APPENDIX K. AIR MOVING EFFICIENCY

TABLE OF CONTENTS

LIST OF FIGURES

APPENDIX K. AIR MOVING EFFICIENCY

K.1 INTRODUCTION

The purpose of calculating the overall air-moving efficiency for the basic furnace models used in the LCC analysis is to show typical efficiency levels for furnace air handlers.

K.2 METHODOLOGY

The overall air-moving efficiency is a ratio of the air power divided by the electric power used by the blower motor:

$$\eta_{overall} = \frac{AHP}{BE} \qquad \textbf{Eq. 1}$$

where:

$\eta_{overall}$	=	overall air-moving efficiency,
AHP	=	air horsepower (watts), and
BE	=	circulating air fan electrical energy consumption (watts).

Air power is the power embodied in the air due to its motion and pressure increase. Air power at any operating condition can be calculated for any furnace from pressure, airflow, and supply air outlet area. Air power (air horsepower or AHP) is calculated as[1]:

$$AHP = \left(\frac{745.7}{6356}\right) \times Q \times \left[P + \left(\frac{Q}{4005 \times A}\right)^2 \right] \qquad \textbf{Eq. 2}$$

where:

AHP	=	air power (watts),
Q	=	airflow (cfm),
$\left(\frac{745.7}{6356}\right)$	=	a conversion factor to express air horsepower in watts,
4005	=	a conversion factor to express the velocity pressure of standard air in w.g.,[1]
P	=	external static pressure (in.w.g.), and

[1] The velocity pressure is the increase in pressure caused by the motion of air.

A	=	cross-sectional airflow area of the supply-air outlet area (sq.ft.) determined by equation 1 or 2 in Chapter 7, section 7.2.5..

The power consumption of the fan (BE) is calculated by multiplying the Watts/CFM by the CFM at the operating point:

$$BE = \frac{Watts}{CFM} \times Q \qquad \textbf{Eq. 3}$$

where,

BE	=	circulating air fan electrical energy consumption (watts),
Watts/CFM	=	determined by equation 1 or equation 2 in Appendix J, and
Q	=	airflow (cfm) determined in Chapter 7, section 7.5.2.

K.3 OVERALL AIR EFFICIENCY CURVES

In order to generate the overall air moving efficiency curves we followed the following procedure (a 3-ton non-condensing single-stage furnace is used as an example):

STEP 1: Using the coefficients in Appendix I and J generate the Airflow (CFM) vs. pressure and Watts/CFM vs. pressure curves. See Figure K.3.1 for the sample 3-ton non-condensing furnace (single-stage, PSC motor).

STEP 2: Using Equation 3, DOE multiplied the airflow times the Watt/CFM at each pressure from Step 1 to calculate *BE* in terms of pressure. See Figure K.3.2 for the sample 3-ton non-condensing furnace (single-stage, PSC motor)..

STEP 3: Using Equation 2, DOE used the airflow (CFM) and pressure from Step 1 to calculate the variables *Q* and *P* and used the equations in Chapter 7, section 7.2.5, to calculate the *A*, the supply-air outlet area. These values were used to calculate *AHP* in terms of pressure. See Figure K.3.3 for the sample 3-ton non-condensing furnace (single-stage, PSC motor), where A is equal to 2.04 sq. ft. (at 75 kBtu input capacity).

STEP 4: Using Equation 1, finally DOE substituted BE and AHP from Step 2 and Step 3, respectively, to calculate the overall air moving efficiency in terms of pressure. See Figure K.3.4.

Figures K.3.5 through K.3.10 show the overall air moving efficiency vs. pressure curves for single-stage non-condensing, single-stage condensing, two-stage non-condensing (high and low fire), and two-stage condensing (high and low fire). Not all 25 basic design options are shown on graphs, just 4 are shown: 2-ton at 50 kBtu, 3-ton at 75 kbtu, 4-ton at 100 kbtu, and 5-ton at 120 kbtu.

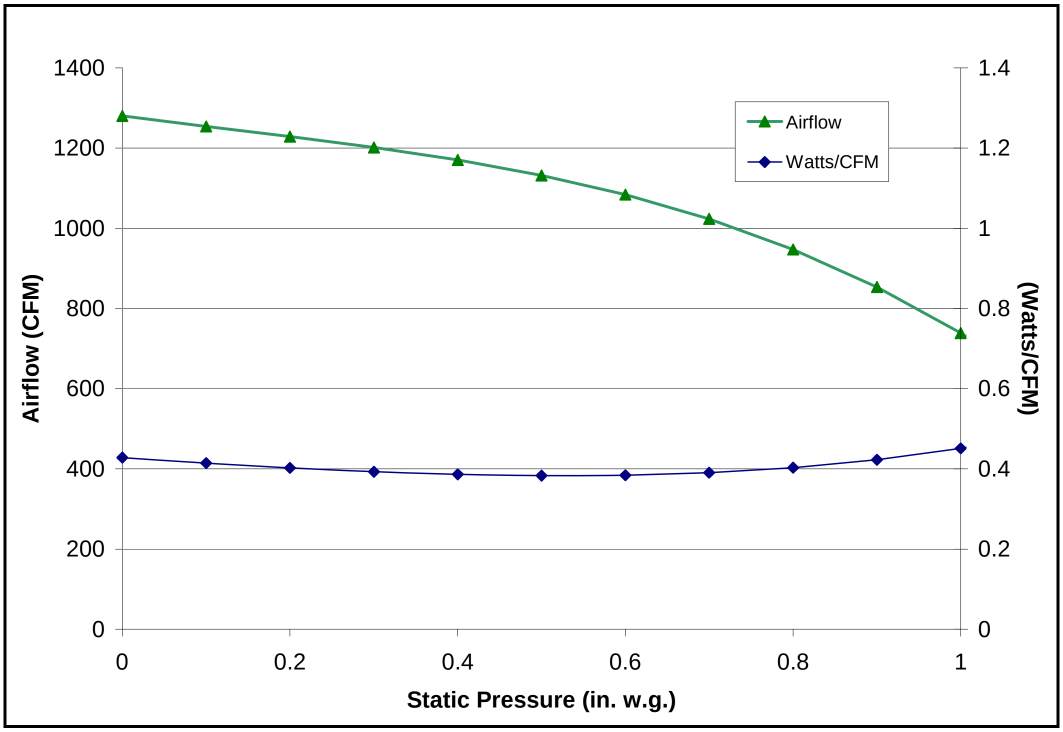

Figure K.3.1 Airflow and Watts/CFM vs. Pressure for 3-Ton Non-Condensing Furnace - Single-Stage, PSC motor

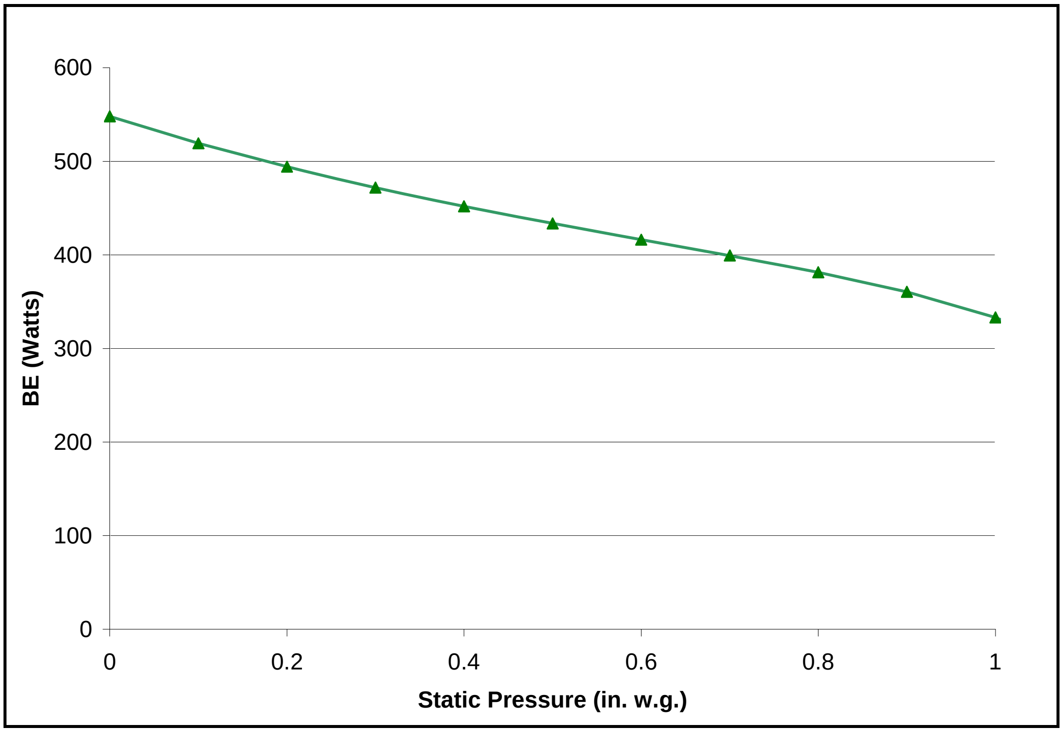

Figure K.3.2 BE vs. Pressure for 3-Ton Non-Condensing Furnace - Single-Stage, PSC motor

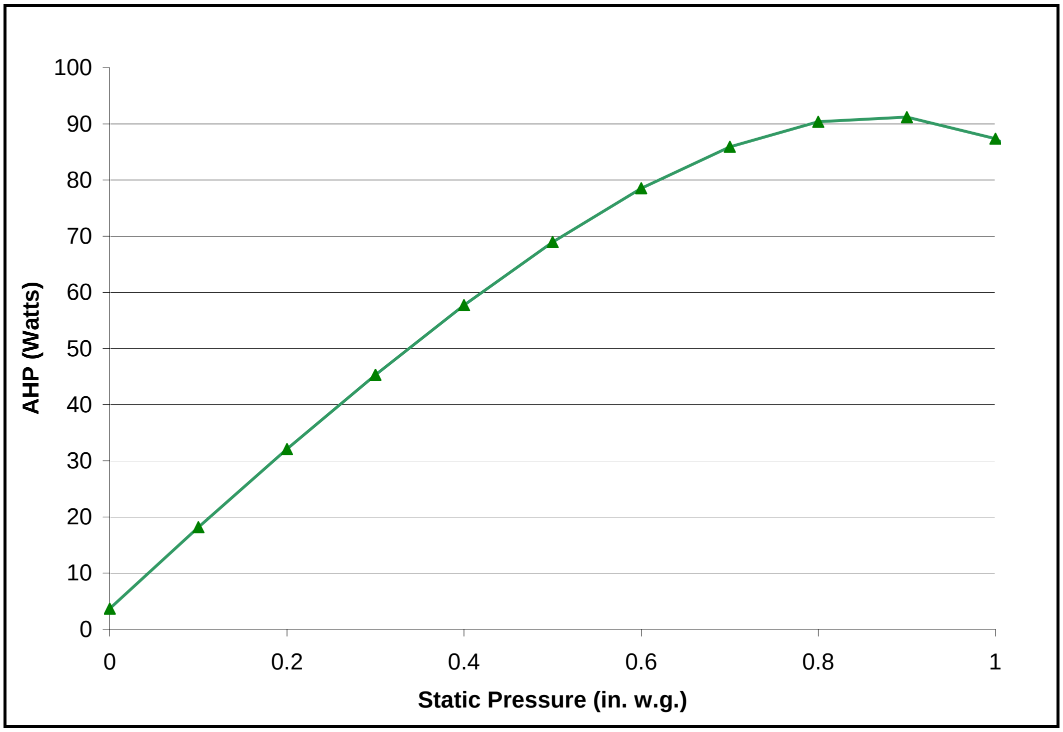

Figure K.3.3 Air Horsepower (AHP) vs. Pressure for 3-Ton Non-Condensing Furnace - Single-Stage, PSC motor

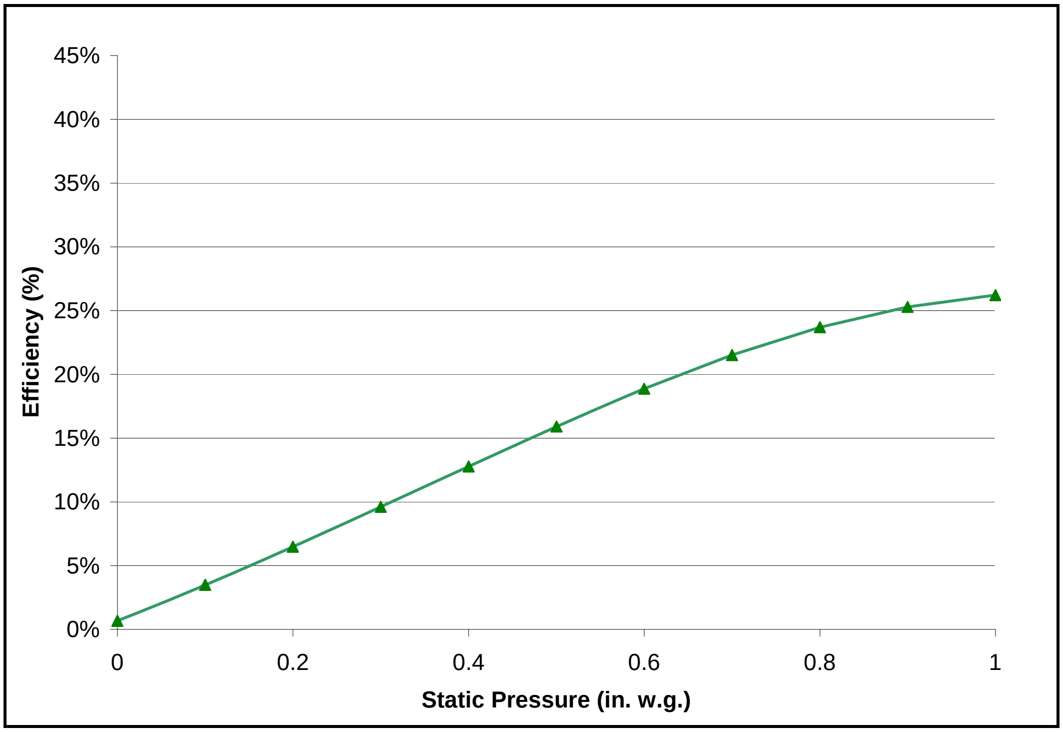

Figure K.3.4 Overall Blower Motor Efficiency vs. Pressure for 3-Ton Non-Condensing Furnace - Single-Stage, PSC motor

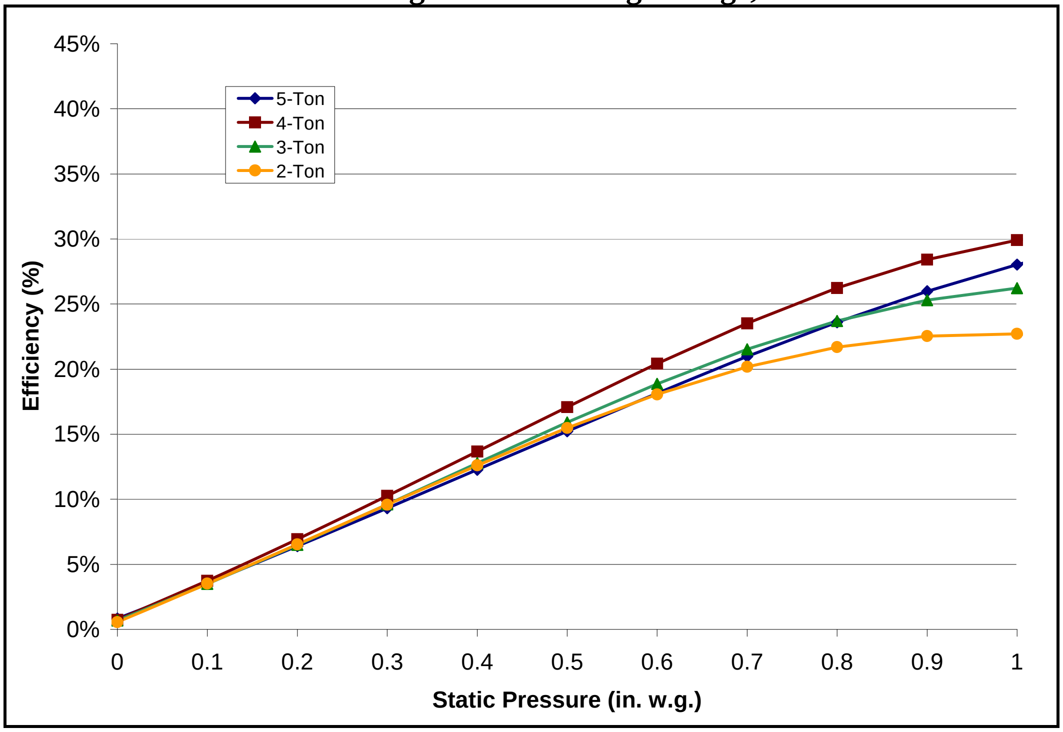

Figure K.3.5 Blower Efficiency vs. Pressure Curves for Non-Condensing Furnace - Single-Stage Control, PSC Motor

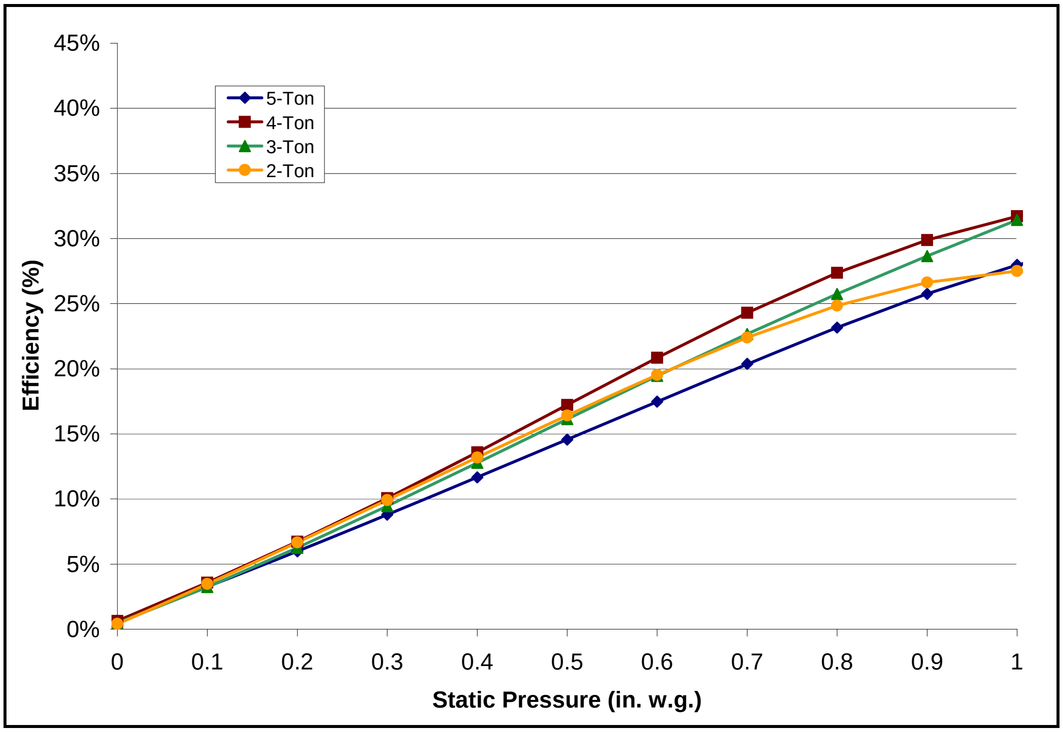

Figure K.3.6 Blower Efficiency vs. Pressure Curves for Condensing Furnace - Single-Stage Control, PSC Motor

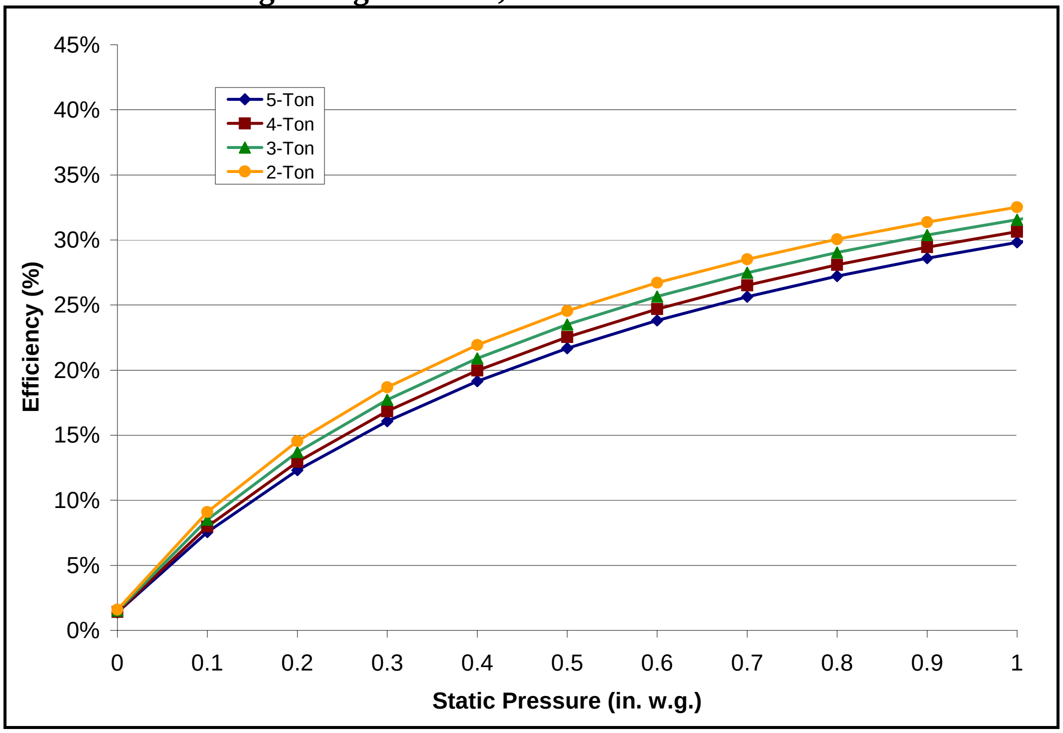

Figure K.3.7 Blower Efficiency vs. Pressure Curves for Non-Condensing Furnace - Two-Stage Virtual Control, ECM Motor, High Fire

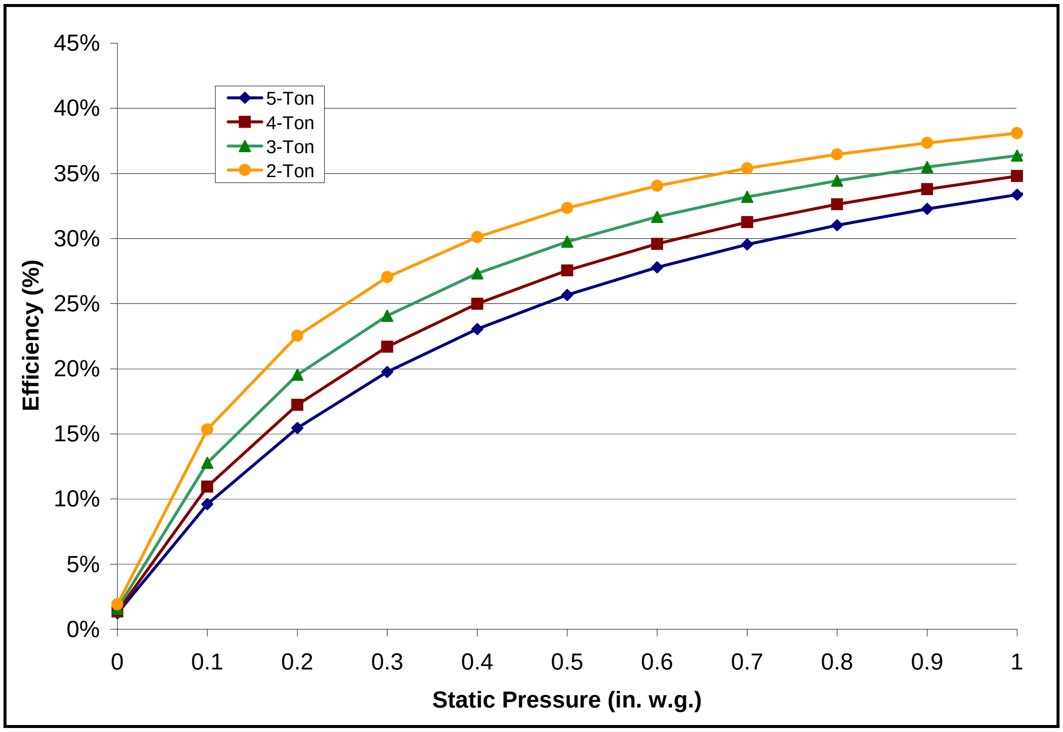

Figure K.3.8 Blower Efficiency vs. Pressure Curves for Non-Condensing Furnace - Two-Stage Virtual Control, ECM Motor, Low Fire

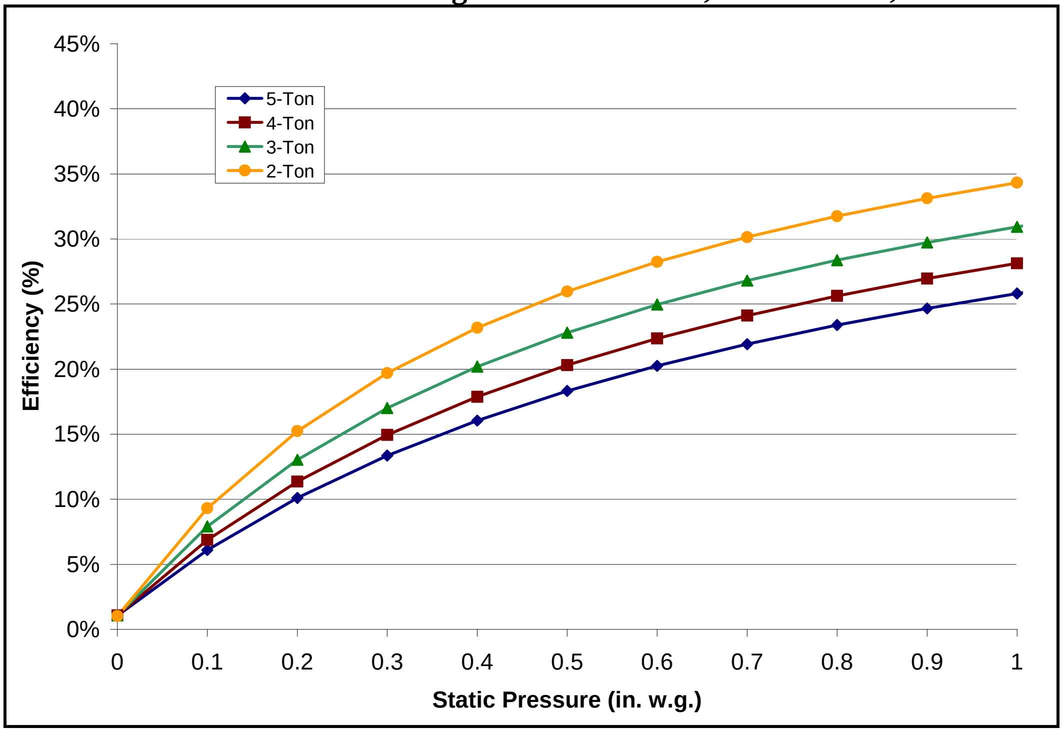

Figure K.3.9 Blower Efficiency vs. Pressure Curves for Condensing Furnace - Two-Stage Virtual Control, ECM Motor, High Fire

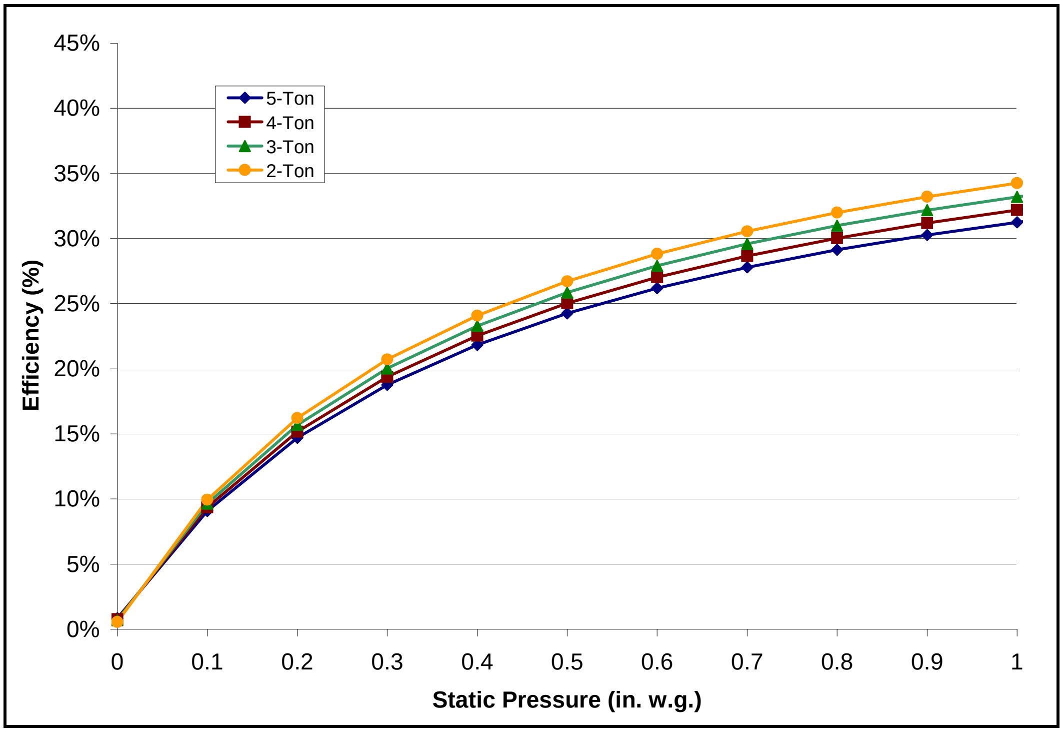

Figure K.3.10 **Blower Efficiency vs. Pressure Curves for Condensing Furnace - Two-Stage Virtual Control, ECM Motor, Low Fire**

REFERENCES

1. Lindeburg, M. R., *Fans and Ductwork, Chapter 20*. In *Mechanical Engineering Reference Manual for the PE Exam*, Michael R. Lindeburg PE, Editor. Tenth ed. 1997. Professional Publications, Inc.: Belmont, CA. p. 20-23