

# Furnace Fans

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## 1. Scope

The ENERGY STAR furnace eligibility requirements will eventually reference the DOE furnace fan test procedure, currently under development. The final rule for the DOE test procedure is expected to be published in April 2012. Prior to the publication of the DOE test procedure, the ENERGY STAR furnace eligibility requirements will reference this test approach. This test approach duplicates that stipulated in EISA 2007.

## 2. Definitions

**Advanced Main Circulating Fan:** A fan used in a furnace which is more efficient than a standard Furnace Fan (defined below). It is a high efficiency class of Furnace Fan, which includes those that have an annual electricity use of no more than two percent of the total annual energy use of the furnace.

**ANSI/ASHRAE Standard 103–1993:** The test standard published in 1993 by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), approved by the American National Standards Institute (ANSI) on October 4, 1993, and entitled “Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers” (with errata of October 24, 1996).

**Annual Fuel Utilization Efficiency (AFUE):** The ratio of annual output energy to annual input energy, which includes any non-heating-season pilot input loss and, for gas or oil-fired furnaces or boilers, does not include electric energy.

**Burner Operating Hours for Furnaces Equipped with Single Stage Controls (BOH<sub>ss</sub>):** The national average number of burner operating hours for furnaces equipped with single-stage controls.

### Control Configurations:

**Single Stage Control:** A control that cycles a burner between the maximum heat input rate and “off”.

**Step Modulating Control:** A modulating control that cycles a burner between the reduced input rate and “off” if the heating load is light. If a higher heating load is encountered that cannot be met with the reduced input rate, the control goes into a modulating mode where it either gradually or incrementally increases the input rate to meet the higher heating load. At that point, if a lower heating load is encountered, the control either gradually or incrementally decreases to the reduced input rate.

**Two Stage Control:** A modulating control that both cycles a burner between reduced heat input rate and “off” and between the maximum heat input rate and “off”. It may also switch from “off” to reduced fire to high fire to “off” under certain load conditions.

**e:** A percent of the total annual energy use of the furnace.

**$E_{AE}$ :** Average annual auxiliary electrical energy consumption for gas or oil-fired furnaces, expressed in kilowatt hours (kWh).

**$E_f$ :** Average annual fuel energy consumption for gas or oil fueled furnaces expressed in British thermal units (Btu), and calculated using the equations defined in Section 3, *Test Approach and Calculation Methodology*.

**$E_{Fan}$ :** Annual electricity use of the Advanced Main Circulating Fan, expressed in kWh.

**$E_M$ :** Average annual energy use during the heating season, expressed in Btu.

**Furnace Fan:** An electrically powered device used in residential central heating, ventilation, and air conditioning (HVAC) systems for the purposes of circulating air through duct work. A furnace fan consists of a fan motor and its controls, an impeller, and sheet metal housing.

**Natural Gas Furnace:** A furnace with natural gas as the energy source.

**Oil Furnace:** A furnace with oil as the energy source.

**Operation Modes:**

**Active Mode:** The mode of operation during which the Furnace Fan is powered and the impeller is in motion. A Furnace Fan is in active mode during the heating season in which the furnace or boiler is connected to the power source, and the burner, electric resistance elements, or any electrical auxiliaries such as blowers or pumps, are activated.

**Standby mode:** The mode of operation during which the Furnace Fan is powered and the impeller is not in motion. A Furnace Fan is in standby mode during the heating season in which the furnace or boiler is connected to the power source, and the burner, electric resistance elements, or any electrical auxiliaries such as blowers or pumps, are not activated.

**Off mode:** The mode of operation during which the Furnace Fan is not powered. A Furnace Fan is in off mode during the non-heating season in which the furnace or boiler is connected to the power source, and the burner, electric resistance elements, and any electrical auxiliaries such as blowers or pumps, are not activated.

**Propane Furnace:** A furnace with propane as an energy source.

**$Q_{IN}$ :** Fuel energy maximum nameplate input rate at steady-state operation, including any pilot light input, expressed in Btu/h.

**$Q_p$ :** Fuel energy input rate to pilot light, expressed in Btu/h.

### 3. Test Approach<sup>1</sup> and Calculation Methodology

The annual electricity use of the Advanced Main Circulating Fan ( $E_{Fan}$ ) shall not exceed a defined percent,  $e$ , of the total annual energy use of the furnace:

$$E_{Fan} = e \times E_F \quad (1)$$

where<sup>2</sup>:

For furnaces fueled by gas or oil and equipped with single stage controls

$$e = \frac{E_{AE} \times 3,412}{(E_{AE} \times 3,412) + (E_F)} \quad (2)$$

$$E_F = BOH_{SS} \times (Q_{IN} - Q_P) + 8,760 \times Q_P \quad (3)$$

For furnaces fueled by gas or oil and equipped with two-stage or step modulating controls

$$e = \frac{E_{AE} \times 3,412}{(E_{AE} \times 3,412) + (E_F)} \quad (4)$$

$$E_F = E_M + 4,600 \times Q_P \quad (5)$$

Additional information, including a full set of detailed equations, is available in the following locations:

1. In the Code of Federal Regulations (CFR), Title 10, Appendix N to Subpart B of Part 430, found here: <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=91ed077a2062df92f6e8cb313723a981&rgn=div9&view=text&node=10:3.0.1.4.16.2.9.6.14&idno=10>.
2. In ANSI/ASHRAE Standard 103–1993, which is available for purchase here: [http://www.techstreet.com/cgi-bin/detail?doc\\_no=ASHRAE|103\\_1993&product\\_id=4146](http://www.techstreet.com/cgi-bin/detail?doc_no=ASHRAE|103_1993&product_id=4146).

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<sup>1</sup> Detailed test set-up and test approach are documented in ANSI/ASHRAE Standard 103-1993.

<sup>2</sup> As defined in the Code of Federal Regulations, Title 10, Appendix N to Subpart B of Part 430. Full summary available here: <http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=95cff987bc3e0a1c94bba37afe439cbf&rgn=div9&view=text&node=10:3.0.1.4.16.2.9.6.14&idno=10>

## 4. Appendices

### A. Additional Equations

The following equations only apply to  $E_f$ , the average annual fuel energy consumption for gas or oil fueled furnaces, and are required to complete the calculations in the equations above. Constants and variables in these equations not already defined are defined in Table 1 of Appendix 4B.

For furnaces fueled by gas or oil and equipped with single stage controls

**Average Annual Auxiliary Electrical Energy Consumption:**

$$E_{AE} = BOH_{SS} \times (y_P PE + y_{IG} PE_{IG} + y_{BE}) + E_{SO} \quad (A1)$$

For furnaces fueled by gas or oil and equipped with two-stage controls

**Average Annual Auxiliary Electrical Energy Consumption:**

$$E_{AE} = BOH_R \times (y_P PE_R + y_{IG} PE_{IG} + y_{BE_R}) + BOH_H \times (y_P PE_H + y_{IG} PE_{IG} + y_{BE_H}) + E_{SO} \quad (A2)$$

**Average Annual Energy Use during the Heating Season:**

$$E_M = (Q_{IN} - Q_P) \times BOH_{SS} + (8,760 - 4,600) \times Q_P \quad (A3)$$

For furnaces fueled by gas or oil and equipped with step modulating controls

**Average Annual Auxiliary Electrical Energy Consumption:**

$$E_{AE} = BOH_R \times (y_P PE_R + y_{IG} PE_{IG} + y_{BE_R}) + BOH_M \times (y_P PE_H + y_{IG} PE_{IG} + y_{BE_H}) + E_{SO} \quad (A4)$$

**Average Annual Energy Use during the Heating Season:**

$$E_M = (Q_{IN} - Q_P) \times BOH_{SS} + (8,760 - 4,600) \times Q_P \quad (A5)$$

## B. Additional Constants and Variables

The remaining constants and variables for use in Equations (1) through (5) and (A1) and (A5) are defined in Table 1, as specified in the CFR, Title 10, Appendix N to Subpart B of Part 430 and ANSI/ASHRAE Standard 103–1993.

**Table 1: Equation Constants and Variables**

<b>Constant</b>	<b>Definition</b>
<b>3,412</b>	Conversion to express energy in terms of kWh instead of Btu
<b>4,600</b>	Average non-heating season hours per year
<b>8,760</b>	Total number of hours per year
<b>Variable</b>	<b>Definition</b>
<b>A</b>	Coefficient for test fuel (more details in Table 8 of ANSI/ASHRAE Standard 103–1993) = $100,000 / [341,300(y_p PE + y_{IG} PE_{IG} + y_{BE}) + (Q_{IN} - Q_p) Eff_{HS}]$ , for forced draft unit, indoors; = $100,000 / [341,300(y_p PE Eff_{motor} + y_{IG} PE_{IG} + y_{BE}) + (Q_{IN} - Q_p) Eff_{HS}]$ , for forced draft unit, Isolated Combustion System (ICS) <sup>3</sup> ; = $100,000 / [341,300(y_p PE(1 - Eff_{motor}) + y_{IG} PE_{IG} + y_{BE}) + (Q_{IN} - Q_p) Eff_{HS}]$ , for induced draft unit, indoors; and = $100,000 / [341,300(y_{IG} PE_{IG} + y_{BE}) + (Q_{IN} - Q_p) Eff_{HS}]$ , for induced draft unit, ICS.
<b>B</b>	Coefficient for test fuel (more details in Table 8 of ANSI/ASHRAE Standard 103–1993) = $2 Q_p (Eff_{HS})(A) / 100,000$
<b>BE</b>	Circulating air fan or water pump electrical input rate at full load steady-state operation, as defined in ANSI/ASHRAE Standard 103-1993.
<b>BE<sub>H</sub></b>	Circulating air fan or water pump electrical input rate measured at the maximum fuel input rate
<b>BE<sub>R</sub></b>	Circulating air fan or water pump electrical input rate measured at the reduced fuel input rate
<b>BOH<sub>H</sub></b>	The national average number of burner operating hours for furnaces equipped with two-stage controls operating at the maximum operating mode
<b>BOH<sub>M</sub></b>	The national average number of burner operating hours for furnaces equipped with step modulating controls operating in the modulating mode
<b>BOH<sub>R</sub></b>	The national average number of burner operating hours for furnaces equipped with two-stage or step modulating controls operating at the reduced operating mode
<b>Eff<sub>HS</sub></b>	Heating Seasonal Efficiency (expressed in %)
<b>Eff<sub>motor</sub></b>	Power burner motor efficiency provided by manufacture or = 0.50 if none provided by manufacturer.
<b>E<sub>SO</sub></b>	Average annual electric standby mode and off mode energy consumption, expressed in kWh.

<sup>3</sup> A system where a unit is installed within the structure, but isolated from the heated space. A significant portion of the jacket heat from the unit is lost and air for ventilation, combustion and draft control comes from outside the heated space.

<b>PE</b>	Burner electrical power input at full-load steady-state operation, including electrical ignition device if energized, as defined in 9.1.2.2 of ANSI/ASHRAE Standard 103–1993, expressed in kW
<b>PE<sub>H</sub></b>	Burner electrical power input measured at the maximum fuel input rate, expressed in kW
<b>PE<sub>IG</sub></b>	Electrical input rate to the interrupted ignition device on burner (if employed), expressed in kW
<b>PE<sub>R</sub></b>	Burner electrical power input measured at the reduced fuel input rate, expressed in kW
<b>t<sub>+</sub></b>	Time delay between burner shutdown and blower shutdown (in minutes). If t <sub>+</sub> exceeds 13.3 minutes, then t <sub>+</sub> = 13.3.
<b>t<sub>-</sub></b>	Time between the burner start-up and the blower start-up, in minutes
<b>t<sub>IG</sub></b>	On-time of the burner interrupted ignition device, in minutes
<b>t<sub>P</sub></b>	Post purge time, in minutes
<b>y</b>	Ratio of blower or pump on-time to average burner on-time, as follows: = 1 for furnaces without fan delay; = 1 for boilers without a pump delay; = $1+(t_+ - t_-)/3.87$ for single stage furnaces with fan delay; = $1+(t_+ - t_-)/10$ for two-stage and step modulating furnaces with fan delay; = $1+(t_+/9.68)$ for single stage boilers with pump delay; or = $1+(t_+/15)$ for two stage and step modulating boilers with pump delay.
<b>y<sub>IG</sub></b>	Ratio of burner interrupted ignition device on-time to average burner on-time, as follows: = 0 for burners not equipped with interrupted ignition device; = $(t_{IG}/3.87)$ for single stage furnaces; = $(t_{IG}/10)$ for two-stage and step modulating furnaces; = $(t_{IG}/9.68)$ for single stage boilers; or = $(t_{IG}/15)$ for two stage and step modulating boilers.
<b>y<sub>P</sub></b>	Ratio of induced or forced draft blower on-time to average burner on-time, as follows: = 1 for units without post purge; = $1+(t_P/3.87)$ for single stage furnaces with post purge; = $1+(t_P/10)$ for two-stage and step modulating furnaces with post purge; = $1+(t_P/9.68)$ for single stage boilers with post purge; or = $1+(t_P/15)$ for two stage and step modulating boilers with post purge.