APPENDIX I. FURNACE FAN CURVES

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDIX I. FURNACE FAN CURVES

I.1 Furnace Fan Curves

Depending on the resistance (measured as static pressure) of the supply and return air ducts, a furnace will move more or less air. When these airflow values are plotted graphically against pressure, they are referred to as fan curves.

The Department developed fan curves for the single-stage virtual furnace models by fitting the manufacturer airflow and pressure data points from the basic model furnaces[1, 2, 3, 4, 5, 6, 7] to a fourth-order polynomial. The Department did this separately for each of the four nominal air handlers sizes for both non-condensing and condensing furnaces. The CFM for PSC blower motors is given by the following equation:

$$CFM = m_0 + m_1 \times (P) + m_2 \times (P^2) + m_3 \times (P^3) + m_4 \times (P^4) \qquad \textbf{Eq. 1}$$

where,

CFM	=	airflow in CFM reported by manufacturer,
$m_{0,1,2,3,and4}$	=	coefficients derived from 4th degree polynomial approximation (see Table I.1 for actual coefficient values), and
P	=	external static pressure (in. w.g.).

Table I.1 Coefficients for CFM equation for PSC motors

		m_0	m_1	m_2	m_3	m_4
Non-Condensing	2-ton	891.0	-590.8	564.6	-552.2	0.0
	3-ton	1280.6	-279.8	194.4	-456.3	0.0
	4-ton	1585.1	32.8	-575.7	-78.4	12.3
	5-ton	1998.1	260.9	-93.2	-359.8	115.9
Condensing	2-ton	840.4	70.0	-908.4	294.3	56.4
	3-ton	1169.5	-226.1	-272.6	-95.7	137.0
	4-ton	1541.2	-110.3	-777.3	419.0	0.0
	5-ton	1915.1	-198.0	-594.5	-277.8	8.3

Figure I.1 shows an example of a CFM curve for a 3-ton Non-Condensing Single-Stage Furnace fitted with the manufacturers' raw data.

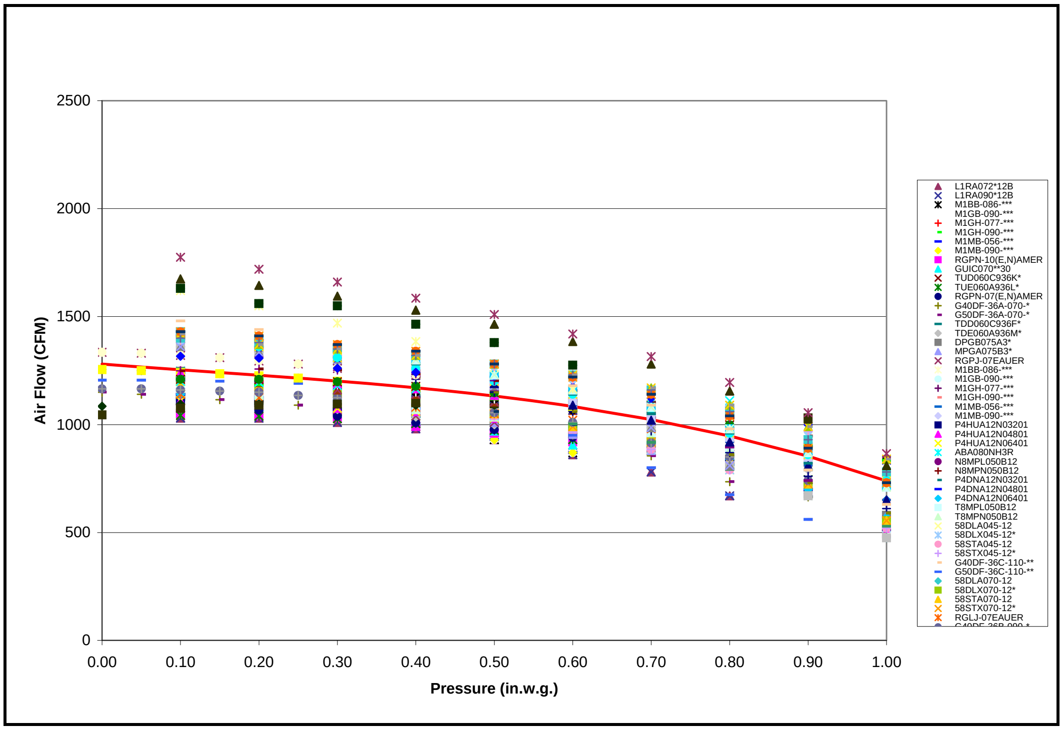

Figure I.1 Example Fit of CFM for 3-ton Non-Condensing Single-Stage Furnace

Figures I.2 and I.3 show the fan curves for non-condensing and condensing furnaces. Appendix H, Determination of Basic Furnace and Boiler Models, contains the data on the basic models that were used to develop these fan curves.

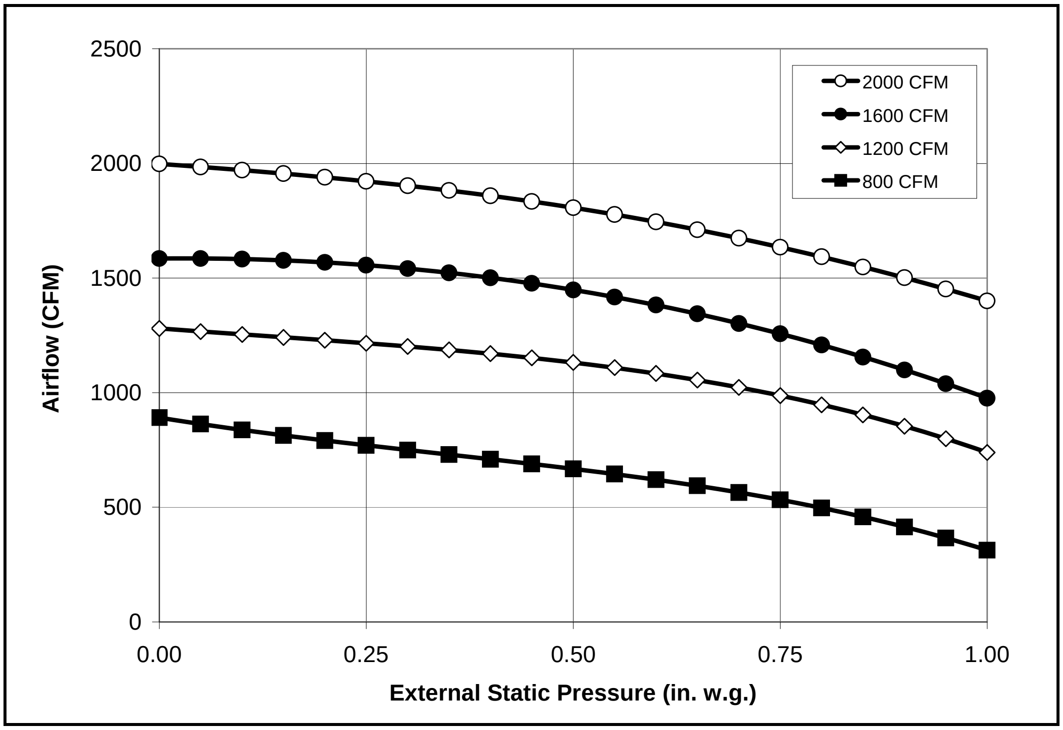

Figure I.2 Fan Curves for Non-Condensing Single-Stage Virtual Model Furnaces

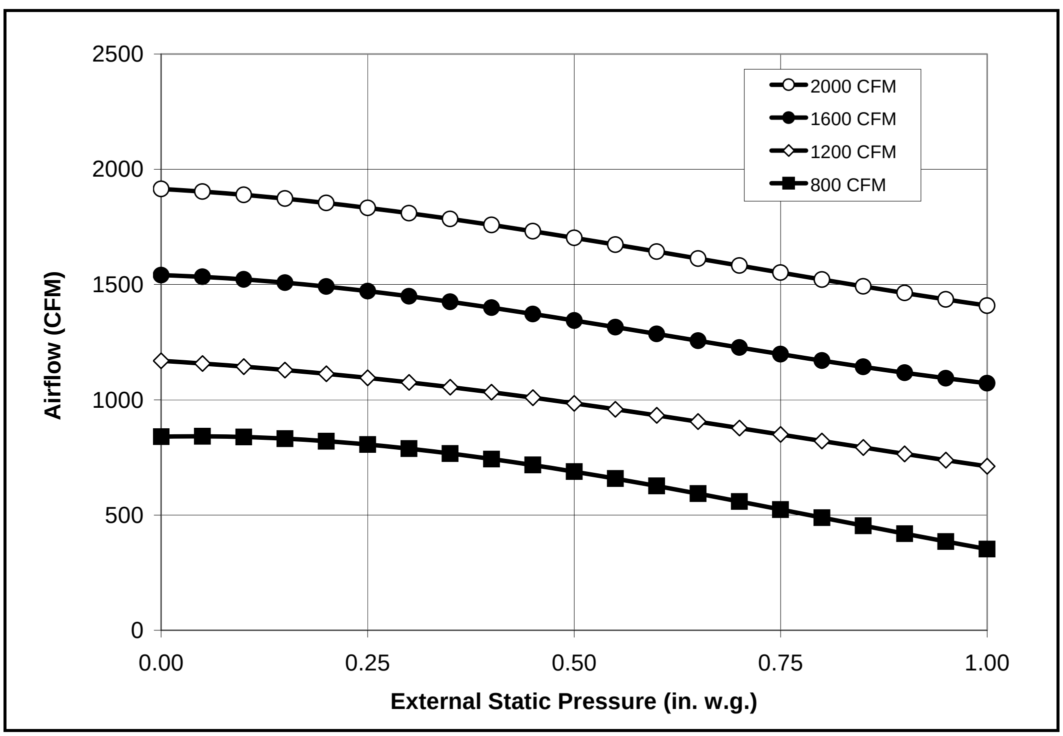

Figure I.3 Fan Curves for Condensing Single-Stage Virtual Model Furnaces

The two-stage and step-modulating design options in this analysis use brushless permanent magnet motors (or sometimes referred as Electronically Commutated Motors (ECM)). Unlike PSC motors, these motors are electronically commutated and the speed they operate at can be varied across a wide range. These motors are controlled to operate the blower fans at a wide variety of air flows and static pressures. In the furnaces with these motors currently on the market, the controls are designed to provide a nearly constant air flow across the entire range of pressures at which they operate.

Because of the versatility of the motors, manufacturers only offer furnaces with blowers nominally designed for operation with five-ton and three-ton air conditioners. The manufacturers provide control options to decrease the airflow for installations that use smaller air conditioners.

To develop fan curves for furnaces with ECM motors, the Department fit quadratic curves through the air flow and pressure data points reported by manufacturers.[8, 9, 10, 11, 12, 13, 14] DOE did this separately for high-fire and low-fire operation for both non-condensing and condensing furnaces. See Figures I.4 through I.7 for charts showing the fit lines. Table I.2 shows the coefficients for two-stage and step-modulating furnaces with ECM motors using Eq. 2. Data from the basic models that were used to develop these fan curves is shown in Appendix H, Determination of Basic Furnace and Boiler Models.

$$CFM = m_0 + m_1 \times (P) + m_2 \times (P^2) \qquad \textbf{Eq. 2}$$

where,

CFM	=	airflow in CFM reported by manufacturer,
$m_{0,1,\text{ and }2}$	=	coefficients derived from 2nd degree polynomial approximation (see Table I.2 for actual coefficient values), and
P	=	external static pressure (in. w.g.).

Table I.2 Coefficients for CFM equation for Two-Stage and Step-Modulating furnaces with ECM motors

		High Fire			Low Fire		
		m_0	m_1	m_2	m_0	m_1	m_2
Non-Condensing	2-ton	857.5	62.0	0.0	634.7	37.5	0.0
	3-ton	1091.1	37.4	0.0	831.7	6.4	0.0
	4-ton	1324.8	12.9	0.0	1028.7	-24.7	0.0
	5-ton	1558.5	-11.7	0.0	1225.7	-55.8	0.0
Condensing	2-ton	714.0	-16.4	-13.8	489.4	-50.2	0.0
	3-ton	1003.0	-27.4	0.0	680.2	-31.5	0.0
	4-ton	1291.9	-38.4	13.8	870.9	-12.9	0.0
	5-ton	1580.9	-49.5	27.6	1061.6	5.8	0.0

To be consistent with the analysis it did for the single-stage furnaces with PSC blower motors, the Department created virtual models for furnaces intended to act as air handlers for four and two ton air conditioners even though these are not currently offered by manufacturers. To generate the fan curves for the virtual furnaces intended to be used with 4 ton air conditioners, DOE calculated the average of the slopes and intercepts of the virtual furnaces with air handler for 5 ton and 3 ton air conditioners. This was done separately for high and low fire operations for non-condensing and condensing furnaces.

For the virtual furnace models intended to operate with two-ton air conditioners, the fan curves were created by extrapolating the values for the slopes and intercepts of the virtual furnace models with air handlers intended to operate with three-ton and five- ton air conditioners. This was also done separately for high fire and low fire operation for both non-condensing and condensing furnaces. See Figures I.4 through I.7 for charts showing the fan curves for these air handlers.

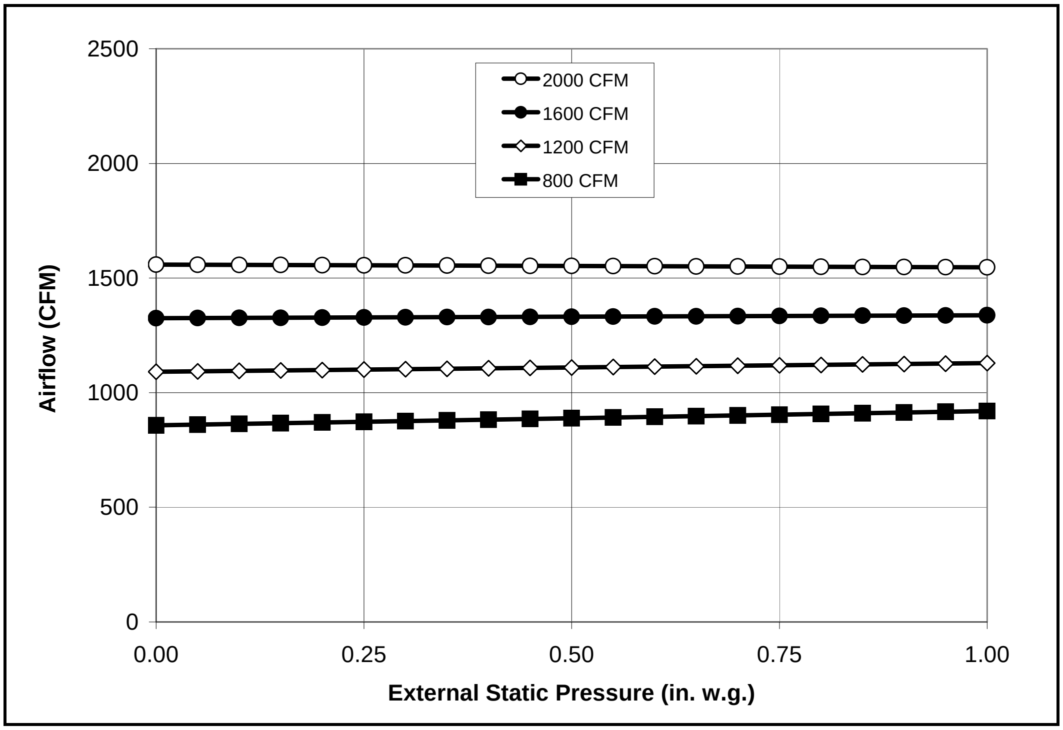

Figure I.4 Fan Curves for Non-Condensing Two-Stage Virtual Model Furnaces - High Fire

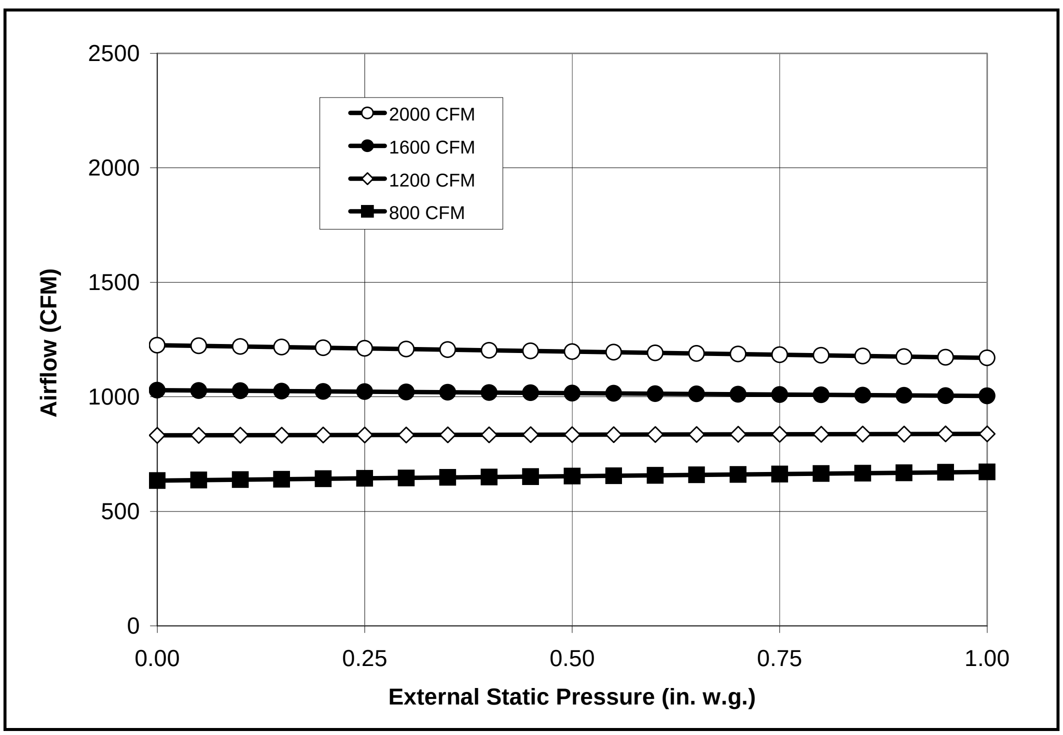

Figure I.5 Fan Curves for Non-Condensing Two-Stage Virtual Model Furnaces - Low Fire

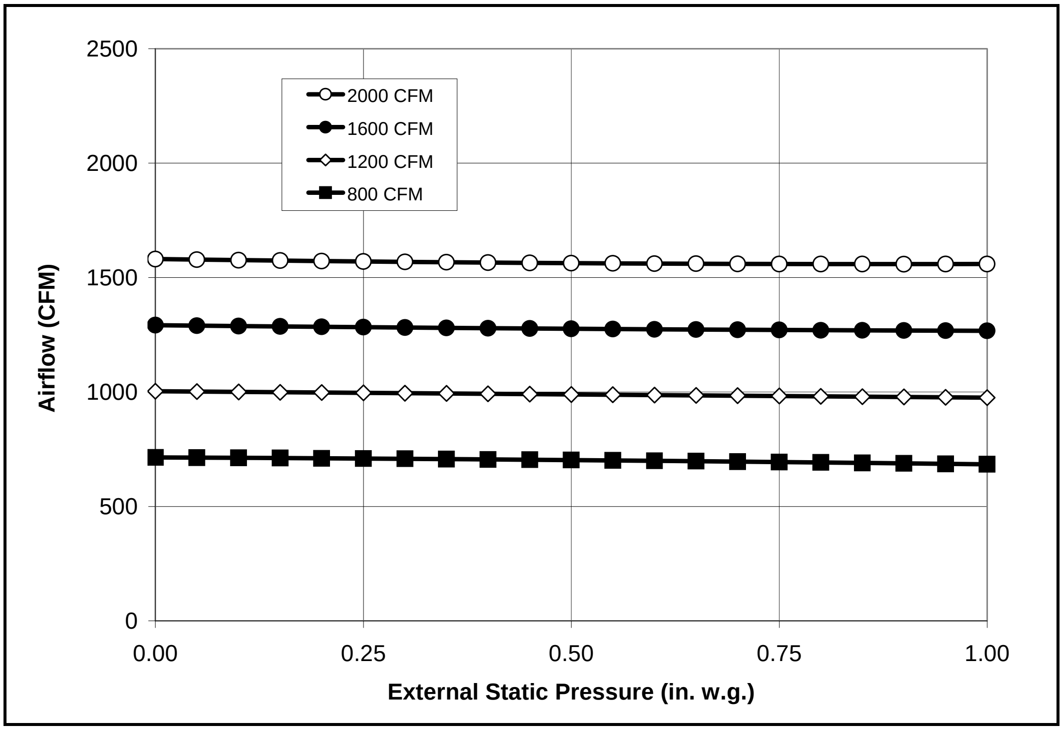

Figure I.6 Fan Curves for Condensing Two-Stage Virtual Model Furnaces - High Fire

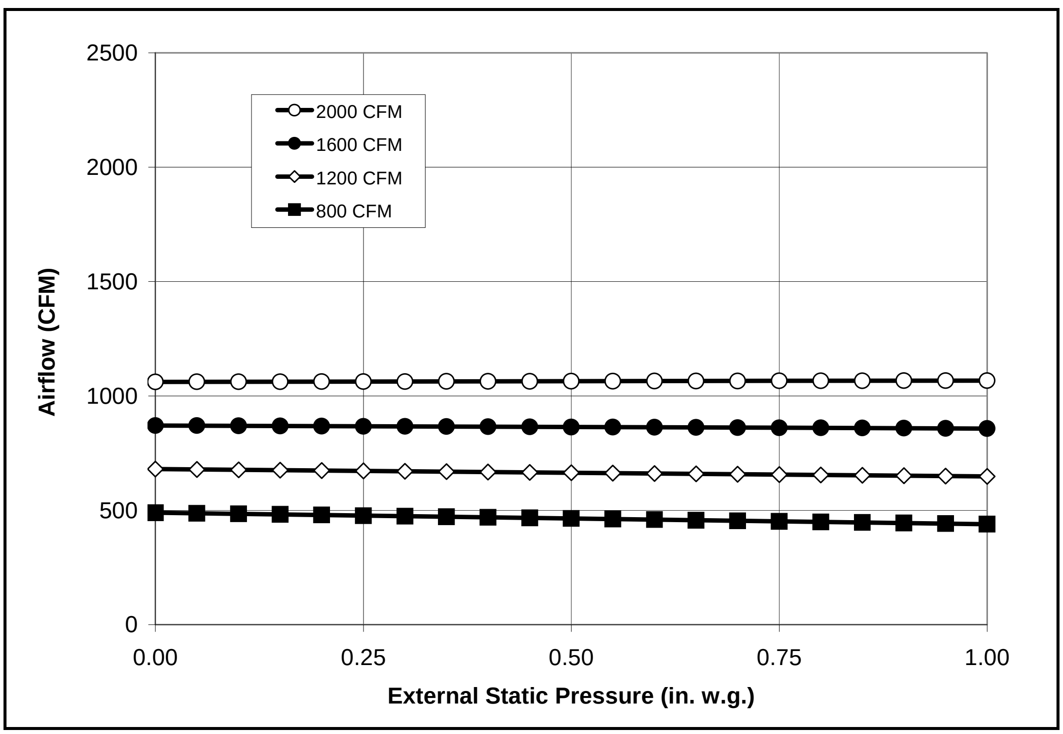

Figure I.7 Fan Curves for Condensing Two-Stage Virtual Model Furnaces - Low Fire

REFERENCES

1. Lennox Industries Inc. *Lennox Engineering Data: G40DF (Merit Series Upflow/Horizontal Gas Furnace).* 2003. Lennox Industries, Inc. 2003.) <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g40df_0307.pdf>

2. Lennox Industries Inc. *Lennox Engineering Data: G40UH (Merit Series Upflow/Horizontal Gas Furnace).* 2004. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g40uh_0407.pdf>

3. Lennox Industries Inc. *Lennox Engineering Data: G41UF (Merit Series Downflow Gas Furnace).* 2004. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g41uf_0402.pdf>

4. Lennox Industries Inc. *Lennox Engineering Data: G43UF (Merit Series Upflow Gas Furnace).* 2004. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g43uf_0412.pdf>

5. Lennox Industries Inc. *Lennox Engineering Data: G50DF (Elite Series Downflow Gas Furnace).* 2003. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g50df_0307.pdf>

6. Lennox Industries Inc. *Lennox Engineering Data: G50UH (Elite Series Upflow/Horizontal Gas Furnace).* 2003. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g50uh_0307.pdf>

7. Lennox Industries Inc. *Lennox Engineering Data: G51MP (Elite Series Multi-Position Gas Furnace).* 2004. Lennox Industries, Inc. <http://pirl.lennox.com/C03e7o14l/76E0ZC21u/ehb_g51mp_0412.pdf>

8. Carrier Corporation. *Carrier Product Data: 58CVA/CVX(Infinity 80 Series MultiPoise Furnace).* 2004. Carrier Co. <http://www.xpedio.carrier.com/idc/groups/public/documents/techlit/58cv-3pd.pdf>

9. Carrier Co. *Carrier Product Data: 58MVP (Infinity 96 Deluxe 4-Way Multipoise Furnace).* 2004. Carrier Co. <http://www.xpedio.carrier.com/idc/groups/public/documents/techlit/58mvp-11pd.pdf>

10. Lennox Industries Inc. *Lennox Engineering Data: G61MPV (Multi-Position - Variable Speed Blower - Two-Stage Heat - Direct Vent/Non-Direct Vent).* 2004. Lennox Industries, Inc.

11. Lennox Industries Inc. *Lennox Engineering Data: G60UHV (Up-Flow/Horizontal - Two Stage Heat - Variable Speed Blower).* 2003. Lennox Industries, Inc.

12. Lennox Industries Inc. *Lennox Engineering Data: G60DFV (Down-flow - Variable Speed Blower - Two-Stage Heat).* 2004. Lennox Industries, Inc.

13. Trane Co. *Trane Product Data: XV 80.* 2004. Trane Co.

14. Trane Co. *Trane Product Data: XV 90.* 2004. Trane Co.