APPENDIX 8.6. FURNACE AIRFLOW CAPACITY TESTING

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APPENDIX 8.6. FURNACE AIRFLOW CAPACITY TESTING

8.6.1 SUMMARY

This Appendix provides a discussion of the task of testing various circulating-air blowers in a common-size furnace to assess the applicability of using the Air Movement and Control Association test standard 210 (AMCA 210) as a method of determining the airflow capacity of a furnace circulating-air blower.

8.6.2 BACKGROUND

Furnace manufacturers already use and report a measure of furnace electrical energy—the annual auxiliary electrical energy (E_{AE}) parameter. One method of setting a maximum level of electrical energy consumption without requiring extensive revision to the furnace test procedure could be to set limits on E_{AE}. However, the maximum E_{AE} limit should depend on the maximum airflow of the circulating-air blower. The Department needs to take into consideration the maximum airflow capacity of the furnace because some furnaces of the same input—such as furnaces coupled with larger split-system air conditioners—require larger airflow-capacity circulating-air blowers to accommodate the larger cooling function. When a furnace is intended to be installed with a larger air conditioner, it is manufactured with a larger circulating-air blower. If a furnace is designed to provide more airflow, then it will necessarily use more electricity. The Department thus needed to determine a method of measuring the maximum circulating blower airflow capacity.

To simplify the test procedure, the Department to considered maximum air-flow capacity at 0.5 inches water gauge (in.w.g.) of external static pressure (ESP). Manufacturer literature typically categorizes the cooling capacity that a furnace is designed to handle based on the amount of airflow the furnace can deliver at 0.5 in.w.g. In the product literature of their furnaces, manufacturers provide tables of airflow at a range of ESPs, including airflow at 0.5 in.w.g. If the furnace has multiple settings to provide different amounts of airflow, the product literature will include tables of airflow by ESP for every setting.

8.6.3 INTRODUCTION

8.6.3.1 Objectives of the Furnace and Blower Airflow Testing

The objectives of the furnace blower testing were to:

- gauge the appropriateness of using AMCA 210 for measuring furnace airflow and identify potential testing difficulties, and to

- identify any potential issues with regard to testing different types of motor and blower combinations.

8.6.3.2 How is Airflow Tested Now

It is the Department's understanding that the airflow and static pressures reported in product literature are typically determined using a "code tester," i.e., an airflow-measurement apparatus based on the existing test procedure ANSI/AMCA 210-99/ASHRAE 51-1999. However, DOE only found anecdotal information on how furnace airflow is determined.

Furnaces with electronically commutated motor (ECM) blower motors are often designed to provide constant airflow across the entire range of external static pressures. A consultant reported that at least one manufacturer uses a modified AMCA 210 method to determine air flow of furnaces with ECM blower motors. The motor controller are bypassed and the motor is set to run at specific speeds. Data collected based on the AMCA 210 test method is recorded at each motor speed. These results are then used, along with the motor control algorithm, to determine the power consumption at various static pressures for constant cubic-feet-per-minute (cfm) operation. The procedure used by this manufacturer may not be the same for all manufacturers.

8.6.3.3 Who Did the Testing?

To test the blowers for this task, Lawrence Berkeley National Laboratory (LBNL) contracted with the Energy Systems Laboratory (ESL), which is affiliated with Texas A&M University and has a long history of testing blowers. In fact, ESL was previously an official test facility of AMCA, which now does all of its certification at its own laboratory.

8.6.3.4 Which Furnaces and Blowers were Tested?

The Department selected two furnaces for testing that were as similar as possible, except for their blower-motor types. The furnaces have 88 kBtu input and are designed for use with up to a four-ton air conditioner. The entire project at ESL consisted of testing the following three combinations of motors and blowers in the same size furnace:

1. Permanent split capacitor (PSC) motor with forward-inclined blower wheel (Carrier 58CTA090-14, 88 kBtuh, 3.5 ton AC, 10x8 Blower Size);

2. GE ECM 2.3 motor with forward-inclined blower wheel (Carrier 58CVA090-16, 2-stage, 88 kBtuh, 1.5- 4 Ton AC, 10x8 Blower Size); and

3. GE ECM 4.0 prototype motor combined with a prototype backward-inclined blower wheel. (GE supplied the sample motor / blower / blower wheel to DOE. See memorandum Integrated Intelligent Blower , November 1, 2002; Project DE-FC26-00NT40993 for a complete description of the prototype. It was installed into the Carrier 58CVA090-16 furnace housing.)

ESL tested each of the above blower-motor combinations, both installed in a furnace and as a blower unit alone.

8.6.3.5 What Data are Provided in the Carrier Furnace Literature for the Installer?

Details on the tested furnaces can be found at the manufacturer web sites below.

Owners Manuals

- http://www.commercial.carrier.com/details/0,1240,CLI1_DIV12_ETI3757,00.html?SMSESSION=NO

- http://www.commercial.carrier.com/wcs/literature_model_search/0,,CLI1_DIV12_ETI499,00.html?SMIDENTITY=NO

Product Drawings

- http://www.residential.carrier.com/products/gas_furnaces/58cva_cvx.htm

For the ECM motor, the airflow is given in cfm, at static pressures from 0.1 to 1.0 ESP, for each operation mode. The static pressure includes the resistance of an air filter. Operating modes include low heat, high heat, air-conditioning capacities from 1.5 ton to 4 ton, and maximum airflow.

For the PSC motor, the cfm is given for ESPs of 0.1 to 1.0 in. wg. for four speeds: low, med-low, med-high, and high.

The GE blower, ECM 4.0 is a prototype and did not come with a manual.

8.6.3.6 How was the Testing Conducted?

ESL performed the furnace tests without an air conditioner evaporator coil. Gas was not connected, so the furnace was not providing heat during the test. ESL measured airflow as specified by AMCA 210-99 Figure 12, to produce a fan curve. ESL performed testing for high speed, and reported both actual and standard (adjusted to standard temperature and pressure) airflow data. In addition, ESL measured blower motor power consumption at each point measured for airflow.

8.6.3.7 Basic Description of PSC and ECM Motors

PSC motor - Permanent split capacitor single-phase induction motor. The majority of residential furnaces currently use PSC motors.

ECM motor - The electrically-commutated motor is a permanent-magnet, brushless direct-current (DC) motor (go to www.GEindustrial.com, enter keyword: ECM). In furnaces, ECM motors typically are combined with controls that allow the installer to set the airflow desired. The blower will then vary the speed and torque of the motor to achieve the desired airflow, regardless of the external static pressure drop.

8.6.3.8 Furnace Circulating-Air Blowers

Most residential circulating-air blowers use a blower wheel with forward-curved blades. The GE 4.0 Prototype has a backward inclined blower.

8.6.3.9 Testing with AMCA 210

The method of test, AMCA 210, provides several procedures for testing blowers. It also specifies the equations to correct to standard conditions. However, even with this test standard, there can be differences on some of the testing details, since the tester is given a choice of test apparatus configurations. The Department based the tests reported in this Appendix on Figure 12 of the AMCA 210 test procedure. In this test configuration, the blower or furnace inlet is open to air and the outlet is connected to the airflow apparatus.

8.6.3.10 How did ESL do the testing?

AMCA 210 is written as a test procedure for blowers. ESL tested the air flow with the blowers installed in the furnace. In addition, ESL tested the PSC blower outside of the furnace. ESL measured the furnace airflow with the filter housing installed, but without the air filter installed (so as not to create another variable in determining airflow)—thus increasing the repeatability of the tests. The primary output of fan testing is a plot of static pressure versus airflow. Watts are also plotted versus airflow on the same chart. The Department corrected the data plotted as per AMCA 210 equations, although ESL also made available the original uncorrected data.

8.6.3.11 Differences from a Typical Blower Curve Test by ESL

Typically, ESL tests airflow at ten points, including complete airflow shutoff. This is done in equal increments of airflow quantity (cfm). In this case, the Department instructed ESL to instead measure ten data points based on even increments of static pressure at the furnace outlet. The original plan was to start at 0 in. wg static pressure and increase the airflow in 0.1 in. wg increments. Typically, the data points are connected by a smooth curve based on airflow affinity laws.

The departure from normal test point selection was due to how ECM motors are used in a furnace. Unlike PSC motors, an ECM motor combined with furnace control circuitry is designed to provide constant airflow, regardless of the external static pressure. It accomplishes this by controlling the speed and torque of the motor.

8.6.3.12 Instrumentation and Test Setup

Figure 8.6.3.1 is a schematic of the airflow test apparatus. (See AMCA 210 Figure 12 for a detailed explanation.)

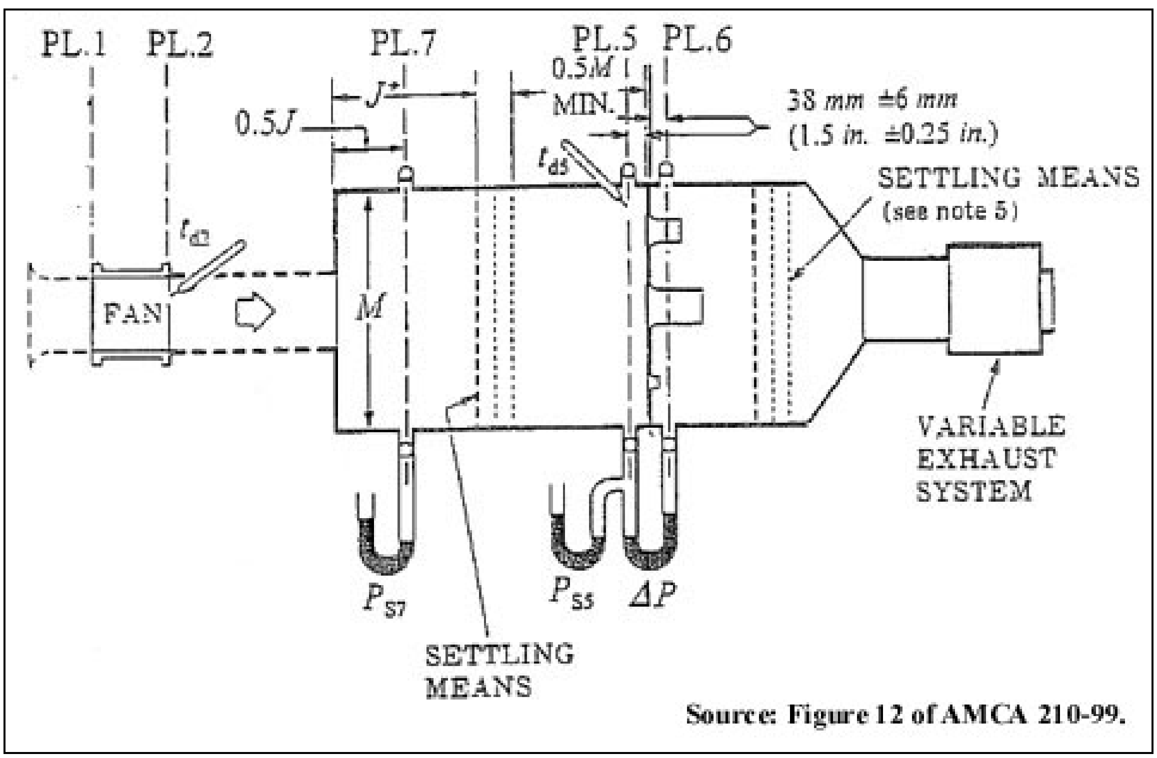

Figure 8.6.3.1 Schematic of Airflow Apparatus – from Figure 12 of AMCA 210

Figure 8.6.3.2 is a photograph of the apparatus used for the test. Note that the photograph is in the opposite orientation from the schematic shown in Figure 8.6.3.1 (AMCA schematic Figure 12). The inlet, where the furnace or blower would be mounted, is on the right side of the photograph. The airflow exit and variable speed blower that sets the static pressure are on the left.

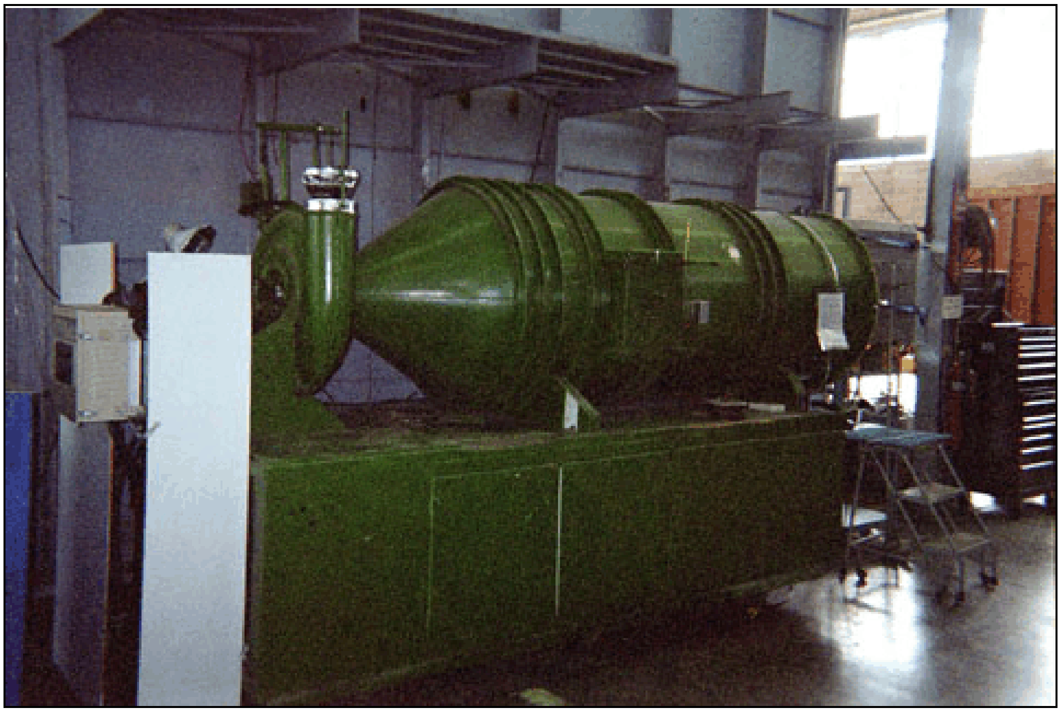

Figure 8.6.3.2 Airflow Measurement Apparatus at Energy System Laboratory

8.6.4 RESULTS

The testing results provided additional information in the following areas:

- Should AMCA 210 test procedure be used to measure furnace airflow?
- Are there energy savings benefits possible for furnace blowers?
- What are the characteristics of blower curves at other than the highest speed?

8.6.4.1 Should AMCA 210 be Used to Measure Airflow to More Accurately Measure Furnace Electrical Energy Use?

The Department measured airflow against various static pressures to determine if there are any problems with using the AMCA 210 test methods for measuring the airflow of furnaces, especially at 0.5 in. wg ESP, which is used as a reference point during cooling season operation. Figure 8.6.4.1 shows static pressure-versus-airflow results for PSC, ECM2.3, and ECM4.0 motor types at high speed.

While it was possible to measure airflow at 0.1 in. wg for the PSC blower, 0.5 in. wg pressure was the lowest possible ESP at which ESL could obtain results for blowers with ECM motors. It is not obvious why this was a problem, since manufacturer literature reports airflow measurements down to 0.1 in. wg. The ESL airflow testing with the ECM motors/blowers showed that, as the static pressure was decreased below about 0.5 in. wg, the speed would also decrease. This was an even greater problem when the blower was tested outside of the furnace. Because of this discrepancy between the ESL test results and the manufacturer-reported data, the Department concluded that the AMCA 210 test procedure, as it is, can not be used for testing blowers with ECM motors.

As expected, Figure 8.6.4.1 also shows that there is less variation in airflow with a change in static pressure for the ECM motor blowers. In the case of ECM 4.0 and ECM 2.3 motors (blower with backward-inclined blades and forward-inclined blades), as ESP goes down, cfm increases. In the case of PSC motors (blower with forward-inclined blades), as ESP goes down, cfm increases.

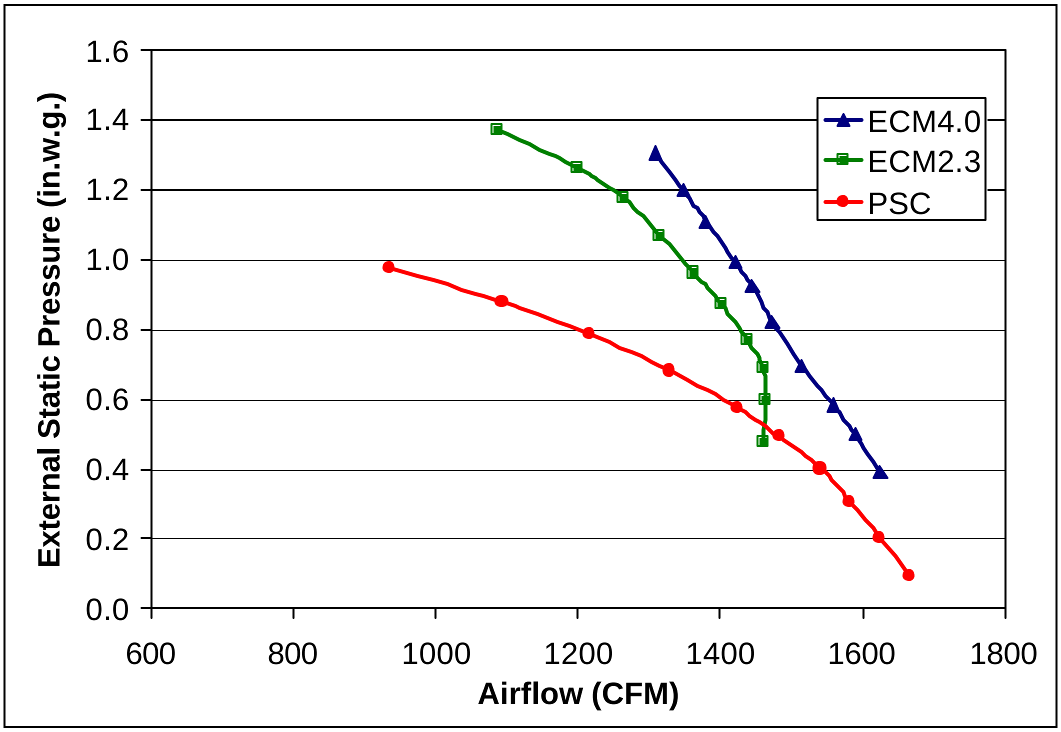

Figure 8.6.4.1 Airflow versus Static Pressure for Three Motor/Blower Combinations at Highest Speed

Figure 8.6.4.2 compares static-pressure-with-airflow curves for ESL test data and data published by the manufacturer in the product literature, at the highest airflow. Note that, for the case of a PSC motor, the tested airflow was greater than the manufacturer's reported airflow, whereas for the ECM motor, the tested airflow was lower than what the manufacturer reported. Additional research is needed to explain the observed differences between the manufacturer's results and ESL test results.

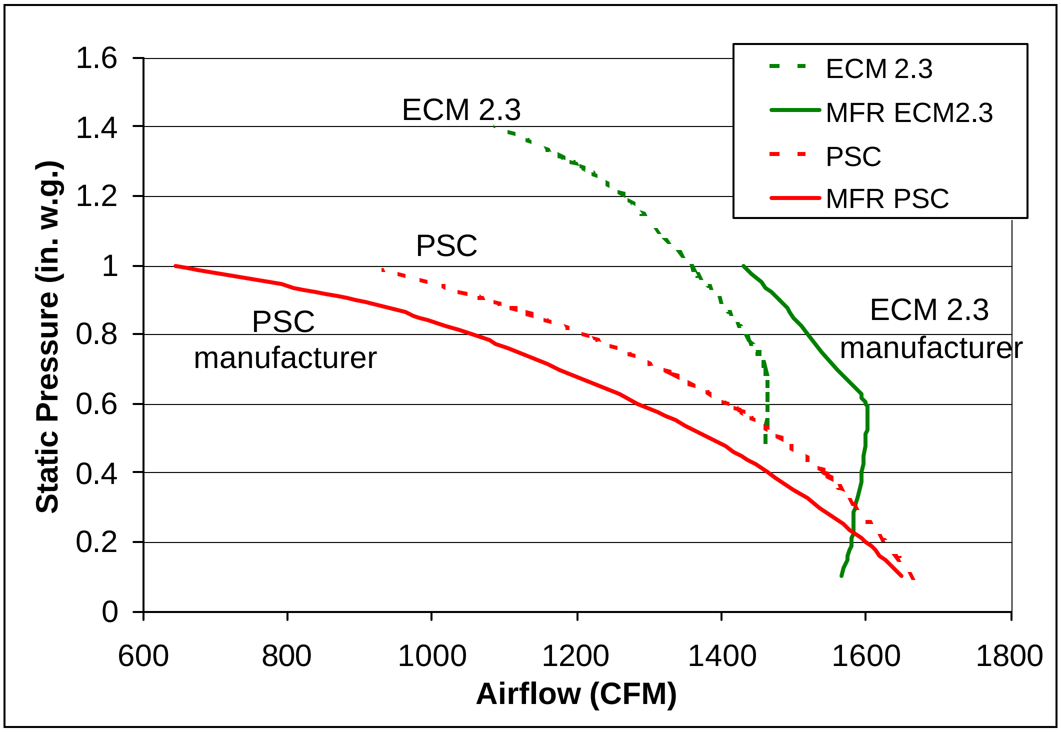

Figure 8.6.4.2 Comparison with Manufacturer's Reported Airflow versus Static Pressure Data at the Highest Blower Speed

8.6.4.2 Are There Energy Savings Benefits Possible for Furnace Blowers?

Figure 8.6.4.3 shows that, at a given static pressure, the cfm per watt is higher for the ECM motors than for the PSC motor. These results contradicted the Department's expectations that the ECM 4.0 motor with the backward-inclined blower wheel blades would use less energy than the ECM 2.3 motor. Because the ECM 4.0 motor was installed in a standard blower scroll in an un-optimized prototype assembly, its performance may be less than could normally be achieved. One factor decreasing performance could be the larger prototype motor blocking more of the airflow at the blower inlet. Also, the outlet area of the prototype blower may have been restricted more than it needed to be. Adjusting the furnace so the blower outlet area is not blocked off (as it needs to be for forward-inclined blowers) should increase the blower efficiency. This could be optimized in furnaces manufactured at high production volumes.

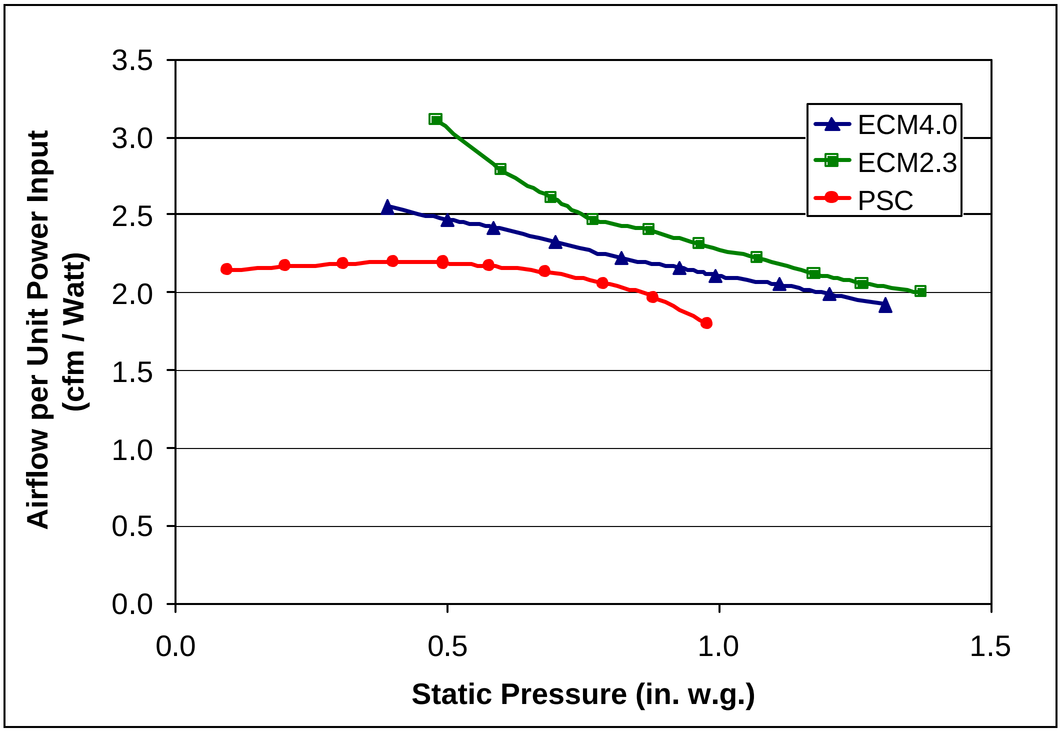

Figure 8.6.4.3 Airflow Efficiency versus Static Pressure at Highest Blower Speed Setting

8.6.5 BLOWER SPEED AND AIRFLOW

The ECM motor/blowers can be set to a specific airflow by controlling the blower speed. Figure 8.6.5.1 demonstrates blower speed versus airflow for all three tested blower/motor combinations. The speed and torque are controlled by an electronic control board. The ECM blowers are designed to attempt to keep the airflow constant regardless of the external static pressure. Note that the ECM 4.0 speed is much higher than the speed for the ECM 2.3 and PSC motor/blowers. The higher speed is a requirement of using backward-inclined blades, instead of forward-curved blades, on a blower.

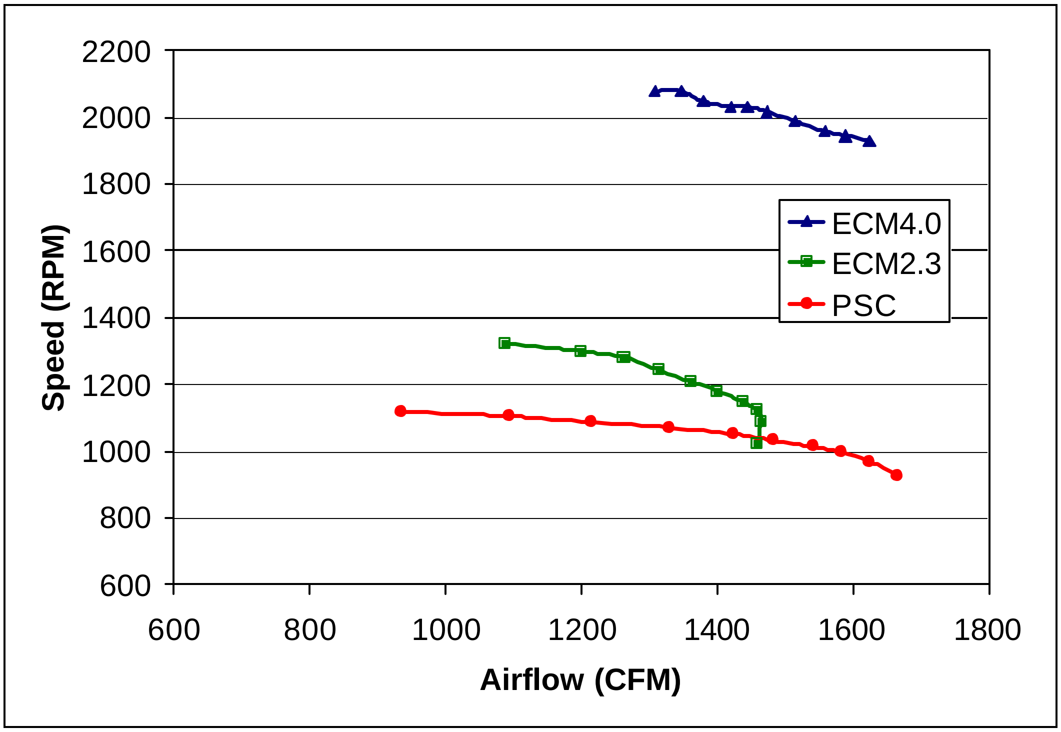

Figure 8.6.5.1 Blower Speed versus Airflow

8.6.6 DISCUSSION OF RESULTS

The ESL tests for furnaces with ECM motors do not report measurements below 0.5 in.w.g. ESP. This is because, during the testing of the three furnace blower/motor combinations, as the static pressure was decreased the motors would slow down and start to rotate in the opposite direction. In some cases, if the furnace was set at a lower-than-maximum blower speed, it was impossible to measure the airflow at static pressures as low as 0.5 in.w.g. This means that, for some furnace designs, it may not be possible to test airflow at 0.5 in.w.g. static pressure with the current AMCA 210 protocol. Possible solutions to this issue should be examined.

8.6.7 CONCLUSIONS

Testing has determined that simply referencing the AMCA 210 test procedure to measure furnace blower airflow at 0.5 in.w.g. ESP is insufficient. The Department found differences between the AMCA 210 test results and the manufacturer's reported data. These may be due to differences in the test setup or in the testing methods. Measurement of airflow in furnaces using ECM motors requires further investigation.