Residential HVAC System Analysis: Furnace Temperature Rise, Static Pressure, and Air Flow

Performed by:

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I. Introduction

The mission at Impeccable Air is to create a solution for indoor air quality that is extremely efficient, but workable and affordable at the same time. By focusing on revolutionizing the residential indoor air quality industry - we have created registers that allow for the maximization of air purification throughout the home environment. While these filters are exceptionally efficient at removing contaminants from the air, it was equally as important to ensure that they did not cause an increase in air resistance and static pressure throughout the existing HVAC system. In this analysis, the HVAC system's temperature rise, static pressure, and flow rate were monitored to verify that the Impeccable Air Filters did not create any deficiencies in the system.

II. Methodology

The residential HVAC system analysis was conducted in three main parts, consisting of recording - the temperature rise from the return plenum to the supply plenum, the static pressure over the air handler, and the air flow rate. The main purpose of the first part of the analysis was to ensure that the furnace was working properly before any Impeccable Air Registers/Filters were installed and that it continued to work properly after the Impeccable Air filters were in place. The purpose of the second and third parts of the analysis were to verify that the installation of Impeccable Air Filters throughout the home created a negligible difference in air resistance and did not cause an increase in static pressure on the system or decrease in air flow rate.

A. Theory

Air temperature rise is the difference between the temperature of the air in the return plenum and the temperature of the heated supply air. Temperature rise must be measured and must be within the allowable temperature range that is found on the furnace rating plate. Low temperature rise is a result of moving an excess of air over the heat exchanger. If the temperature rise is too close to the low-end of the allowable range, the air coming out of the supply registers might feel too cool to the occupants, and "cold air drafts" could occur. If the temperature rise is below the lowest allowable temperature, condensation can occur in the heat exchanger – leading to corrosion.

Most importantly, high temperature rise is due to "choking" the system, or not moving enough air over the heat exchanger. Over-heating the furnace will cause several problems and needs corrected immediately with a blower adjustment or by resolving the source of low airflow in the system. In this analysis, it was expected that the Impeccable Air filters would not cause an increase in air resistance to the system, but it was important that it was validated.

Likewise, it was necessary to ensure that there was no increase in static pressure or decrease in air flow throughout the system. Improper ductwork installation, poor system design, filter choices, etc. all contribute to high static pressure. A system that experiences high pressure and improper airflow will consist of stress, noisiness, and equipment failure. Static pressure and flow rate measurements were made throughout the system before and after the filter installation to verify that everything was working properly.

B. Objectives

The main objectives of the Temperature Rise Recordings:

- Ensure that the system's temperature rise was within the maximum allowable temperature rise according to the furnace manufacturer's specified range
- Ensure that the system's temperature rise did not vary when the Impeccable Air Filters were installed throughout the home
- Utilize the recorded temperature difference to calculate theoretical flow rate, which could then be compared to the experimental flow rate

The main objectives of the Static Pressure Recordings:

- Ensure that the static pressure over the system's air handler is less than 0.5 in of water
- Ensure that the static pressure over the system's air handler does not vary when the Impeccable Air Filters were installed throughout the home

The main objective of the Air Flow Rate Recording:

- Ensure that there were no considerable restrictions to the air flow rate throughout the home
- Utilize the recorded air flow rate to compare to the calculated air flow rate to determine if the analysis was performed accurately
- Ensure that there was no decrease in air flow rate when the Impeccable Air Filters were installed throughout the home

C. Apparatus

In this analysis, a customer's furnace/ductwork system was used to obtain results regarding the affect, or lack of affect, that the Impeccable Air Filters had on the air flow. More specifically, a Trane XE80 Gas Furnace was used and can be seen in Figure 1 below.

Figure 1: Trane XE80 Gas Furnace Model #TUD100C948J

Before the Impeccable Air Installation, the system was examined to verify that it was working properly by recording the temperature rise from the return plenum to the supply plenum while the heat was on. A Klein Tools digital thermometer was used to perform the recordings and is shown in Figure 2.

Figure 2: Klein Tools Digital Thermometer

Once it was determined that the customer's HVAC system was working properly, the Impeccable Air Registers and Filters were installed throughout the home.

The Impeccable Air Register is a two-piece register that consists of a backplate that gets secured to the wall and a friction fit front cover that opens for very simple filter changes. The register is 15.75" wide by 7.75" tall - created to fit as a direct replacement for the most universally used residential ductwork opening - the 14" by 6" opening. To accompany the functionality, the registers were designed to be durable and aesthetically pleasing. They consist of rounded corners, no exterior screw construction, they are made of ABS Plastic - so they will not dent, scratch, or rust - they can come in different colors or can be painted to match any existing home décor, and the front grille covers are dishwasher safe. An image of an installed register can be seen in Figure 3.

Figure 3: Impeccable Air Return Registers

The Impeccable Air Filter is rated MERV 6, consists of Activated Carbon, and is coated with PRO-Techs® Antimicrobial Disinfectant to maximize the number of contaminants that are captured. An image of the Filters that are used is shown in Figure 4.

Figure 4: Impeccable Air Filter

When the Filters were installed the static pressure and flow rate measurements were recorded using a manometer and flow plate. The digital manometer that was used was a DG-8 digital pressure gauge from a company named The Energy Conservatory and can be seen in Figure 5. Likewise, the flow plate that was used was a Digital True Flow HVAC System Air Flow Meter from the same company and is shown in Figure 6.

Figure 5: DG-8 Digital Pressure Gauge Manometer

Figure 6: The Energy Conservatory Digital TrueFlow HVAC System Airflow Meter

D. Procedure

To begin the analysis, the customer's furnace/ductwork system was examined by obtaining the temperature rise between the air in the return plenum and the supply plenum. Once the furnace specifications were reviewed to understand the allowable temperature rise for the system, the temperatures were recorded, and Equation 1 was used to calculate the temperature rise:

$$\Delta T = T_{Supply} - T_{Return} \quad (1)$$

Where ΔT is the temperature rise, T_{Supply} is the temperature in the supply plenum, and T_{Return} is the temperature in the return plenum.

When the temperature rise was recorded the theoretical airflow could be calculated using Equation 2:

$$CFM = \frac{Output\ BTU}{1.08(\Delta T)} \quad (2)$$

Then, the Impeccable Air Registers and Filters were installed, and the same method was performed to ensure that the addition of the filters did not affect the system's temperature rise.

Next, the DG-8 Digital Pressure Gauge Manometer was used to record static pressure throughout the system with and without the Impeccable Air Filters installed. The pressure was measured in the return plenum and the supply plenum, and the total static pressure was recorded using Equation 3:

$$P = P_{Supply} - P_{Return} \quad (3)$$

Finally, the air flow rate was measured using the Digital TrueFlow HVAC System Airflow Meter to record the air flow throughout the system with and without the Impeccable Air Filters installed. When the air flow was recorded, it was compared to the theoretical air flow

that was calculated using Equation 2, to verify that the analysis was performed properly. A percent error was calculated using Equation 4.

$$\delta = \left[\frac{v_a - v_e}{v_e}\right] \times 100\% \quad (3)$$

Where δ is the percent error, v_a is the actual value observed, and v_e is the estimated or expected value.

III. Results and Discussion

During the initial evaluation of the customer's system, important classifications were made and can be seen in Table 1.

Table 1 - HVAC System and Conditions

System & Conditions	
System Type	Fuel
System Orientation	Up flow
Filter Location	In Duct
Cooling Capacity (Tons)	2.67

First, the system's temperature rise from the return plenum to the supply plenum was monitored and calculated using Equation 1. The results of the allowable temperature rise, the temperature rise of the system as is, the temperature rise after the furnace filter was replaced, and the temperature rise after the Impeccable Air filters were installed can be seen in Table 2.

Table 2 - Furnace Temperature Rise

Furnace Temperature Rise			
System's Allowable Temperature Rise		35°F to 65°F	
Measurement	**Return Plenum (°F)**	**Supply Plenum (°F)**	**Temperature Rise, ΔT (°F)**
Initial Measurement	138	70	68
After Furnace Filter was Replaced	127	73	54
After Impeccable Air Filter Installation	126	71	54
Percent Difference		0%	

The initial temperature rise of 68°F exceeds the maximum allowable temperature by 3°F, so it was addressed immediately. The furnace filter was entirely congested, so it was replaced, and the temperature rise decreased by 14°F. Once it was determined that the furnace was working at an allowable temperature rise and the Impeccable Air filters did not have an effect, the static pressure over the air handler was measured. The results of these measurements are shown in Table 3.

Table 3 - Static Pressure Measurements

Static Pressure Measurements			
Measurement	**Return Plenum (in-H_2O)**	**Supply Plenum (in-H_2O)**	**Static Pressure (in-H_2O)**
Initial Measurement	0.184	0.078	0.262
After Impeccable Air Filter Installation	0.192	0.076	0.268
Percent Difference		2.3%	

With an allowable static pressure measurement of 0.5 in-H2O, it was proven that the system was working properly, and the Impeccable Air Filters did not cause a considerable increase in pressure throughout the system. Finally, the system's flow rate was monitored, and the theoretical flow rate was calculated using Equation 2 to compare the results - shown in Table 4 and Table 5.

Table 4 - Flow Rate Measurements

Flow Rate Measurements	
Initial Recorded Flow Rate ($^{ft^3}/_{min}$)	1053
Flow Rate After Impeccable Air Filter Installation ($^{ft^3}/_{min}$)	1042
Percent Difference	1%

Table 5 - Flow Rate Comparison

Flow Rate Comparison	
Average Recorded Flow Rate ($^{ft^3}/_{min}$)	1047.5
Theoretical Calculated Flow Rate ($^{ft^3}/_{min}$)	1083.7
Percent Error	3.3%

Since the cooling capacity was defined as 2.67 tons, the system had an acceptable flow rate of about 390-400 cfm/ton. Also, with a negligible difference between the initial flow rate recording and the recording after the filters were not installed, it was determined that the Impeccable Air Filters did not cause an increase in air resistance and did not create any deficiencies in the system.

The percent error between the actual flow rate and the calculated flow rate was 3.3%, which validates the analysis.

IV. Conclusion

In this analysis, the HVAC system's temperature rise, static pressure, and flow rate was monitored to verify that the Impeccable Air Filters did not create any deficiencies in the customer's HVAC system.

The system's allowable temperature rise was defined as 35°F to 65°F, and the initial temperature rise recording was 68°F - which exceeded the allowable temperature rise by 3°F. After replacing the furnace filter, the temperature rise recording decreased by 14°F to 54°F and was considered allowable. The Impeccable Air Filters were then installed, and the temperature rise recording was 54°F - a 0% difference in the temperature rise – verifying that the filters did not have an effect on the airflow.

The system's maximum static pressure was defined as 0.5 in-H_2O. The initial static pressure measurements were: 0.184 in-H_2O in the return plenum, 0.078 in-H_2O in the supply plenum, and 0.262 in-H_2O total. The static pressure measurements after the Impeccable Air Filter Installation were: 0.192 in-H_2O in the return plenum, 0.076 in-H_2O in the supply plenum, and 0.268 in-H_2O total. This resulted in a negligible percent difference of 2.3% - further verifying that the filters did not have an effect on the airflow.

Finally, the flow rate was examined. The initial recorded air flow rate was 1053 cfm, and the flow rate after the Impeccable Air Filter Installation was 1042 cfm – resulting in a negligible percent difference of 1% - fully verifying that the filters did not have an effect on the airflow. Also, since the system had a defined 2.67 tons of cooling capacity, the flow rate was about 390-400 cfm/ton - manufacturer recommended air flow rates for residential systems are 350-450 cfm/ton – resulting in an acceptable airflow.

To validate the analysis, a theoretical flow rate was calculated using the recorded temperature rise and Equation 2 and was compared to the actual value. The average recorded flow rate was 1047.5 cfm, and the theoretical flow rate was 1083.7 cfm – resulting in an acceptable percent error of 3.3%.