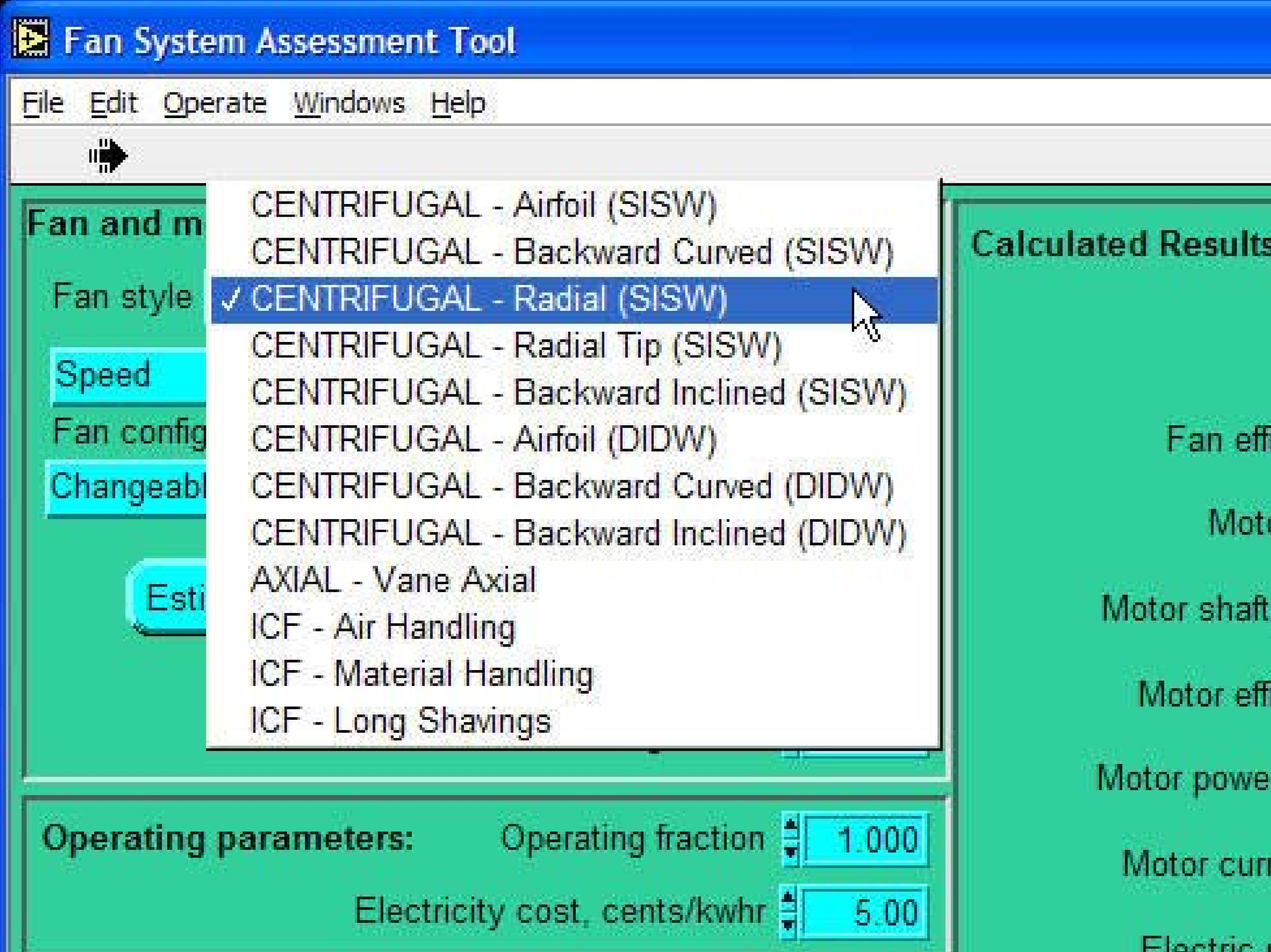
Existing summary files
CREATE NEW
Facility OSB plant
Application core dryer
System combustion air
Date 08 March 2005
Evaluator rgw
Notes Combustion Air fan - Core Dryer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CENTRIFUGAL - Backward Curved (DIDW)
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ICF - Air Handling
ICF - Material Handling
ICF - Long Shavings
Calculated Results
Fan eff
Moto
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Motor powe
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Operating parameters:
Operating fraction
1.000
Electricity cost, cents/kwhr
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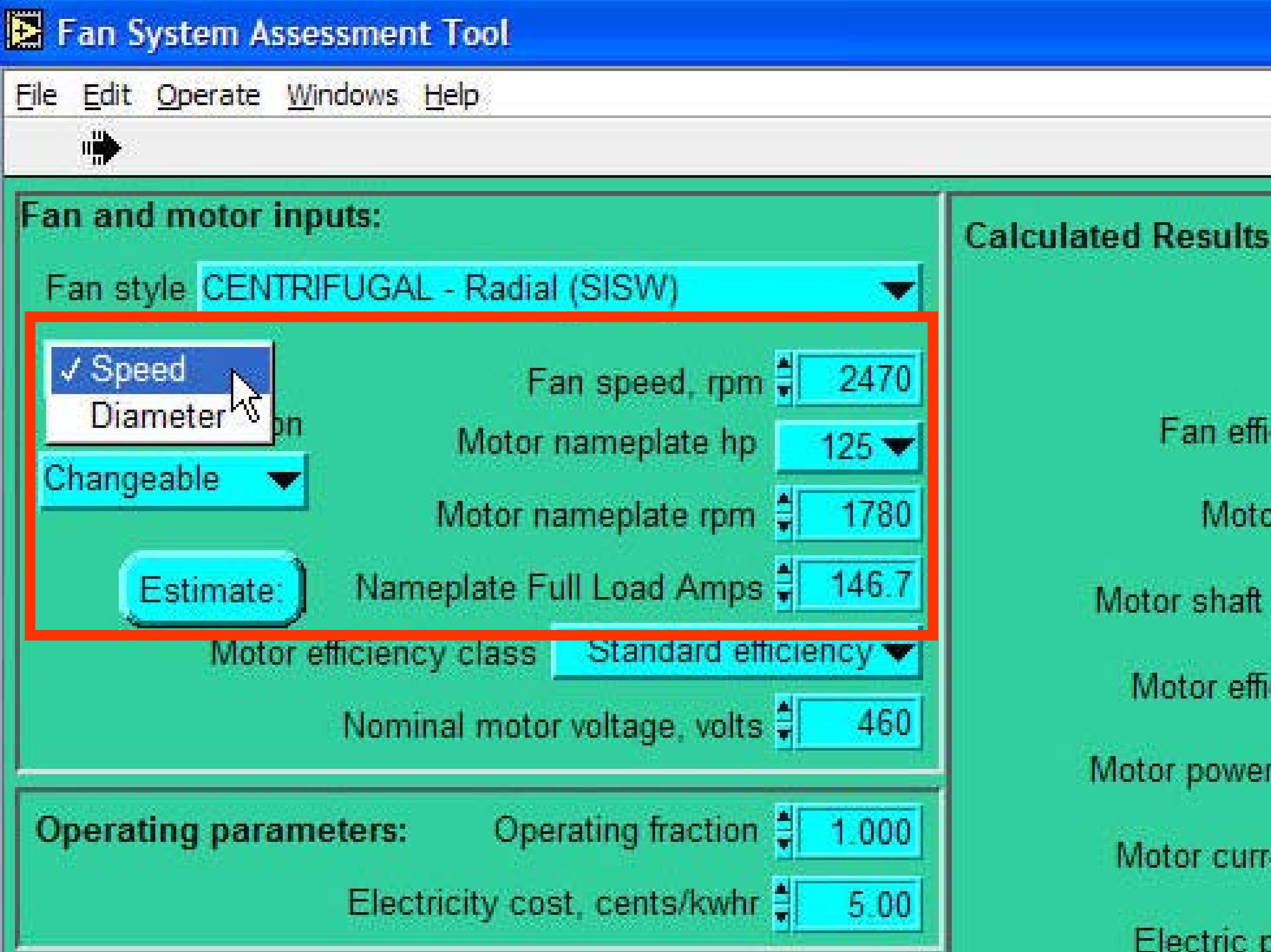
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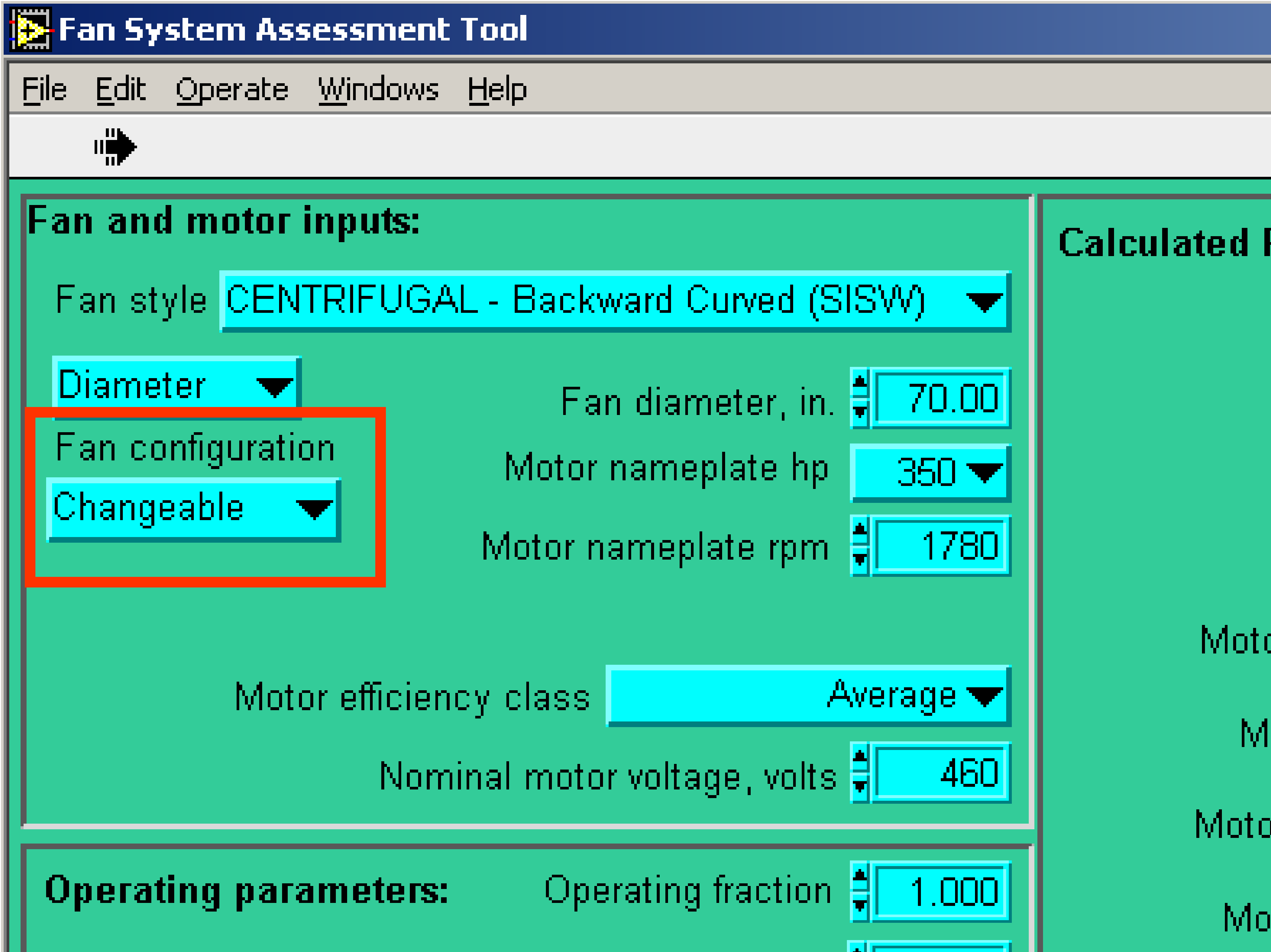
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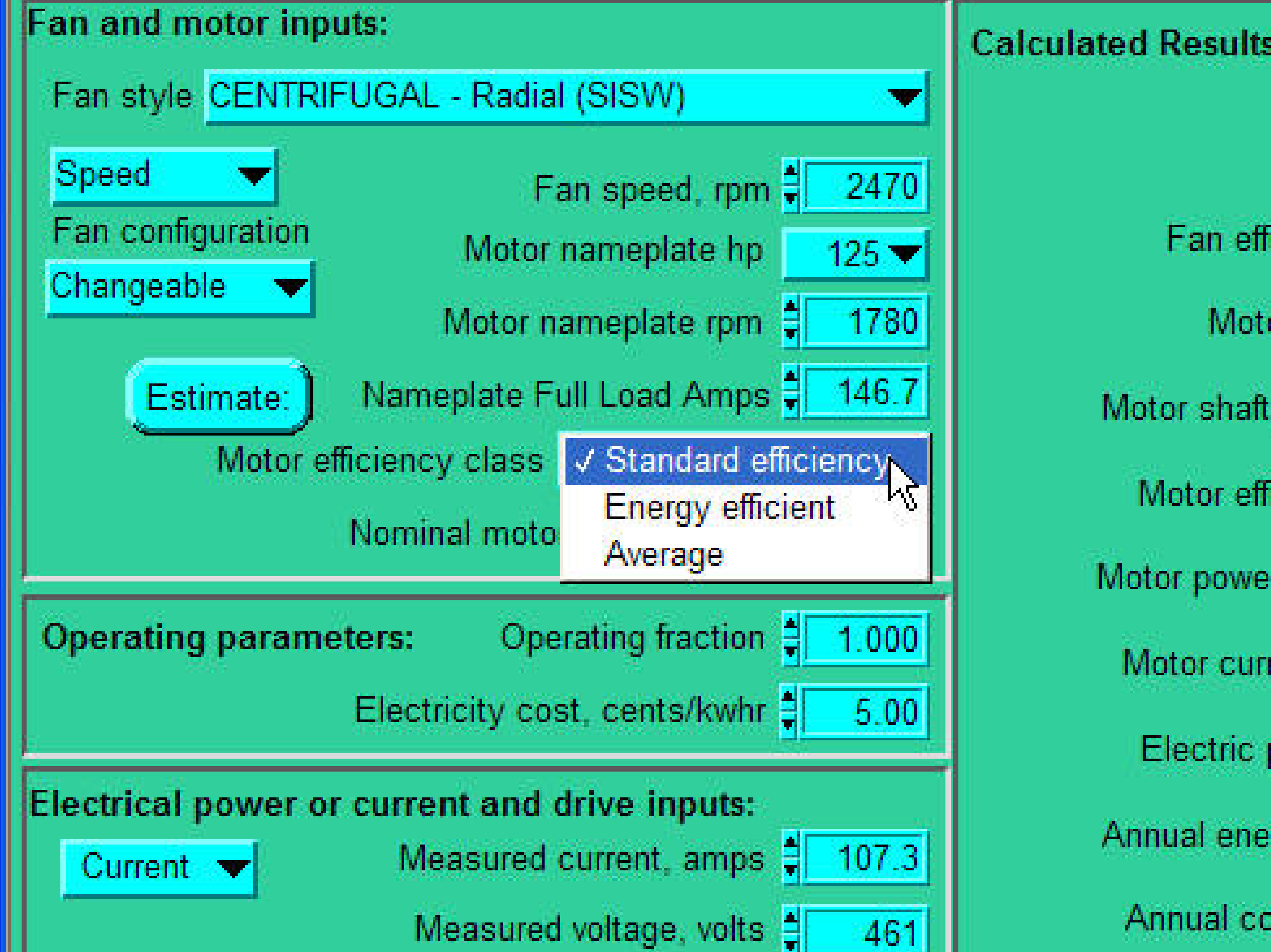
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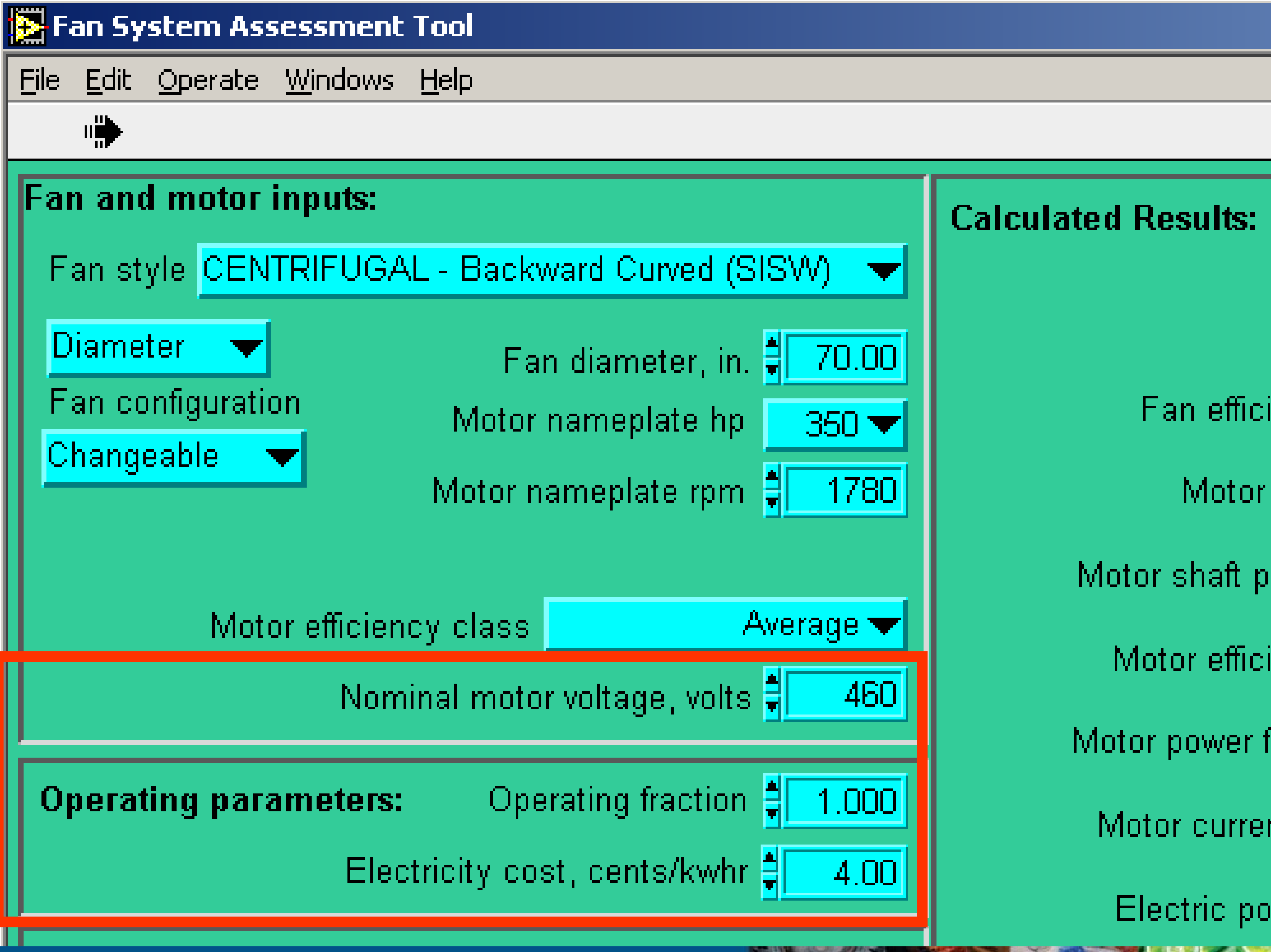
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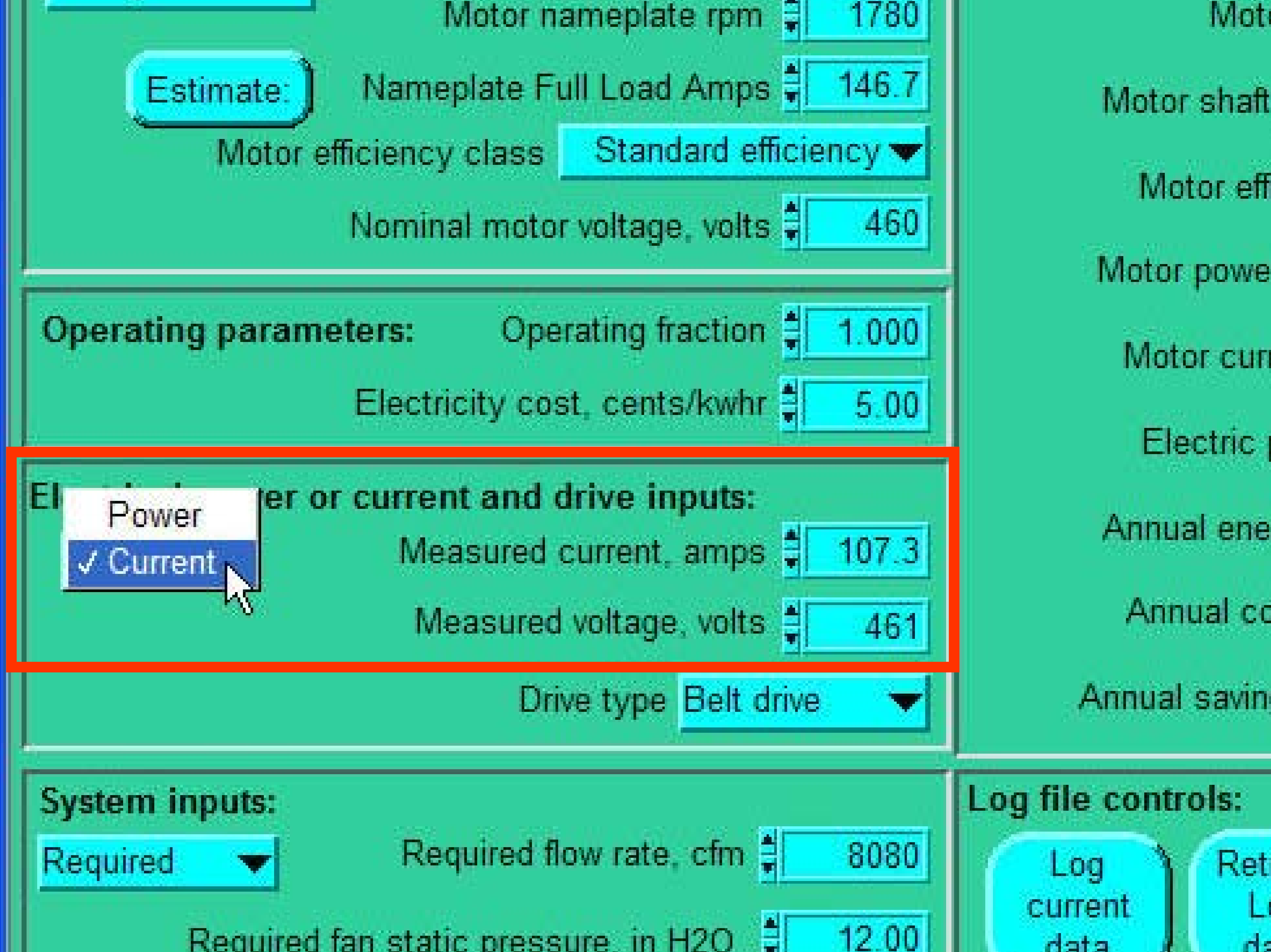

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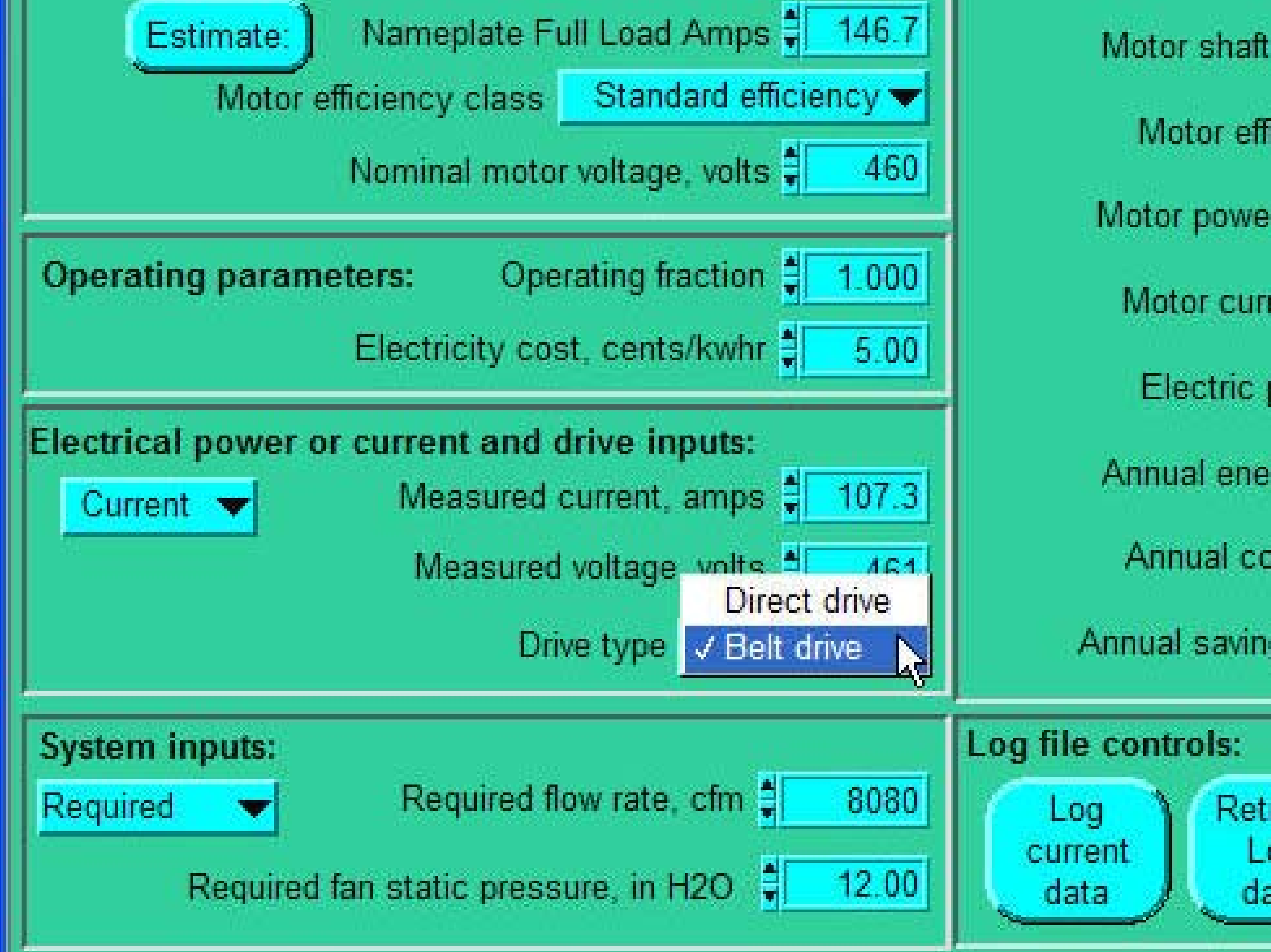
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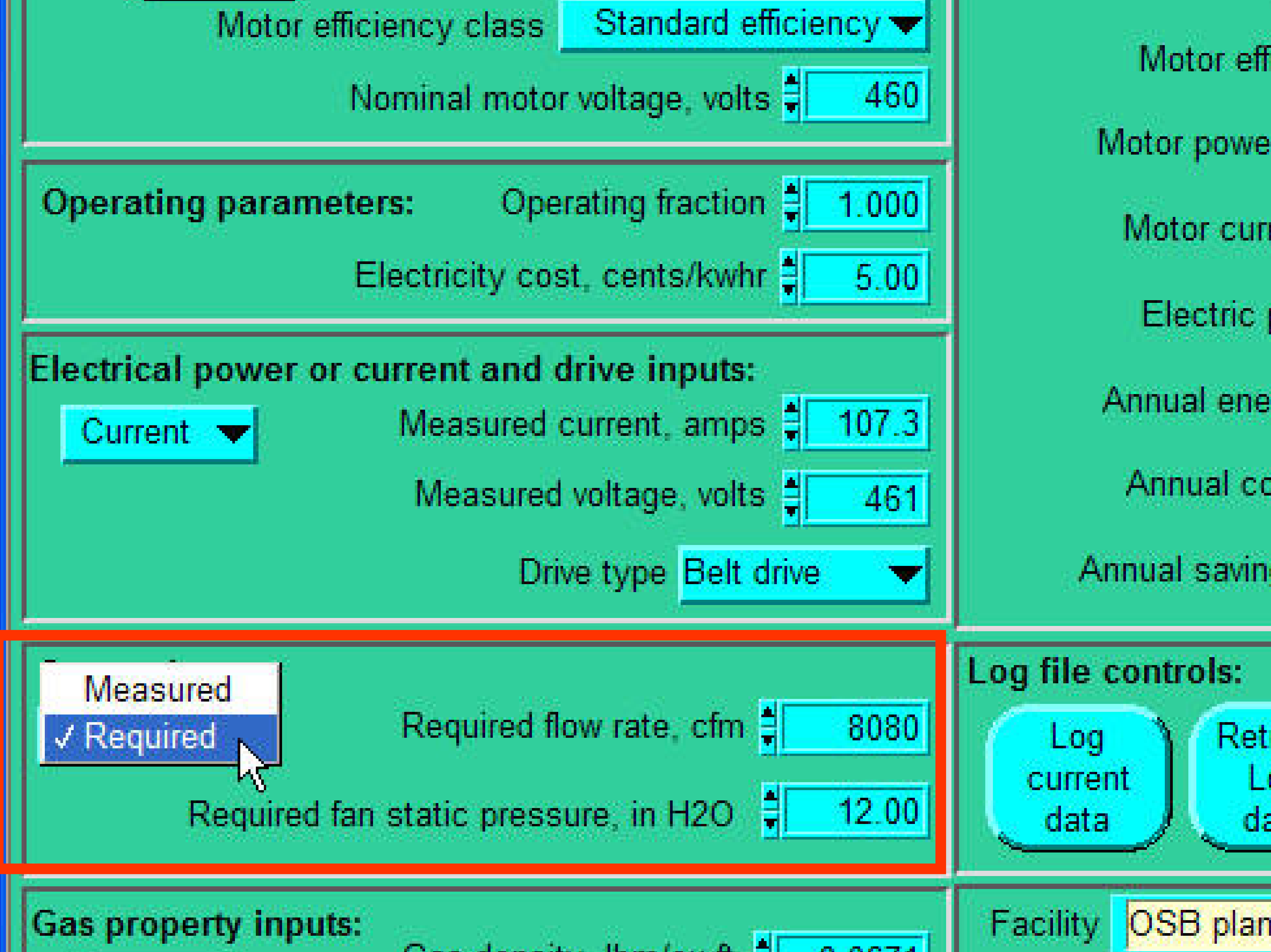
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Facility

Return to
Motor Efficiency Factors

% full load amps
% FLA fit
power factor (%)
power factor fit
efficiency (%)
efficiency fit

Nameplate hp: 125

Synch. rpm: 1800

Rated voltage: 460

Motor class: Standard efficiency

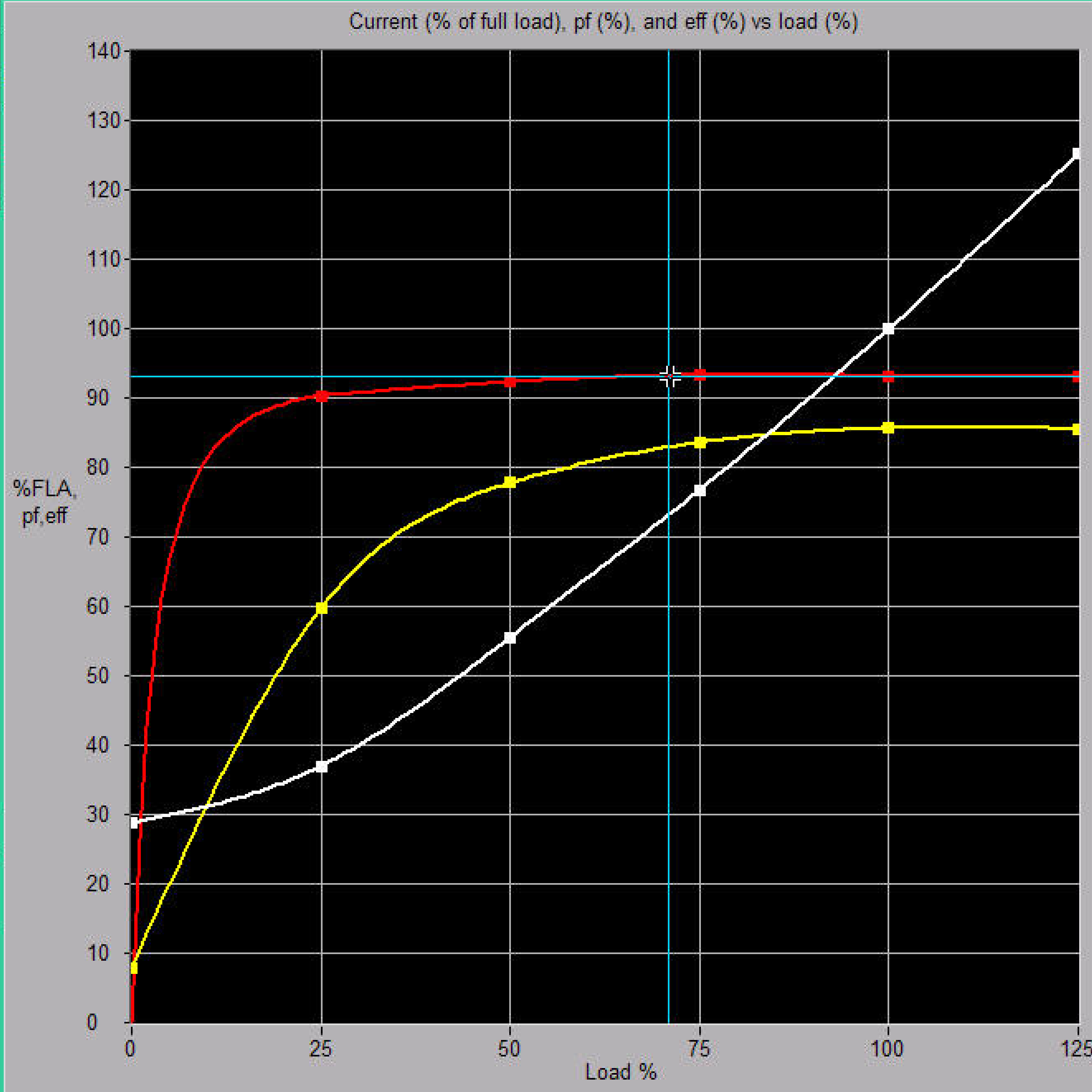
Energy efficiency standards (NEMA MG1 Table 12-10) — ODP: 94.50; TEFC: 94.50

Full load amps: 146.70

Current, power factor, efficiency

% load	%FL amps	pf%	eff%
25	36.99	59.71	90.31
50	55.60	77.76	92.27
75	76.75	83.59	93.27
100	100.00	85.63	93.17

A 71.0 95.1



Return to
Motor Efficiency Factors

% full load amps
% FLA fit
power factor (%)
power factor fit
efficiency (%)
efficiency fit

Nameplate hp 20

Synch. rpm 1800

Rated voltage 460

Motor class Standard efficiency

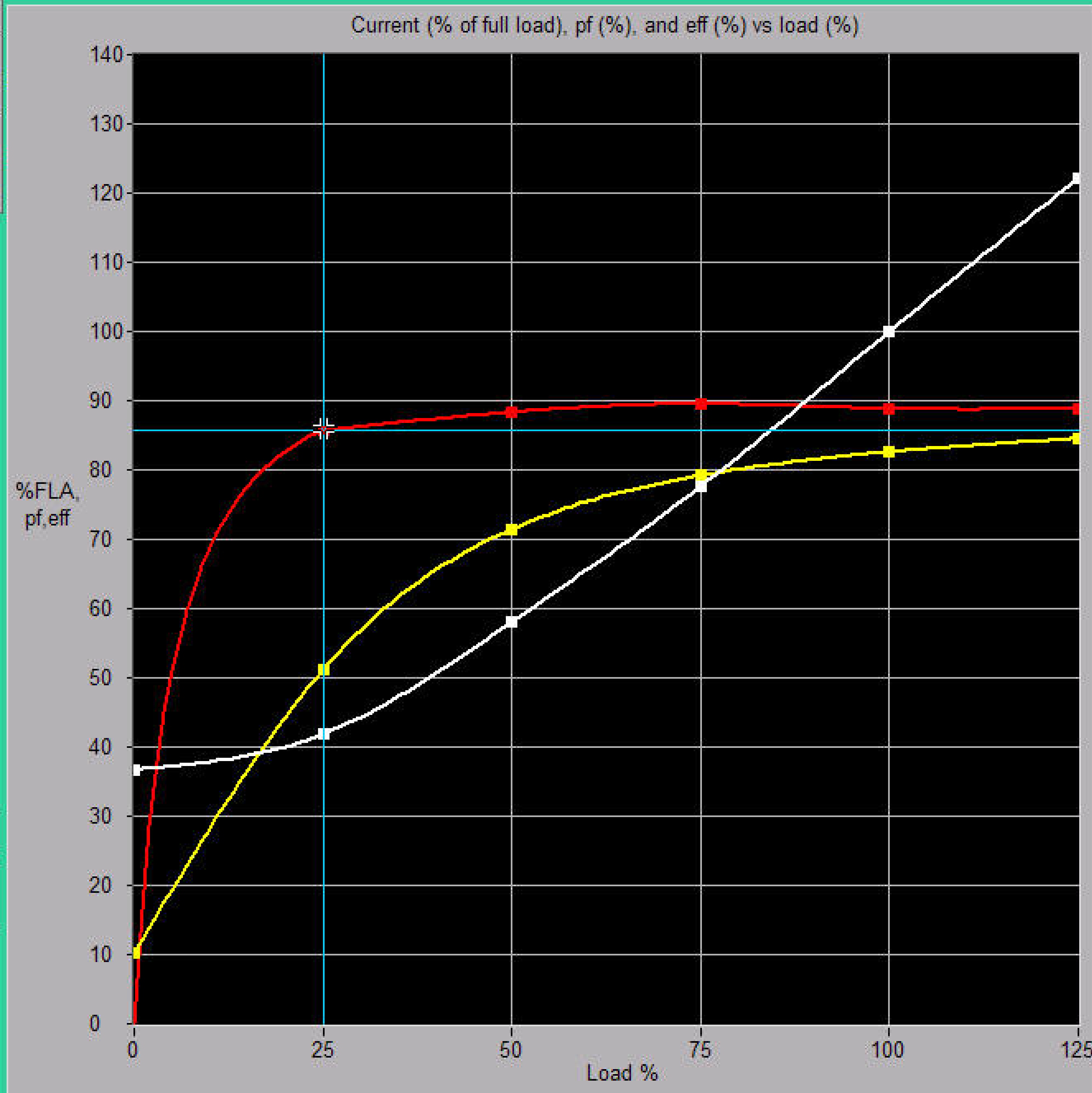
Energy efficiency standards (NEMA MG1 Table 12-10) ODP 91.00 TEFC 91.00

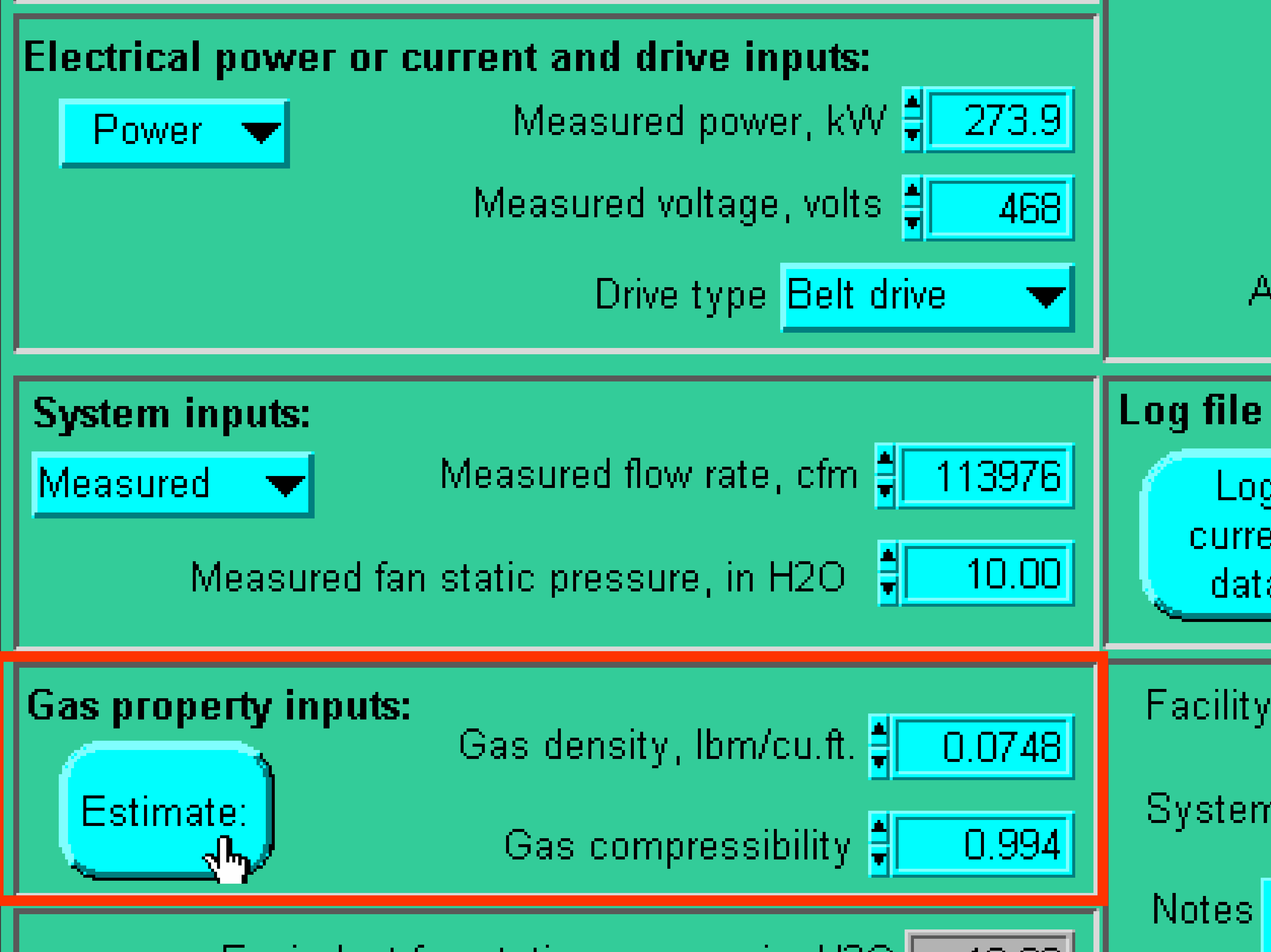
Full load amps 25.54

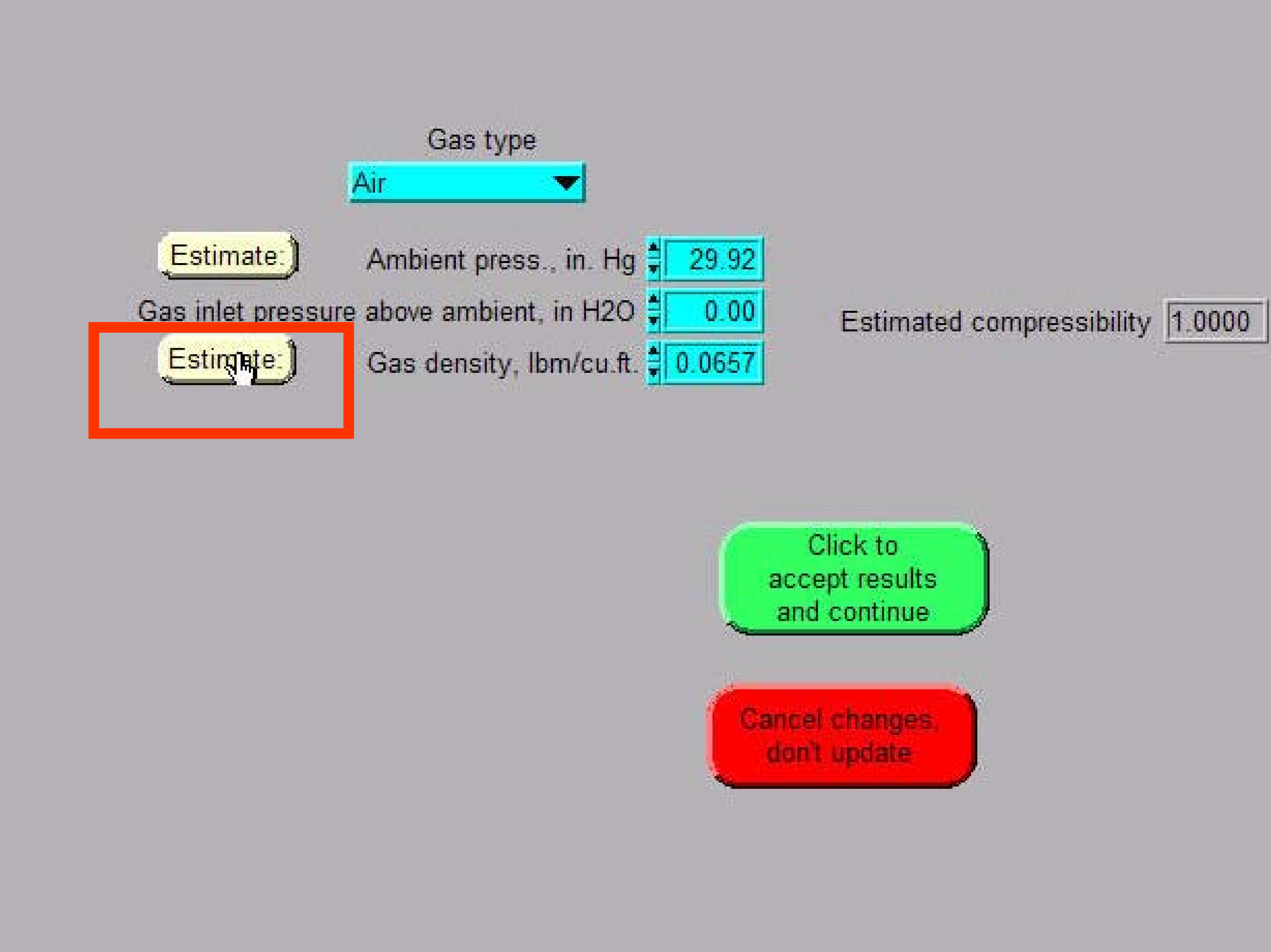
Current, power factor, efficiency

% load	%FL amps	pf%	eff%
25	41.83	51.15	85.67
50	58.08	71.48	88.32
75	77.62	79.18	89.48
100	100.00	82.57	88.80

A 25.0 85.7




Electrical power or current and drive inputs:
Power
Measured power, kW
273.9
Measured voltage, volts
468
Drive type
Belt drive
System inputs:
Measured
Measured flow rate, cfm
113976
Measured fan static pressure, in H2O
10.00
Log file
Gas property inputs:
Estimate:
Gas density, lbm/cu.ft.
0.0748
Gas compressibility
0.994
Facility
System
Notes


Gas type
Air
Estimate:
Ambient press., in. Hg
29.92
Gas inlet pressure above ambient, in H2O
0.00
Estimated compressibility
1.0000
Estimate:
Gas density, lbm/cu.ft.
0.0657
Click to accept results and continue
Cancel changes, don't update

inlet above ambient pressures will be reflected in the values shown on the panel that called on this estimator. If changes are made to either after leaving this estimator, the density will NOT be updated to reflect those changes unless the user returns here.

Inlet dry bulb temperature, deg F	128.00
Absolute ambient pressure, in Hg	29.92
Air inlet pressure above ambient, in H20	0.00
Inlet relative humidity, %	50.0

Data type
- ✓ Relative humidity
- Dew point temperature
- Wet bulb temperature

Saturation pressure, psia	2.1091E+0
Water vapor partial pressure, psia	1.0545E+0
Humidity ratio, W	4.8083E-2
Saturation humidity ratio, W_s	1.0422E-1
Degree of saturation, μ	0.461
Specific volume, ft^3/lb dry air	15.96
Enthalpy, B/lb	84.47
Dewpoint, deg F	103.49
Wet bulb temperature	106.80
Actual air density, lbm/cu.ft.	6.5668E-2
Relative humidity, %	50.00

Print a copy of the calculated data

Click to accept results and continue

Cancel changes, don't update

Absolute inlet pressure, in. Hg	29.92
Absolute inlet pressure, in. H2O	407.46
Absolute inlet pressure, psia	14.70

With the exception of the saturation pressure values for temperatures of 32 F and above, all results are based on methods described in the ASHRAE Fundamentals Handbook (1997), Chapter 6, Psychrometrics.

The terms are consistent with those used in the ASHRAE publication.

The saturation pressures for temperatures above 32 F are based on the algorithm used in Steam Tables, by Keenan, Keyes, Hill, and Moore (1969 edition).

Questions & Answers

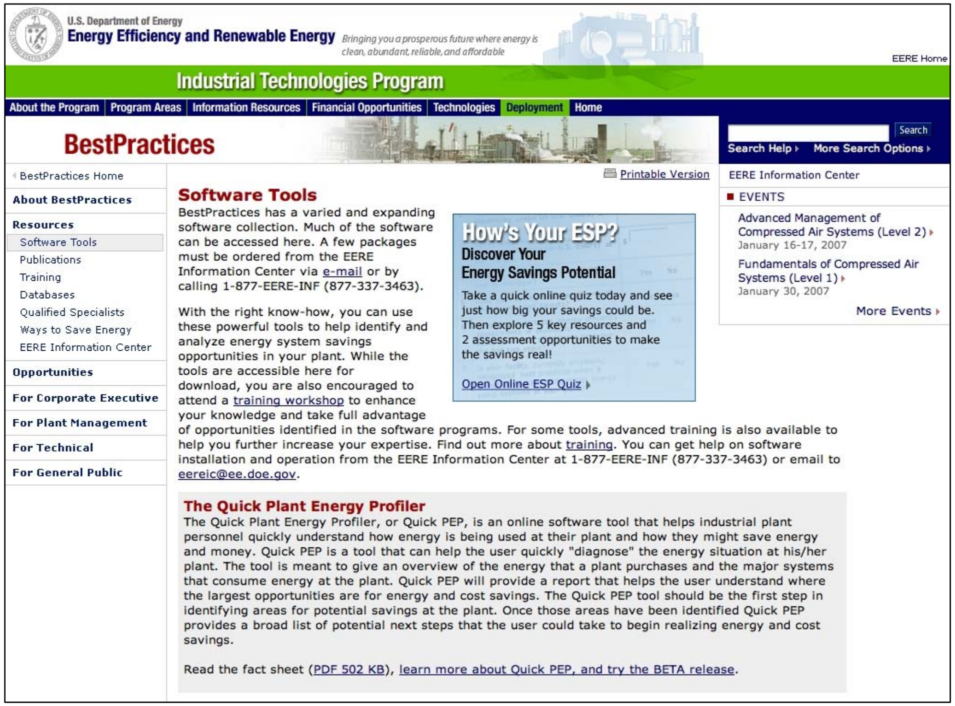
Summary

- Use the Fan System Optimization checklist to:
  - Identify poorly performing fan systems
  - Justify resources to develop project ideas into implementation plans
- Use the FSAT Tool at your plant to:
  - Identify cost impacts of poorly performing fan systems
  - Identify cost effective projects
  - Justify capital projects at corporate level
  - Benchmark individual systems at the plant level

Download the Tool

DOE BestPractices Web site:

http://www.eere.energy.gov/industry/bestpractices/software.html



Find Additional Training

Visit the DOE BestPractices Training Web site:

www.eere.energy.gov/industry/bestpractices/training

See the Training Calendar for events in your area:

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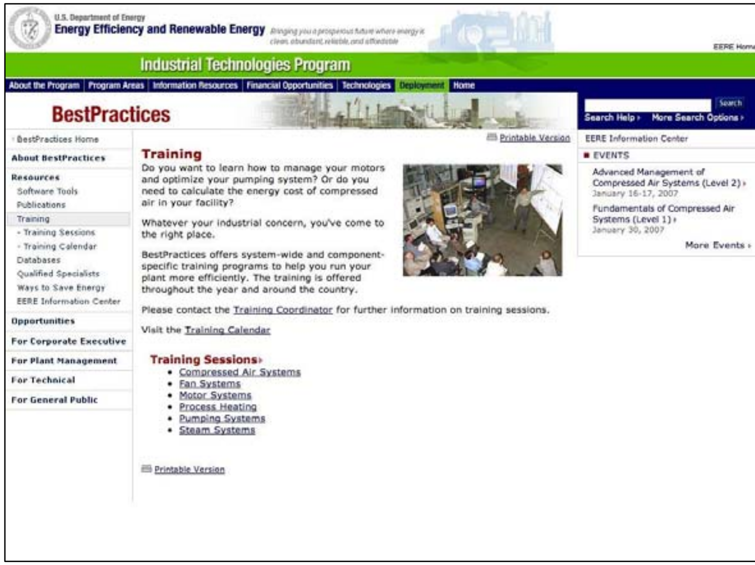
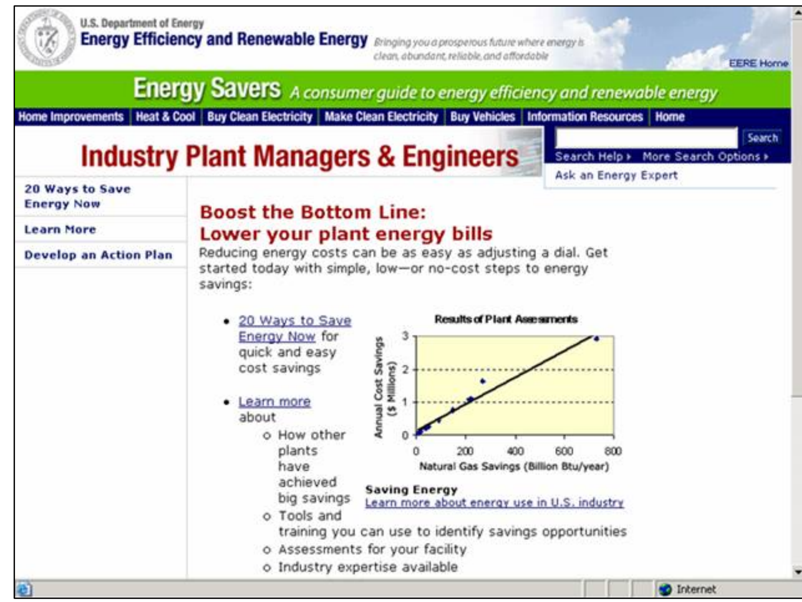
qualified_specialists.html



See the “Industrial Energy Savers” Web Site

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



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Web Site and Resources

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

Industrial Technologies Program (ITP) Web site:

www.eere.energy.gov/industry/

BestPractices Web site:

www.eere.energy.gov/industry/bestpractices

Save Energy Now Web site:

www.eere.energy.gov/industry/saveenergynow

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Acknowledgments

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