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

#### Fan and motor inputs:
- **Fan style**: CENTRIFUGAL - Backward Curved (SISW)
- **Fan diameter, in.**: 70.00
- **Motor nameplate hp**: 350
- **Motor nameplate rpm**: 1760
- **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 flow rate, cfm**: 113976
- **Measured fan static pressure, in H2O**: 10.00

#### Gas property inputs:
- **Gas density, lbm/cu.ft.**: 0.0748
- **Gas compressibility**: 0.994
- **Equivalent fan static pressure, in H2O**: 10.03
- **Specific size**: 0.370

#### Calculated Results:
<table>
<thead>
<tr>
<th></th>
<th>Existing fan, motor</th>
<th>Existing fan, EE motor</th>
<th>Optimal fan, EE motor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fan efficiency, %</strong></td>
<td>53.1</td>
<td>53.1</td>
<td>81.4</td>
</tr>
<tr>
<td><strong>Motor rated hp</strong></td>
<td>350</td>
<td>350</td>
<td>300</td>
</tr>
<tr>
<td><strong>Motor shaft power, hp</strong></td>
<td>350.0</td>
<td>350.0</td>
<td>228.3</td>
</tr>
<tr>
<td><strong>Motor efficiency, %</strong></td>
<td>95.3</td>
<td>95.6</td>
<td>95.9</td>
</tr>
<tr>
<td><strong>Motor power factor, %</strong></td>
<td>87.6</td>
<td>87.8</td>
<td>85.0</td>
</tr>
<tr>
<td><strong>Motor current, amps</strong></td>
<td>385.8</td>
<td>382.6</td>
<td>257.9</td>
</tr>
<tr>
<td><strong>Electric power, kW</strong></td>
<td>273.9</td>
<td>272.4</td>
<td>177.6</td>
</tr>
<tr>
<td><strong>Annual energy, MWhr</strong></td>
<td>2399.4</td>
<td>2366.5</td>
<td>1555.5</td>
</tr>
<tr>
<td><strong>Annual cost, $1,000</strong></td>
<td>96.0</td>
<td>95.5</td>
<td>52.2</td>
</tr>
<tr>
<td><strong>Annual savings, $1,000</strong></td>
<td>0.0</td>
<td>0.5</td>
<td>33.8</td>
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#### 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

**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

Fan Curve at High Speed

Flow

Pressure

Fan Curve at Lower Speed
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?

\[ \eta = \frac{\text{output}}{\text{input}} \quad \text{or} \quad \eta = \frac{\text{Useful Output}}{\text{Energy Input}} \]

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
### FSAT Calculated Results

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### Fan System Assessment – Introduction
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, then add points for size and run hours as follows: 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 not good candidates for optimization.

Fan System

Are there problems with the system?

<table>
<thead>
<tr>
<th>Points**</th>
<th>Motor _____ hp</th>
<th>Points*</th>
<th>Operating hours</th>
<th>Tally the points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control</th>
<th>Production &amp; Maintenance</th>
<th>System Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Points</td>
<td>Points</td>
</tr>
<tr>
<td>2</td>
<td>Too much flow or pressure for production</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Unstable or hard to control system</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Unreliable system breaks down regularly</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>Not enough flow or pressure for production</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>System is excessively noisy</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Buildup on fan blades</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Need to weld ductwork cracks regularly</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Radial fan handling clean air</td>
<td>1</td>
</tr>
</tbody>
</table>

Facility/Contact/phone/fax: _______________________

See full size handout
FSAT Data Collection Worksheet

System Name ________________________

FAN AND MOTOR

- Arfoi SISW
- Backward Curved SISW
- Backward Inclined SISW
- Arfoi 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: E Energy Efficient  S Standard Efficient  U 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: E Direct  S 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

See full size handout
FSAT Inputs - Key Points

- Fill in the FSAT Data Collection Worksheet 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

Fan and motor inputs:

- Fan style: CENTRIFUGAL - Radial (SISW)
- Speed: ✔
- Diameter: ▼
- Changeable: ▼
- Estimate: ▼
- Fan speed, rpm: 2470
- Motor nameplate hp: 125
- Motor nameplate rpm: 1780
- 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

Calculated Results
## Fan System Assessment Tool

### Fan and motor inputs:
- **Fan style**: CENTRIFUGAL - Backward Curved (SISW)
- **Diameter**:
- **Fan configuration**: Changeable
- **Fan diameter, in.**: 70.00
- **Motor nameplate hp**: 350
- **Motor nameplate rpm**: 1780
- **Motor efficiency class**: Average
- **Nominal motor voltage, volts**: 460

### Operating parameters:
- **Operating fraction**: 1.000
Fan and motor inputs:

- Fan style: CENTRIFUGAL - Backward Curved (SISW)
- Diameter: 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
## Engineering Data Sheet

### Motor Specifications
- **Motor nameplate rpm**: 1780
- **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
- **Measured current, amps**: 107.3
- **Measured voltage, volts**: 461
- **Drive type**: Belt drive

### System Inputs
- **Required flow rate, cfm**: 8080
- **Required fan static pressure, in H2O**: 12.00

### Log File Controls
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: Direct drive
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
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: Current
- Measured current, amps: 107.3
- Measured voltage, volts: 461
- Drive type: Belt drive

Required flow rate, cfm: 8080
Required fan static pressure, in H2O: 12.00
Gas type: Air

- Ambient press., in. Hg: 29.92
- Gas inlet pressure above ambient, in H2O: 0.00
- Gas density, lbm/cu.ft.: 0.0657

Estimated compressibility: 1.0000

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 H2O: 0.00
Inlet relative humidity, %: 50.0

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, %: 50.0

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

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

Become a Qualified Specialist:
www.eere.energy.gov/industry/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
EERE Information Center

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

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E-mail: eereic@ee.doe.gov
Web site: www.eere.energy.gov/informationcenter
Web Site and Resources

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

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www.eere.energy.gov/industry/

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www.eere.energy.gov/industry/bestpractices

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www.eere.energy.gov/industry/saveenergynow

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Acknowledgments

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