**APPENDIX 6.3. DETERMINATION OF FURNACE AND BOILER ENERGY USE**

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# APPENDIX 6.3. DETERMINATION OF FURNACE AND BOILER ENERGY USE

## 6.3.1 INTRODUCTION

The DOE test procedure for measuring the energy consumption of furnaces and boilers provides a calculation approach for determining the energy use of furnaces and boilers under test conditions.[1] This approach requires the calculation of the average annual fuel energy consumption ($E_F$), the average annual electrical energy consumption ($E_{AE}$), and the national average number of burner operating hours ($BOH_{SS}$) of furnaces and boilers.

The following calculations and summary tables describe the determination of $E_F$, $E_{AE}$, and $BOH_{SS}$ for gas- and oil-fired furnaces and boilers.

## 6.3.2 CALCULATIONS

### 6.3.2.1 Determination of Average Annual Fuel Energy Consumption ($E_F$)

The average annual fuel consumption is calculated in sections 10.2.2 and 10.2.2.1 of the DOE test procedure:[1]

$E_F$ = BOHss * ($Q_{IN}$ - $Q_P$) + 8,760 * $Q_P$ , for single-stage furnaces and boilers **Eq. 1**

and

$E_F$ = $E_M$ + 4,600 * $Q_P$, for two-stage and step modulating furnaces and boilers **Eq. 2**

where:

| | | |
|---|---|---|
| *BOHss* | = | National average number of burner operating hours (see section 6.3.2.3 of this appendix for derivation)**,** |
| $Q_{IN}$ | = | Steady-state nameplate input rate in Btu/h for single-stage furnaces and boilers or steady-state nameplate maximum input rate in Btu/h for two-stage and step modulating furnaces and boilers, |
| $Q_P$ | = | Pilot flame fuel input rate in Btu/h, and |
| $E_M$ | = | Average annual energy used during the heating season for two-stage and modulating furnaces. |

$Q_{IN}$ is based on the baseline value for each product class. $Q_P$ is zero for all product classes, except for the baseline mobile home gas furnace and gas boiler.

### 6.3.2.2 Determination of Average Annual Electrical Energy Consumption ($E_{AE}$)

Using the DOE test procedure,[1] the average annual electrical energy consumption is calculated in sections 10.2.3, 10.2.3.1, and 10.2.3.2:

$$E_{AE} = BOH_{SS} (y_P * PE + y_{IG} * PE_{IG} + y * BE)$$, for single-stage furnaces and boilers **Eq. 3**

and

$$E_{AE} = BOH_R (y_P*PE_R + y_{IG}*PE_{IG} + y*BE_R) + BOH_{HorM} (y_P*PE_H + y_{IG}*PE_{IG} + y*BE_H)$$, for two-stage and step modulating furnaces and boilers **Eq. 4**

where:

| | | |
|---|---|---|
| $BOHss$ | = | See section 6.3.2.3 of this appendix, |
| $BOH_H$ | = | National average number of burner operating hours at the maximum operating mode (see section 6.3.2.4 of this appendix), |
| $BOH_M$ | = | National average number of burner operating hours at the modulating operating mode (see section 6.3.2.4 of this appendix), |
| $BOH_R$ | = | National average number of burner operating hours at the reduced operating mode (see section 6.3.2.4 of this appendix), |
| $y_P$ | = | Ratio of induced or forced draft blower on-time to average burner on-time, |
| $PE$ | = | Burner electrical power input at full-load steady-state operation in kW, |
| $PE_R$ | = | Burner electrical power input at full-load steady-state operation in kW, measured at the reduced fuel input rate, |
| $PE_H$ | = | Burner electrical power input at full-load steady-state operation in kW, measured at the maximum fuel input rate, |
| $y_{IG}$ | = | Ratio of burner interrupted-ignition device on-time to average burner on-time, |
| $PE_{IG}$ | = | Electrical input rate to the interrupted ignition device on the burner, |
| $y$ | = | Ratio of blower or pump on-time to burner on-time, |
| $BE$ | = | Circulating-air fan or water pump electrical energy input rate in kW, |
| $BE_R$ | = | Circulating-air fan or water pump electrical energy input rate in kW, measured at the reduced fuel input rate, and |
| $BE_H$ | = | Circulating-air fan or water pump electrical energy input rate in kW, measured at the maximum fuel input rate. |

The value $y_P$ is calculated using $t_P$ (post-purge time in minutes). For this calculation, the Department took $t_P$ to be less than or equal to 30 seconds and set it equal to 0 seconds, according to sections 8.2 and 8.4. The Department calculated the value $y_{IG}$ using $t_{IG}$ (on-time of the burner interrupted ignition device in minutes). The Department calculated the value y using $t^+$ (blower or pump on-delay in minutes) and $t^-$ (blower or pump off-delay in minutes). For furnaces, $t^+$ = 2 min and $t^-$ =

1.5 min. $t^+ = 0$ and $t^- = 0$ for gas and oil boilers. *PE*, $t_{IG}$, $PE_{IG}$, and *BE* values are corrected for different design options. For design options which include modulation, the Department set $PE_R$ and $PE_H$ to have the same values as *PE*, since it assumed no inducer modulation. The Department set $BE_H$ equal to *BE*, and set $BE_R$ to be 80 percent of *BE* for furnaces.

### 6.3.2.3 Determination of National Average Number of Burner Operating Hours ($BOH_{SS}$)

From the test procedure, the national average number of burner operating hours is calculated in section 10.2.1:

$$BOH_{SS} = 2080 * 0.77 * A * DHR - 2080 * B \qquad \textbf{Eq. 5}$$

where:

| | | |
|---|---|---|
| *A* | = | As defined in sections 10.2.1 and 10.2.1.1, |
| *B* | = | As defined in sections 10.2.1, and |
| *DHR* | = | Typical design heating requirements as listed in Table 8,[2] using the proper value of $Q_{OUT}$. |

To calculate factors *A* and *B*, the Department calculated $y_P$, *PE*, $y_{IG}$, $PE_{IG}$, *y*, *BE*, $Q_{IN}$, and $Q_P$ as described in section 6.3.2.2 of this appendix. To calculate *A*, the Department assumed the burner motor efficiency $Eff_{motor} = 0.5$ (as defined in section 10.2.1[1]), except for oil furnaces and boilers with fan-atomized burners—where $Eff_{motor} = 0.8$. The Department calculated $Effy_{HS}$, heating seasonal efficiency, as defined in section 10.2.1. For $Q_P = 0$, $Effy_{HS}$ is equal to the annual fuel utilization efficiency (AFUE). The factor *R*, used in calculating *A*, is defined in section 10.2.1.1. For factor *B*, if $Q_P = 0$, then $B = 0$, which is true for all cases except for the baseline mobile home gas furnace and baseline gas boiler. To calculate factor A for weatherized furnaces, the Department used the equation for induced-draft unit isolated combustion systems (ICS), because the intention is to account for the heat from the motor, which always goes into the air distribution system.

$Q_{OUT}$ (heating capacity for single-stage furnaces and boilers, or maximum heat capacity for two-stage and step modulating furnaces and boilers) is used to calculate design heating rate (*DHR*) for the considered efficiency levels and design options. Furthermore, to calculate $Q_{OUT}$ (see eqn. 8 defined in section 6.3.2.5 of this appendix), DOE used $Q_{IN}$ (defined in section 6.3.2.1 of this appendix), $Effy_{SS}$ (defined in section 6.3.2.5 of this appendix), *K* (factor that adjusts the jacket losses, where $K = 1.7$ for non-weatherized furnaces, 3.3 for weatherized furnaces, and 1 for boilers), and *Lj* (jacket loss, where $Lj = 1$ is the default value).

In the current test procedure *DHR* is a step function of furnace output capacity ranges (Table 8[2]). It was observed that small changes in $Q_{OUT}$ may assign an efficiency level to a different *DHR* range, which could cause significant variations of $BOH_{SS}$ (in some cases up to 20-30 percent).

For example, the non-weatherized gas furnace at 81 percent AFUE and at 75 kBtu/h capacity has a $Q_{OUT}$ which calls for a *DHR* value of 30, while the same capacity furnace at 82 percent AFUE require a *DHR* value of 40. As a result, an AFUE change of 1 percent (from 81 percent to 82 percent AFUE) represents a 24 percent increase in energy consumption for the 82 percent AFUE furnace as compared to the 81 percent AFUE furnace. It results in higher energy consumption for a more efficient furnace (82 percent AFUE vs 81 percent AFUE) and as a result the payback for 82 percent AFUE becomes negative. This test procedure feature impacts several efficiency levels in the engineering analysis for non-weatherized gas furnaces, mobile home furnaces and gas and oil-fired boilers.

Note: The ASHRAE committee in charge of the furnace/boiler test procedure (SPC 103) is taking steps to correct this anomaly in the current test procedure. The approach by ASHRAE SPC 103 is to eliminate the *DHR* parameter from the formula for calculating $BOH_{SS}$ and replace it with a parameter containing $Q_{OUT}$ and an oversized factor, which has a constant value of 0.7. ASHRAE SPC 103 plans to present this furnace/boiler test procedure update for public comment in the near future.

#### 6.3.2.4 Determination of National Average Number of Burner Operating Hours for Two-Stage and Step Modulating Furnaces and Boilers

From the test procedure, the national average number of burner operating hours are calculated in sections 10.2.1.2, 10.2.1.3, and 10.2.1.4[1]:

$BOH_R = X_R*E_M / Q_{IN,R}$, at the reduced operating mode, **Eq. 6**

$BOH_H = X_H*E_M / Q_{IN}$, at the maximum operating mode, and **Eq. 7**

$BOH_M = X_H*E_M / Q_{IN,M}$, at the modulating operating mode **Eq. 8**

where:

| | | |
|---|---|---|
| $X_R$ | = | Fraction of heating load at the reduced fuel input operating mode, Table 10,[2] |
| $X_H$ | = | Fraction of heating load at the reduced fuel input operating mode, Table 10,[2] |
| $E_M$ | = | Average annual energy used during the heating season for two-stage and modulating furnaces, |
| $Q_{IN}$ | = | As defined in section 6.3.2.1 of this appendix, |
| $Q_{IN,R}$ | = | Steady-state reduced-fuel input rate, and |
| $Q_{IN,M}$ | = | Steady-state modulating fuel input rate. |

The Department calculated $X_R$ and $X_H$ using $T_C$ (balance-point temparature), α (the oversize factor), $Q_{OUT,R}$ (reduced fuel input rate heating capacity), $Effy_{SS,M}$ (steady-state efficiency at the modulating fuel input rate), $Effy_{SS,R}$ (steady-state efficiency at the reduced fuel input rate), $T_{OA,H}$ (average outdoor temperature at the modulating or maximum fuel input operating mode), and $Q_{OUT,M}$

(modulating fuel input rate heating capacity), which are defined in section 11.4.[2] The Department determined $Q_{OUT}$, as defined in section 6.3.2.3 of this appendix. To calculate $E_M$, the Department used $BOH_{SS}$, $Q_{IN}$, and $Q_P$ as defined in section 6.3.2.1 of this appendix. The Department set $Q_{IN,R}$ to be 68 percent of $Q_{IN}$, where this value represents the average ratio $Q_{IN}/Q_{IN,R}$ as derived using manufacturer product literature and Gas Appliance Manufacturers Association (GAMA) April 2002 Directory data for all listed two-stage furnace models.[3] From section 11.4.8.6 or 11.5.8.6,[2] $Q_{IN,M}$ is calculated using $Q_{OUT}$ and $Effy_{SS,M}$ (as defined in section 11.4.8.8 or 11.5.8.8)[2].

### 6.3.2.5 Determination of Heating Seasonal Efficiency ($Effy_{SS}$)

$Effy_{SS}$ is required to calculate $Q_{OUT}$, the heating capacity and is also used to determine $AFUE$, the annual fuel utilization efficiency for heating equipment with pilot lights. The approach DOE chose was to determine the average ($Effy_{SS}$ - $AFUE$) difference for each product class.

From Section 11.2.8.1 of ANSI/ASHRAE 103-1993[2]:

$$Q_{OUT} = Q_{IN} * [Effy_{SS} - (K)(Lj)]/100 \qquad \textbf{Eq. 9}$$

The ($Effy_{SS}$ -AFUE) values were calculated by solving Eqn.8 for $Effy_{SS}$ and subtracting AFUE from both sides:

$$Effy_{SS} - AFUE = 100 * [(Q_{OUT} / Q_{IN}) + (K)(Lj)] - AFUE \qquad \textbf{Eq. 10}$$

The Department used the available model information ($Q_{IN}$, $Q_{OUT}$, and $AFUE$) from the GAMA directory to determine average ($Effy_{SS}$ -$AFUE$) values for each product class.[4] The average ($Effy_{SS}$ -$AFUE$) values are listed in the look-up table which is a part of the engineering spreadsheet (see "SSE Analysis.xls" spreadsheet).

## 6.3.3 PARAMETERS TO DETERMINE THE ENERGY USE OF MODULATING FURNACES

The furnace energy use calculations are based on the current DOE test procedure for determining the AFUE of residential furnaces and boilers,[1] which for the most part references the industry test standard ANSI/ASHRAE 103/1993 of the American Society of Heating, Refrigerating, and Air Conditioning (ASHRAE).[2] In the case of single stage and two-stage furnaces rated at one and the same AFUE level, the analysis points to a significant difference in the energy use between both designs, which result in very different national energy savings (0.4 quads for single-stage furnaces vs 1.0 quads for two-stage furnaces, as determined by the analysis reported in Ch.10 of this document). This introduces an inconsistency, because with a ratio of reduced to maximum input of about 70 percent the test procedure shows that the furnace would supply almost 95 percent of the annual heating load at the reduced input. Therefore a two stage furnace operates almost all of the time as a single-stage furnace at a reduced input rate. However, as pointed out above, the calculations based on the current test procedure indicate much more efficient operation.

This section outlines the parameters involved in the calculations and provides an additional basis upon which the stakeholders can comment on this part of the analysis.

### 6.3.3.1 Parameters to Determine Average Annual Fuel Energy Consumption

The average annual fuel energy consumption for both single-stage and two-stage furnaces (as calculated using CFR Appendix N, Subpart B of Part 430, *Uniform Test Method for Measuring the Energy Consumption of Furnaces and Boilers*, sections 10.2.2 and 10.2.2.1[1]) is:

$$E_F = BOH_{SS} * (Q_{IN} - Q_P) + 8{,}760 * Q_P \qquad \textbf{Eq. 11}$$

$E_F$ (for single and two-stage furnaces) differs due to the different approach used to calculate the national average number of burner operating hours - $BOH_{SS}$:

$$BOH_{SS} = 2080 * 0.77 * A * DHR - 2080 * B \qquad \textbf{Eq. 12}$$

where for single-stage furnaces

$$A = 100{,}000 / [341{,}300 * (y_{IG} * PE_{IG} + y * BE) + (Q_{IN} - Q_P) * Effy_{HS}], \qquad \textbf{Eq. 13}$$

and for two-stage and step modulating furnaces

$$A = 100{,}000 / [341{,}300 * (y_{IG} * PE_{IG} + y * BE)*R + (Q_{IN} - Q_P) * Effy_{HS}] \qquad \textbf{Eq. 14}$$

where the term $(y_{IG} * PE_{IG} + y * BE)$ in the formula for two-stage furnaces is increased by the factor $R$=2.3.

The derivation of $R$-values for single and two-stage furnaces is described in Kweller[5] as follows: Burner on-time for single-stage furnace is assigned values in the DOE test procedure of 3.8 minutes on and 13.3 minutes off. The corresponding values for two-stage modulating furnaces are 10 minutes and 10 minutes. The ratio of percent time-on for a single-stage furnace is 3.8/(3.8+13.3)=0.22 and for a two-stage furnace is 10/(10+10)=0.50. Using these on-time fractions, the ratio "*R*" of on-time for the two-stage furnace vs the single-stage furnace is 0.50/0.22=2.27. In other words the amount of electrical energy required for the two stage furnaces is 227 percent (or *R*=2.3) of the single-stage furnace.

The different value of *R* is the cause for the reduced energy consumption for modulating furnaces compared to single-stage at the same efficiency level. In this case, the increased electrical energy use for two-stage furnaces is credited in reducing the house heating load.

### 6.3.3.2 Parameters to Determine Annual Fuel Utilization Efficiency

The $AFUE$ equals the heating seasonal efficiency ($Effy_{HS}$) when no pilot light is present. The detailed test procedure approach to determine $Effy_{HS}$ requires specific information on heat-up and cool down temperatures as measured during an actual test. When test results are not available, the general approach is to make an assumption for the value of the $AFUE$.

From Section 11.2.12 and 11.4.12 of ANSI/ASHRAE 103-1993[2] (DOE furnace/boiler test procedure refers to this standard):

$AFUE = Effy_{HS}$ (when no pilot light is present) **Eq. 15**

$Effy_{HS}$ for two-stage furnaces is a function of $X_H$ and $X_R = 1 - X_H$, ratios representing the fraction of heating load at maximum and reduced input rate.

$X_H$ is a function of the steady-state efficiency at maximum ($Effy_{SS}$) and reduced ($Effy_{SS,R}$) fuel input rate capacities. From several actual modulating furnace tests described in Liu[6] DOE found that the values for $Effy_{SS,R}$ are sometimes higher and sometimes lower than the $Effy_{SS}$ values. Therefore, based on these tests it is possible to assume that $Effy_{SS,R} = Effy_{SS}$. This assumption is confirmed in the above cited reference,[5] where the furnace steady-state efficiency at maximum ($Effy_{SS}$) and reduced ($Effy_{SS,R}$) fuel input rate capacities are assumed the same. Once this assumption is confirmed, then it is straightforward to calculate the reduced fuel input heating capacity $Q_{OUT,R} = Q_{OUT} * Q_{IN,R} / Q_{IN}$ and the balance-point temperature $T_C$. Knowing $T_C$ allows one to determine $X_H$ and $X_R$ from Table 10.[2]

DOE did not use the above approach to determine $Effy_{HS}$ . The Department examined 8 families of furnace models at 80 percent $AFUE$ from six manufacturers, and compared pairs of models which are essentially identical with the exception of the modulating component. (See Table 6.3.3.1) The comparison showed that the reported $AFUE$ for each pair is identical. This finding indicates that $Effy_{HS}$ is the same for single-stage and two-stage furnaces, which are otherwise identical and therefore $AFUE$ value may be used as proxy for $Effy_{HS}$ in the equation 13 and 14.

**Table 6.3.3.1 AFUE for Similar Single-Stage and Two-Stage Furnace Models Series**

| Manufacturer | Single-Stage Series | Two-Stage Series | AFUE |
|---|---|---|---|
| Amana | GUIC | GUIS | 80% |
| Carrier | 58DLA | 58CTA | 80% |
| Lennox | G50 (UH/DF) | G60 (UH/DF) | 80% |
| Rheem[a] | RGLJ/RGPH | RGLK/RGPK | 80% |
| Trane | TDD-C/TUD-C | TDD-R/TUD-R | 80% |
| York | PDN/PHU | PDD/PDU | 80% |

#### 6.3.3.3 Conclusions

The fuel consumption difference between single-stage and modulating furnaces is determined by:

1) the value of the parameter *R*, and

2) the value of $X_R$ and $X_H$, (ratios representing the fraction of heating load at maximum and reduced input rate), where they are functions of the steady-state efficiency at maximum and reduced fuel input rate capacities as determined by test procedure measured quantities.

To bring the energy use of single-stage and two-stage furnaces in line with the actually observed field performance it may be necessary to correct at least the above parameters. This may require assuming different values for the furnace time on/off and also changing the oversizing factor. There may be other factors in the test procedure which should be examined.

### 6.3.4 SUMMARY TABLES

The summary tables below include single-stage and two-stage modulation tables referenced in Chapter 6 (section 6.7.2) of the TSD. Tables 6.3.3.1 and Tables 6.3.4.1 through 6.3.4.6 in this appendix contain data about the furnaces with single-stage controls, and Tables 6.3.4.7 through 6.3.4.11 present data about two-stage modulation furnace designs.

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[a] Some models in this series have AFUE of 80% or 81%.

## Table 6.3.4.1 Single-Stage Non-Weatherized Gas Furnaces

| Description | QIN | QOUT | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas Furnace, 78% w/time delays, w/o pilot | 75,000 | 57,809 | 0 | 78 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 792 | 558 | 59.42 |
| Gas Furnace, 80%(A) w/time delays, w/o pilot | 75,000 | 58,704 | 0 | 80 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 773 | 545 | 57.99 |
| 80%(A1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 59,742 | 0 | 80 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 774 | 532 | 58.04 |
| 80%(A2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 59,135 | 0 | 80 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 778 | 459 | 58.36 |
| 80%(A3) - ImprovedCircBlowerMotor(SR) | 75,000 | 59,264 | 0 | 80 | 0.076 | 0.43 | 0.4 | 0.62 | 30 | 776 | 487 | 58.23 |
| 80%(A4) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 59,482 | 0 | 80 | 0.076 | 0.42 | 0.4 | 0.62 | 30 | 777 | 480 | 58.26 |
| 80%(A5) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 58,725 | 0 | 80 | 0.076 | 0.34 | 0.4 | 0.62 | 30 | 781 | 407 | 58.58 |
| Gas Furnace, 81% w/time delays, w/o pilot | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 764 | 538 | 57.29 |
| 81%(A1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 765 | 525 | 57.35 |
| 81%(A2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 769 | 453 | 57.65 |
| 81%(A3) - ImprovedCircBlowerMotor(SR) | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.43 | 0.4 | 0.62 | 30 | 767 | 481 | 57.54 |
| 81%(A4) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.42 | 0.4 | 0.62 | 30 | 768 | 475 | 57.56 |
| 81%(A5) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 59,475 | 0 | 81 | 0.076 | 0.34 | 0.4 | 0.62 | 30 | 772 | 402 | 57.87 |
| Gas Furnace, 82% w/time delays, w/o pilot | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 1007 | 709 | 75.49 |
| 82%(A1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.48 | 0.4 | 0.62 | 40 | 1008 | 692 | 75.56 |
| 82%(A2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.40 | 0.4 | 0.62 | 40 | 1013 | 597 | 75.96 |
| 82%(A3) - ImprovedCircBlowerMotor(SR) | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.43 | 0.4 | 0.62 | 40 | 1011 | 634 | 75.81 |
| 82%(A4) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.42 | 0.4 | 0.62 | 40 | 1011 | 625 | 75.84 |
| 82%(A5) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 60,225 | 0 | 82 | 0.076 | 0.34 | 0.4 | 0.62 | 40 | 1017 | 529 | 76.24 |
| Gas Furnace, 83% w/time delays, w/o pilot | 75,000 | 60,975 | 0 | 83 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 995 | 701 | 74.61 |
| Gas Furnace, 90% w/time delays, w/o pilot | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 920 | 648 | 68.99 |
| 90%(A1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.48 | 0.4 | 0.62 | 40 | 921 | 633 | 69.05 |
| 90%(A2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.40 | 0.4 | 0.62 | 40 | 925 | 545 | 69.38 |
| 90%(A3) - ImprovedCircBlowerMotor(SR) | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.43 | 0.4 | 0.62 | 40 | 923 | 579 | 69.25 |
| 90%(A4) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.42 | 0.4 | 0.62 | 40 | 924 | 571 | 69.28 |
| 90%(A5) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 66,225 | 0 | 90 | 0.076 | 0.34 | 0.4 | 0.62 | 40 | 928 | 483 | 69.62 |
| Gas Furnace, 92% w/time delays, w/o pilot | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 900 | 635 | 67.53 |
| 92%(A1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.48 | 0.4 | 0.62 | 40 | 901 | 619 | 67.59 |
| 92%(A2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.40 | 0.4 | 0.62 | 40 | 905 | 534 | 67.91 |
| 92%(A3) - ImprovedCircBlowerMotor(SR) | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.43 | 0.4 | 0.62 | 40 | 904 | 567 | 67.79 |
| 92%(A4) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.42 | 0.4 | 0.62 | 40 | 904 | 559 | 67.82 |
| 92%(A5) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 67,725 | 0 | 92 | 0.076 | 0.34 | 0.4 | 0.62 | 40 | 908 | 473 | 68.14 |

**Table 6.3.4.2 Single-Stage Weatherized Gas Furnaces**

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas Furnace, 78% w/time delays, w/o pilot | 75,000 | 56,004 | 0 | 78 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 792 | 558 | 59.42 |
| Gas Furnace, 80% w/time delays, w/o pilot | 75,000 | 57,504 | 0 | 80 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 773 | 545 | 57.99 |
| 80%AFUE - Improved Insulation | 75,000 | 57,616 | 0 | 80 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 772 | 544 | 57.88 |
| 80%AFUE - ImprovedCircBlowerMotor (PSC) | 75,000 | 57,504 | 0 | 80 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 774 | 532 | 58.04 |
| 80%AFUE - ImprovedSupplyFanMotor (ECM) | 75,000 | 57,504 | 0 | 80 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 778 | 459 | 58.36 |
| Gas Furnace, 81% w/time delays, w/o pilot | 75,000 | 58,254 | 0 | 81 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 764 | 538 | 57.29 |
| 81%AFUE - Improved Insulation | 75,000 | 58,366 | 0 | 81 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 763 | 537 | 57.19 |
| 81%AFUE - ImprovedCircBlowerMotor (PSC) | 75,000 | 58,254 | 0 | 81 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 765 | 525 | 57.35 |
| 81%AFUE - ImprovedSupplyFanMotor (ECM) | 75,000 | 58,254 | 0 | 81 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 769 | 453 | 57.65 |
| Gas Furnace, 82% w/time delays, w/o pilot | 75,000 | 59,004 | 0 | 82 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 755 | 532 | 56.62 |
| 82%AFUE - Improved Insulation | 75,000 | 59,116 | 0 | 82 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 754 | 531 | 56.52 |
| 82%AFUE - ImprovedCircBlowerMotor (PSC) | 75,000 | 59,004 | 0 | 82 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 756 | 519 | 56.67 |
| 82%AFUE - ImprovedSupplyFanMotor (ECM) | 75,000 | 59,004 | 0 | 82 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 760 | 448 | 56.97 |
| Gas Furnace, 82.5% w/time delays, w/o pilot | 75,000 | 59,379 | 0 | 83 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 751 | 529 | 56.29 |
| 82.5%AFUE - Improved Insulation | 75,000 | 59,866 | 0 | 83 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 745 | 525 | 55.86 |
| 82.5%AFUE - ImprovedCircBlowerMotor (PSC) | 75,000 | 59,379 | 0 | 83 | 0.076 | 0.48 | 0.4 | 0.62 | 30 | 751 | 516 | 56.34 |
| 82.5%AFUE - ImprovedSupplyFanMotor (ECM) | 75,000 | 59,379 | 0 | 83 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 755 | 445 | 56.64 |

## Table 6.3.4.3 Single-Stage Mobile Home Furnaces

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MH Gas Furnace, 75% w/time delays, w/ pilot | 75,000 | 55,992 | 500 | 77 | 0.076 | 0.50 | 0 | 0.00 | 30 | 781 | 500 | 62.96 |
| MH Gas Furnace, 80% w/time delays, w/o pilot | 75,000 | 59,742 | 0 | 80 | 0.076 | 0.50 | 0.4 | 0.62 | 30 | 773 | 545 | 62.37 |
| 80% AFUE ImprovedSupplyFanMotor (ECM) | 75,000 | 59,742 | 0 | 80 | 0.076 | 0.40 | 0.4 | 0.62 | 30 | 778 | 459 | 62.74 |
| MH Gas Furnace, 81% w/time delays, w/o pilot | 75,000 | 60,492 | 0 | 81 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 1019 | 718 | 80.77 |
| 81% AFUE ImprovedSupplyFanMotor (ECM) | 75,000 | 60,492 | 0 | 81 | 0.076 | 0.40 | 0.4 | 0.62 | 40 | 1025 | 604 | 81.25 |
| MH Gas Furnace, 82% w/time delays, w/o pilot | 75,000 | 61,242 | 0 | 82 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 1007 | 709 | 79.87 |
| 82% AFUE ImprovedSupplyFanMotor (ECM) | 75,000 | 61,242 | 0 | 82 | 0.076 | 0.40 | 0.4 | 0.62 | 40 | 1013 | 597 | 80.34 |
| MH Gas Furnace, 90% w/time delays, w/o pilot | 75,000 | 67,242 | 0 | 90 | 0.076 | 0.50 | 0.4 | 0.62 | 40 | 920 | 648 | 73.37 |

## Table 6.3.4.4 Single-Stage Oil-Fired Furnaces

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Furnace, 78% w/time delays, w/o pilot | 105,000 | 80,689 | 0 | 78 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 944 | 969 | 99.09 |
| Oil Furnace, 80% w/time delays, w/o pilot | 105,000 | 82,789 | 0 | 80 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 921 | 946 | 96.69 |
| Oil Furnace, 81% w/time delays, w/o pilot | 105,000 | 83,839 | 0 | 81 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 910 | 934 | 95.54 |
| 81%AFUE Interrupted Ignition | 105,000 | 83,839 | 0 | 81 | 0.16 | 0.50 | 0.025 | 0.75 | 50 | 921 | 671 | 96.66 |
| 81%AFUE ImprovedSupplyFanMotor (ECM) | 105,000 | 83,839 | 0 | 81 | 0.16 | 0.40 | 0.045 | 26.00 | 50 | 914 | 833 | 95.97 |
| Oil Furnace, 82% w/time delays, w/o pilot | 105,000 | 84,889 | 0 | 82 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 899 | 923 | 94.41 |
| 82%AFUE Interrupted Ignition | 105,000 | 84,889 | 0 | 82 | 0.16 | 0.50 | 0.025 | 0.75 | 50 | 910 | 663 | 95.50 |
| 82%AFUE ImprovedSupplyFanMotor (ECM) | 105,000 | 84,889 | 0 | 82 | 0.16 | 0.40 | 0.045 | 26.00 | 50 | 903 | 824 | 94.83 |
| Oil Furnace, 83% w/time delays, w/o pilot | 105,000 | 85,939 | 0 | 83 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 889 | 913 | 93.31 |
| 83%AFUE Interrupted Ignition | 105,000 | 85,939 | 0 | 83 | 0.16 | 0.50 | 0.025 | 0.75 | 50 | 899 | 656 | 94.38 |
| 83%AFUE ImprovedSupplyFanMotor (ECM) | 105,000 | 85,939 | 0 | 83 | 0.16 | 0.40 | 0.045 | 26.00 | 50 | 893 | 814 | 93.72 |
| Oil Furnace, 84% w/time delays, w/o pilot | 105,000 | 86,989 | 0 | 84 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 878 | 902 | 92.24 |
| 84%AFUE Interrupted Ignition | 105,000 | 86,989 | 0 | 84 | 0.16 | 0.50 | 0.025 | 0.75 | 50 | 888 | 648 | 93.28 |
| 84%AFUE ImprovedSupplyFanMotor (ECM) | 105,000 | 86,989 | 0 | 84 | 0.16 | 0.40 | 0.045 | 26.00 | 50 | 882 | 804 | 92.64 |
| Oil Furnace, 85% w/time delays, w/o pilot | 105,000 | 88,039 | 0 | 85 | 0.16 | 0.50 | 0.045 | 26.00 | 50 | 868 | 892 | 91.19 |
| 85%AFUE Interrupted Ignition | 105,000 | 88,039 | 0 | 85 | 0.16 | 0.50 | 0.025 | 0.75 | 50 | 878 | 641 | 92.20 |
| 85%AFUE ImprovedSupplyFanMotor (ECM) | 105,000 | 88,039 | 0 | 85 | 0.16 | 0.40 | 0.045 | 26.00 | 50 | 872 | 795 | 91.58 |

## Table 6.3.4.5 Single-Stage Hot-Water Gas Boilers

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas Boiler, 80% w/time delays, w/ pilot | 105,000 | 84,754 | 500 | 81 | 0.13 | 0.07 | 0 | 0.00 | 50 | 914 | 183 | 95.93 |
| Gas Boiler, 81% w/time delays, w/o pilot | 105,000 | 85,804 | 0 | 81 | 0.13 | 0.07 | 0.4 | 0.62 | 50 | 936 | 211 | 98.23 |
| 81%AFUE Improved Circulating Pump | 105,000 | 85,804 | 0 | 81 | 0.13 | 0.05 | 0.4 | 0.62 | 50 | 936 | 189 | 98.32 |
| Gas Boiler, 82% w/time delays, w/o pilot | 105,000 | 86,854 | 0 | 82 | 0.13 | 0.07 | 0.4 | 0.62 | 50 | 924 | 209 | 97.04 |
| 82%AFUE Improved Circulating Pump | 105,000 | 86,854 | 0 | 82 | 0.13 | 0.05 | 0.4 | 0.62 | 50 | 925 | 187 | 97.13 |
| Gas Boiler, 83% w/time delays, w/o pilot | 105,000 | 87,904 | 0 | 83 | 0.13 | 0.07 | 0.4 | 0.62 | 50 | 913 | 206 | 95.88 |
| 83%AFUE Improved Circulating Pump | 105,000 | 87,904 | 0 | 83 | 0.13 | 0.05 | 0.4 | 0.62 | 50 | 914 | 185 | 95.97 |
| Gas Boiler, 84% w/time delays, w/o pilot | 105,000 | 88,954 | 0 | 84 | 0.13 | 0.07 | 0.4 | 0.62 | 50 | 902 | 204 | 94.74 |
| 84%AFUE Improved Circulating Pump | 105,000 | 88,954 | 0 | 84 | 0.13 | 0.05 | 0.4 | 0.62 | 50 | 903 | 183 | 94.83 |
| Gas Boiler, 88% w/time delays, w/o pilot | 105,000 | 93,154 | 0 | 88 | 0.13 | 0.07 | 0.4 | 0.62 | 50 | 862 | 194 | 90.46 |
| Gas Boiler, 91% w/time delays, w/o pilot | 105,000 | 96,304 | 0 | 91 | 0.13 | 0.07 | 0.4 | 0.62 | 60 | 1000 | 226 | 105.00 |
| Gas Boiler, 99% w/time delays, w/o pilot | 105,000 | 104,704 | 0 | 99 | 0.13 | 0.07 | 0.4 | 0.62 | 60 | 920 | 207 | 96.56 |

## Table 6.3.4.6 Single-Stage Hot-Water Oil Boilers

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | PE | BE | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Boiler, 80% w/time delays | 140,000 | 113,413 | 0 | 80 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 993 | 348 | 138.99 |
| Oil Boiler, 81% w/time delays | 140,000 | 114,813 | 0 | 81 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 981 | 344 | 137.29 |
| 81%AFUE Interrupted Ignition | 140,000 | 114,813 | 0 | 81 | 0.16 | 0.07 | 0.025 | 0.75 | 70 | 984 | 228 | 137.78 |
| 81%AFUE Improved Circulating Pump | 140,000 | 114,813 | 0 | 81 | 0.16 | 0.05 | 0.045 | 26.00 | 70 | 981 | 321 | 137.39 |
| Oil Boiler, 82% w/time delays | 140,000 | 116,213 | 0 | 82 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 969 | 340 | 135.63 |
| 82%AFUE Interrupted Ignition | 140,000 | 116,213 | 0 | 82 | 0.16 | 0.07 | 0.025 | 0.75 | 70 | 972 | 225 | 136.11 |
| 82%AFUE Improved Circulating Pump | 140,000 | 116,213 | 0 | 82 | 0.16 | 0.05 | 0.045 | 26.00 | 70 | 969 | 318 | 135.72 |
| Oil Boiler, 83% w/time delays | 140,000 | 117,613 | 0 | 83 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 957 | 336 | 134.01 |
| 83%AFUE Interrupted Ignition | 140,000 | 117,613 | 0 | 83 | 0.16 | 0.07 | 0.025 | 0.75 | 70 | 961 | 223 | 134.47 |
| 83%AFUE Improved Circulating Pump | 140,000 | 117,613 | 0 | 83 | 0.16 | 0.05 | 0.045 | 26.00 | 70 | 958 | 314 | 134.10 |
| Oil Boiler, 84% w/time delays | 140,000 | 119,013 | 0 | 84 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 946 | 332 | 132.43 |
| 84%AFUE Interrupted Ignition | 140,000 | 119,013 | 0 | 84 | 0.16 | 0.07 | 0.025 | 0.75 | 70 | 949 | 220 | 132.88 |
| 84%AFUE Improved Circulating Pump | 140,000 | 119,013 | 0 | 84 | 0.16 | 0.05 | 0.045 | 26.00 | 70 | 947 | 310 | 132.51 |
| Oil Boiler, 86% w/time delays | 140,000 | 121,813 | 0 | 86 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 924 | 324 | 129.37 |
| 85%AFUE Interrupted Ignition | 140,000 | 121,813 | 0 | 86 | 0.16 | 0.07 | 0.025 | 0.75 | 70 | 927 | 215 | 129.80 |
| 85%AFUE Improved Circulating Pump | 140,000 | 121,813 | 0 | 86 | 0.16 | 0.05 | 0.045 | 26.00 | 70 | 925 | 303 | 129.45 |
| Oil Boiler, 90% w/time delays | 140,000 | 127,413 | 0 | 90 | 0.16 | 0.07 | 0.045 | 26.00 | 70 | 883 | 310 | 123.66 |
| Oil Boiler, 95% w/time delays | 140,000 | 134,413 | 0 | 95 | 0.16 | 0.07 | 0.045 | 26.00 | 80 | 957 | 336 | 133.94 |

## Table 6.3.4.7 Two-Stage Non-Weatherized Gas Furnaces

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | BE, BEH | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas Furnace, 80% - 2-stage | 75,000 | 59,309 | 0 | 80 | 0.500 | 0.4 | 0.62 | 30 | 747 | 572 | 56.03 |
| 80%(C1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 59,309 | 0 | 80 | 0.484 | 0.4 | 0.62 | 30 | 749 | 559 | 56.14 |
| 80%(C2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 59,309 | 0 | 80 | 0.398 | 0.4 | 0.62 | 30 | 757 | 484 | 56.77 |
| 80%(C3) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 59,309 | 0 | 80 | 0.424 | 0.4 | 0.62 | 30 | 754 | 507 | 56.58 |
| 80%(C4) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 59,309 | 0 | 80 | 0.337 | 0.4 | 0.62 | 30 | 763 | 431 | 57.22 |
| Gas Furnace, 81% - 2-stage | 75,000 | 60,059 | 0 | 81 | 0.500 | 0.4 | 0.62 | 40 | 985 | 754 | 73.85 |
| 81%(C1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 60,059 | 0 | 81 | 0.484 | 0.4 | 0.62 | 40 | 987 | 737 | 73.99 |
| 81%(C2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 60,059 | 0 | 81 | 0.398 | 0.4 | 0.62 | 40 | 997 | 638 | 74.81 |
| 81%(C3) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 60,059 | 0 | 81 | 0.424 | 0.4 | 0.62 | 40 | 994 | 668 | 74.57 |
| 81%(C4) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 60,059 | 0 | 81 | 0.337 | 0.4 | 0.62 | 40 | 1005 | 568 | 75.40 |
| Gas Furnace, 82% - 2-stage | 75,000 | 60,809 | 0 | 82 | 0.500 | 0.4 | 0.62 | 40 | 973 | 745 | 73.00 |
| 82%(C1) - ImprovedCircBlowerMotor (PSC) | 75,000 | 60,809 | 0 | 82 | 0.484 | 0.4 | 0.62 | 40 | 975 | 728 | 73.15 |
| 82%(C2) - ImprovedCircBlowerMotor(ECM) | 75,000 | 60,809 | 0 | 82 | 0.398 | 0.4 | 0.62 | 40 | 986 | 631 | 73.95 |
| 82%(C3) - ImprovedCircBlowerImpeller w/ PSC | 75,000 | 60,809 | 0 | 82 | 0.424 | 0.4 | 0.62 | 40 | 983 | 660 | 73.71 |
| 82%(C4) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 60,809 | 0 | 82 | 0.337 | 0.4 | 0.62 | 40 | 994 | 561 | 74.52 |
| Gas Furnace, 90% - 2-stage, w/ ECM | 75,000 | 66,809 | 0 | 90 | 0.398 | 0.4 | 0.62 | 40 | 903 | 578 | 67.70 |
| 90%(C4) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 66,809 | 0 | 90 | 0.337 | 0.4 | 0.62 | 40 | 909 | 513 | 68.18 |
| Gas Furnace, 92% - 2-stage w/ ECM | 75,000 | 68,309 | 0 | 92 | 0.398 | 0.4 | 0.62 | 40 | 884 | 566 | 66.30 |
| 92%(C4) - ImprovedCompactCircBlowerImpeller + ECM | 75,000 | 68,309 | 0 | 92 | 0.337 | 0.4 | 0.62 | 40 | 890 | 503 | 66.76 |

## Table 6.3.4.8 Two-Stage Mobile Home Furnaces

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | BE, BEH | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 80% AFUE w/ Two-stage Modulation + ECM | 75,000 | 59,742 | 0 | 80 | 0.398 | 0.4 | 0.62 | 30 | 757 | 484 | 61.15 |
| 81% AFUE w/ Two-stage Modulation + ECM | 75,000 | 60,492 | 0 | 81 | 0.398 | 0.4 | 0.62 | 40 | 997 | 638 | 79.19 |
| 82% AFUE w/ Two-stage Modulation + ECM | 75,000 | 61,242 | 0 | 82 | 0.398 | 0.4 | 0.62 | 40 | 986 | 631 | 78.33 |

## Table 6.3.4.9 Two-Stage Hot-Water Oil Furnaces

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | BE, BEH | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 81%AFUE Fan Atomized Burner w/ Two-stage Modulation | 105,000 | 83,839 | 0 | 81 | 0.398 | 0.045 | 26.00 | 50 | 897 | 759 | 94.21 |
| 82%AFUE Fan Atomized Burner w/ Two-stage Modulation | 105,000 | 84,889 | 0 | 82 | 0.398 | 0.045 | 26.00 | 50 | 887 | 750 | 93.12 |
| 83%AFUE Fan Atomized Burner w/ Two-stage Modulation | 105,000 | 85,939 | 0 | 83 | 0.398 | 0.045 | 26.00 | 50 | 877 | 742 | 92.05 |
| 84%AFUE Fan Atomized Burner w/ Two-stage Modulation | 105,000 | 86,989 | 0 | 84 | 0.398 | 0.045 | 26.00 | 50 | 867 | 733 | 91.00 |
| 85%AFUE Fan Atomized Burner w/ Two-stage Modulation | 105,000 | 88,039 | 0 | 85 | 0.398 | 0.045 | 26.00 | 50 | 857 | 726 | 89.98 |

## Table 6.3.4.10 Two-Stage Hot-Water Gas Boilers

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | BE, BEH | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Gas Boiler, 81% w/ Two-stage Modulation | 105,000 | 85,804 | 0 | 81 | 0.070 | 0.4 | 0.62 | 50 | 929 | 241 | 97.50 |
| Gas Boiler, 82% w/ Two-stage Modulation | 105,000 | 86,854 | 0 | 82 | 0.070 | 0.4 | 0.62 | 50 | 917 | 238 | 96.33 |
| Gas Boiler, 83% w/ Two-stage Modulation | 105,000 | 87,904 | 0 | 83 | 0.070 | 0.4 | 0.62 | 50 | 907 | 235 | 95.18 |
| Gas Boiler, 84% w/ Two-stage Modulation | 105,000 | 88,954 | 0 | 84 | 0.070 | 0.4 | 0.62 | 50 | 896 | 233 | 94.06 |

## Table 6.3.4.11 Two-Stage Hot-Water Oil Boilers

| Description | $Q_{IN}$ | $Q_{OUT}$ | QP | $EFFy_{HS}$ | BE, BEH | $PE_{IG}$ | $T_{IG}$ | RDHR | BOHss | $E_{AE}$ | EF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil Boiler, 82% Fan Atomized Burner w/ Two-stage Modulation | 140,000 | 116,213 | 0 | 82 | 0.070 | 0.045 | 26.00 | 70 | 965 | 329 | 135.10 |
| Oil Boiler, 83% Fan Atomized Burner w/ Two-stage Modulation | 140,000 | 117,613 | 0 | 83 | 0.070 | 0.045 | 26.00 | 70 | 954 | 325 | 133.49 |
| Oil Boiler, 84% Fan Atomized Burner w/ Two-stage Modulation | 140,000 | 119,013 | 0 | 84 | 0.070 | 0.045 | 26.00 | 70 | 942 | 321 | 131.92 |
| Oil Boiler, 85% Fan Atomized Burner w/ Two-stage Modulation | 140,000 | 120,413 | 0 | 85 | 0.070 | 0.045 | 26.00 | 70 | 931 | 318 | 130.39 |

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