# APPENDIX 7-E. DERIVATION OF HEATING LOAD FOR POOL HEATERS AND DIRECT HEATING EQUIPMENT

## TABLE OF CONTENTS



## LIST OF TABLES

# APPENDIX 7-E. DERIVATION OF HEATING LOAD FOR POOL HEATERS AND DIRECT HEATING EQUIPMENT

## 7-E.1 INTRODUCTION

RECS 2001[1] provides variables for the energy consumption for direct heating equipment and pool heaters. DOE used this information to determine the annual house heating load (HHL) and pool heater heating load (PHHL).

## 7-E.2 DIRECT HEATING EQUIPMENT

### 7-E.2.1 Derivation of House Heating Load for Direct Heating Equipment

Annual house heating load (HHL) is determined using the DOE's test procedure[2] approach as follows. First, from the test procedure the average annual fuel energy for gas or oil vented heaters, $E_F$, for single-stage direct heating equipment is given by the following equation:

$$E_F = BOH_{SS} \times (Q_{IN} - Q_P) + 8760 \times Q_P$$

Then the burner operating hours ($BOH_{SS}$) can be rewritten as follows using DOE's test procedure equation for $BOH_{SS}$ and substituting in the House Heating Load (HHL):

$$BOH_{SS} = HHL \times A - 4160 \times A \times Q_P \times \eta_U$$

Finally, we determine the House Heating Load (HHL) by replacing $E_F$ with the RECS 2001 calculated annual energy consumption ($Q_{YR,RECS}$):

$$HHL = \frac{Q_{YR,RECS} - 8760 \times Q_P}{A \times (Q_{IN} - Q_P)} + 4160 \times Q_P \times \eta_U$$

Where:

| | | |
|---|---|---|
| $Q_{YR,RECS}$ | = | annual fuel consumption for heating the housing unit, from RECS 2001, kBtu/yr, |
| $Q_P$ | = | pilot input rate,Btu/h, |
| $Q_{IN}$ | = | rated input capacity of direct heating equipment, Btu/h, |
| 8760 | = | hours in a year, h, |
| 4160 | = | average heating season hours according to test procedure, h, |
| $A$ | = | test procedure factor, h/kBtu, |
| | = | $\frac{100{,}000}{341{,}000 \times PE + (Q_{in} - Q_P) \times \eta_U}$, |
| $PE$ | = | power consumption of the direct heating equipment while the burner is on, W, |
| $\eta_U$ | = | part load utilization efficiency (%), |

$$= \frac{2950 AFUE \times \eta_{SS} \times Q_{in}}{2950 \times \eta_{SS} \times Q_{in} - AFUE \times 2.033 \times 4600 \times Q_P}, \text{ and}$$

$\eta_{SS}$ = steady state efficiency (%).

The average pilot input rate for the above calculation is 400 Btu/h for gas wall fan DHE and gas wall gravity DHE, 450 Btu/h for gas floor DHE, and 350 Btu/h for gas room DHE.[3] Chapter 7 describes the input capacity ($Q_{IN}$ ) values.

The PE value reflects a design with electrical components. DOE used values for PE given in the 1993 technical support document.[3]

The steady state efficiency ($\eta_{SS}$) is calculated by solving for $\eta_{SS}$ in the equation given in section 4.1.17 in the DOE test procedure as follows:

$$\eta_{SS} = \frac{AFUE + 1.78 \times D_F + 189 \times D_S - 129 \times P_F - 2.8 \times L_J + 1.81}{0.968}$$

The DOE test procedure gives values for the parameters $D_F$, $D_S$, $P_F$, and $L_J$.

### 7-E.2.2 Adjustment to Direct Heating Equipment Energy Consumption using RECS

For the households for which it is clear that the natural gas use for heating is associated solely with use of the direct heating equipment as primary or secondary heating equipment, DOE used the annual fuel consumption for heating the housing unit from RECS 2001.

For the households that use direct heating equipment as secondary heating equipment and also use primary gas heating equipment other than a direct heating equipment, DOE made adjustments to the house heating load by using a RECS 2001 variable that reports the fraction of heating energy consumption provided by the primary heating system. Using this variable, DOE estimated the fraction of heating provided by the secondary direct heating equipment (see Table 7-E.2.1) using a triangular distribution.

**Table 7-E.2.1 Adjustment of RECS Energy Consumption for Secondary DHE with same fuel primary heating equipment**

| RECS Value for EQMAMT | RECS Value Definition (How much heat main heating equipment provides) | Fraction of DHE Heating *(%)* | | |
|---|---|---|---|---|
| | | Min | Avg | Max |
| 1 | Almost all | 5 | 15 | 25 |
| 2 | About three-fourths | 15 | 25 | 35 |
| 3 | Close to half of all your heat | 35 | 40 | 45 |
| 6 | Don't know | 5 | 25 | 45 |

## 7-E.3 POOL HEATERS

### 7-E.3.1 Derivation of Pool Heaters Heating Load (PHHL) for Pool Heaters

Annual pool heaters heating load (*PHHL*) is determined using the DOE test procedure[4] as follows. First, from the test procedure the average annual fuel energy for gas pool heaters, $E_F$, is given by the following equation:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_P$$

Then the burner operating hours ($BOH_{SS}$) can be written as follows:

$$BOH_{SS} = \frac{PHHL}{Q_{IN} \times E_t}$$

We determine the Pool Heater Heating Load (*HHL*) by replacing $E_F$ with the RECS 2001 calculated annual energy consumption ($Q_{RECS}$):

$$PHHL = \left( \frac{Q_{IN}}{Q_{IN} - Q_P} \right) (Q_{RECS} - Q_P \times POH) \times E_t$$

Finally, we can approximate Pool Heater Heating Load (*HHL*) by following formula since $Q_P$ is much smaller than $Q_{IN}$ for pool heaters:

$$PHHL = (Q_{RECS} - Q_P \times POH) \times E_t$$

Where:

$Q_{RECS}$ = Pool heater annual fuel consumption (kBtu/yr),
$Q_P$ = pilot light input rate (kBtu/yr),
$POH$ = pool operating hours (h/yr), and
$E_t$ = thermal efficiency of the existing pool heater associated with the household (%).

For units that have a pilot light, DOE assigned a pilot light input rate of 1,000 Btu/h.[3, 5] DOE assigned pool heaters with pilot light to 29 percent of the household based on the fraction

of models in the 2007 FTC pool heater directory.[6] DOE estimated the remaining 71 percent were equipped with electronic ignition.

The DOE test procedure uses an average value for pool operating hours (*POH*) of 4,464 hours per year. DOE used a distribution around this average to assign *POH* to the sample households. The distribution ranges from 230 h/yr to 8760 h/year (100 percent of the time). The value of 230 h/year is the minimum value that fits the function used to calculate the distribution, and is close to the minimum number of hours that a pool heater burner can operate.

DOE assigned all sample households a baseline pool heater with a 78 percent thermal efficiency. This assumption is based on the lifetime distribution of pool heaters (see Appendix J), which means that almost all pool heaters associated with RECS 2001 households were installed after the 78 percent energy conservation standard was mandated by EPCA.

### 7-E.3.2 Adjustment of Energy Consumption from RECS

Pool heater annual fuel consumption ($Q_{RECS}$) for each household with a pool heater comes from RECS 2001. In most cases the fuel energy consumption in RECS 2001 includes other gas appliances such as gas clothes dryers and/or gas cooking equipment. For households having a pool heater and gas clothes dryers and/or gas cooking equipment, DOE subtracted the average value that represents the energy use of this equipment from the fuel energy consumption provided in RECS (see Table 7-E.3.1).

**Table 7-E.3.1 Adjustment of RECS Energy Consumption for Pool Heaters in Households with same Fuel Cooking Equipment and/or Clothes Dryer**

| Gas equipment in households with pool heaters | Annual Energy Consumption Subtracted *(kBtu/h)* |
|---|---|
| Cooking Equipment Only | 7235 |
| Clothes Dryer Only | 4314 |
| Cooking Equipment and Clothes Dryer | 10892 |

## REFERENCES


1. U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2001 Public Use Data Files,* 2001. <http://www.eia.doe.gov/emeu/recs/recs2001/publicuse2001.html>

2. Department Of Energy, *Appendix O to Subpart B of Part 430-Uniform Test Method For Measuring The Energy Consumption Of Vented Home Heating Equipment*. filed as "WH Test Procedure 10 CFR 430 subpart B, Appendix E".

3. U.S. Department of Energy-Office of Codes and Standards, *Technical Support Document: Energy Efficiency Standards for Consumer Products: Room Air Conditioners, Water Heaters, Direct Heating Equipment, Mobile Home Furnaces, Kitchen Ranges and Ovens, Pool Heaters, Fluorescent Lamp Ballasts & Television Sets*, 1993. Washington, DC Vol. 1 of 3. Report No. DOE/EE-0009.

4. Department Of Energy, *Appendix P to Subpart B of Part 430-Uniform Test Method For Measuring The Energy Consumption Of Pool Heaters*. filed as "PH Test Procedure 10 CFR 430 subpart B, Appendix P".

5. Hamos, R., *Consultant Report - Pool Heater Pilot Size*, 2008.

6. Federal Trade Commission, *Appliance Energy Data - Water Heaters,* 2007. <http://www.ftc.gov/bcp/conline/edcams/eande/appliances/data/2007/waterheat/index.htm>