Emerging Technology Program

#1149: Furnace Filter Whistle - Final Public Pilot Assessment Report

04/01/2020

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Legal Notice

Executive Summary

Introduction

As a part of the Nicor Gas energySMART energy efficiency program, the Emerging Technology Program (ETP) assesses new technologies that have the potential to realize natural gas savings for the 2.2 million Nicor Gas customers in Northern Illinois. The Gas Technology Institute (GTI) provides program implementation for the Nicor Gas ETP. This report summarizes the findings of laboratory evaluation of a furnace filter whistle technology.

Background

Furnace filters are considered a key component to ensure space heating systems work efficiently and effectively. Maintaining a clean filter can save money, increase system lifetime and improve air quality (See Figure 1). Benefits of a well-maintained air filtering setup are:

- **System Lifetime.** A dirty air filter increases the pressure drop on the air side and increase the possibility of system failure. As dirt accumulates, it prohibits air from passing through the filter causing the motor to work harder and draw more electric current to keep the home warm. Any mechanical component that is working overtime adds stress on the entire system, leading to premature failure. By simply replacing the filter on a routine basis, one can extend the lifetime of the heating system.
- **Air Quality.** Because the HVAC circulates the air inside the house, it distributes small particles and dust around the living area. This can be particularly alarming for anyone who suffers from allergies or asthma. A filter is an important line of defense to keep irritants from circulating in your home.
- **O&M Costs.** A filter clogged with dust and other particles decreases the air flow through the HVAC system and may cause the blower to draw more power to heat to the living space - result in higher maintenance costs.

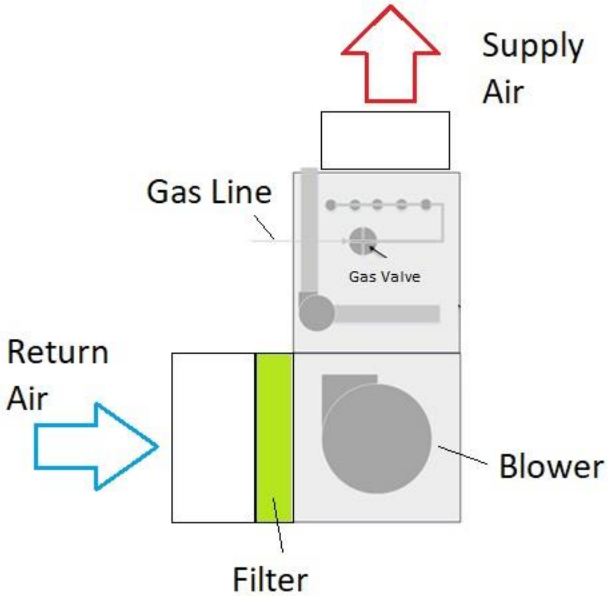

Figure 1 –"Typical" Schematic of the filter location on a typical natural gas furnace

There should be a balance between the working conditions of the HVAC and the interval between replacing the air filter. If the building or residence has pets, smokers, allergies or asthma, a working fireplace, or construction, the filter should usually be replaced more often.

Furnace filter alarm whistles attach to air filters (see Figure 2 and Figure 3) and make an alarming noise when it is time to replace the filter. It is claimed that:

> *"A dirty air handler filter increases electricity consumption for the circulating fan and decreases system heating efficiency and so furnace filter alarms save energy by alerting homeowners when it is time to replace a dirty filter with a new clean filter. Savings estimates are based on reduced blower fan motor power requirements for winter and summer use of the blower fan motor, as well as increased heating system efficiency. This measure applies to central forced-air furnaces, central AC and heat pump systems. Where homes do not have central cooling, only the annual heating savings will apply."*[1]

[1] Illinois Statewide Technical Reference Manual — 5.3.18 Furnace Filter Alarm – Provisional Measure

Figure 2 - Tested Furnace Filter Alarm Whistles – 3 different vendors

Figure 3 - Furnace Filter Alarm Whistle installation

The goal of this project is firstly, to test if commercially available furnace filter alarm whistles work as described. Secondly, to establish effects that a dirty filter has on the performance of a typical furnace and assess the inefficiency penalties of running a furnace with clogged air filter.

Results

A total of 3 furnace filter alarm whistles were tested in the GTI laboratory. Among the 3 tested whistles, one unit whistled intermittently for all test cases, regardless of the amount of contamination put on the air filter. However, the other two units never made any noise. Hence, an accurate operation of the filter alarm whistles cannot be established. Furthermore, considering the steady state tests, the furnace efficiency fluctuates with an interval of 1.5% for different amounts of contamination on the air filter, which is in the uncertainty limitations of the lab test. Therefore, the effect of a clogged air filter on the performance of a gas furnace is negligible.

Next Steps/Recommendations

Furnace Filter Whistles are deemed to be inconsistent in their operation and have no natural gas savings associated with them. It is recommended that Nicor Gas does not pursue these devices any further with regard to energy efficiency.

Moreover, a potential hazard can arise if the filter whistle does not make any noise and as a result, the user refrains from changing the filter. Eventually, the filter will become fully clogged and the furnace will overheat.

Objectives and Testing Methodology

Objective

The following objectives were established as the goals of this project:

- Verify the operation of furnace filter alarm whistles.
- Analyze inefficiency penalties of operating a furnace with a clogged air filter.

Testing Methodology

A 60MBH 90% AFUE Rheem furnace (model # R95TC) was used for this laboratory evaluation. A baseline test was performed to establish the performance of the furnace with a new clean filter. Afterwards, a series of tests were performed with filter alarm whistles installed on filters and various amounts of dirt artificially applied on the filter.

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), created the standard by which the effectiveness of air filters is measured. This is known as the minimum efficiency reporting value (MERV). The MERV rating scale ranges from 1-16. Lower quality filters, in the 1-4 MERV range, are typically made of fiberglass. Most residential HVAC systems use air filters with MERV ratings from 7-12. A higher MERV value of 5-16 would be recommended for commercial buildings. Anything above a 13 MERV rating is considered to be a High-Efficiency Particulate Arrestance (HEPA) filter, often used for hospitals and scientific research lab applications. Furthermore, ASHRAE Standard 62.2-2016[2], notes that filters designated with a minimum efficiency of MERV 6, or better, when testing in accordance with ASHRAE Standard 52.2-2017[3], shall be provided. Therefore, a commercially available filter rated as MERV 8 is selected as the air filter in this study. In order to eliminate the effects of varying the filter characteristics on results, all furnace filter alarm whistles were tested on similar filters. Table 1 summarizes characteristics of the air filters.

Table 1 - Air Filter Characteristic

Trade Size	16 × 16
Thickness	1"
Filter Efficiency	General Purpose
Filter Efficiency Rating	MERV 8
Particles Captured	90% to 99%
Removes Particle Size Down To	3 microns
Material	Polyethylene Plastic/Polypropylene Plastic Blend
Frame Material	Cardboard
Support Grill Material	Galvanized Steel

[2] Ventilation and Acceptable Indoor Air Quality in residential buildings (which covers other residential type buildings including high-rise)
[3] Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

Maximum Temperature	150° F
Specifications Met	UL 900
Useful Life	Disposable
Construction	Pleated
Filter Type	Panel
For Removing	Dust and Particles
For Use With	Air
RoHS	RoHS 3 (2015/863/EU) compliant

Furnace filter alarm whistles tested in this study are shown in Figure 2. The installation instruction of the filter alarm whistles indicates; *"make sure that the whistle is at least 4 inches from the top and side of the filter"*. Figure 4 shows the location of tested filters with filter alarm whistles.

Figure 4 - Installed Filter Alarm Whistles

The test setup and location of the air filter holder is depicted in Figure 5 and Figure 6.

Figure 5 - Test setup

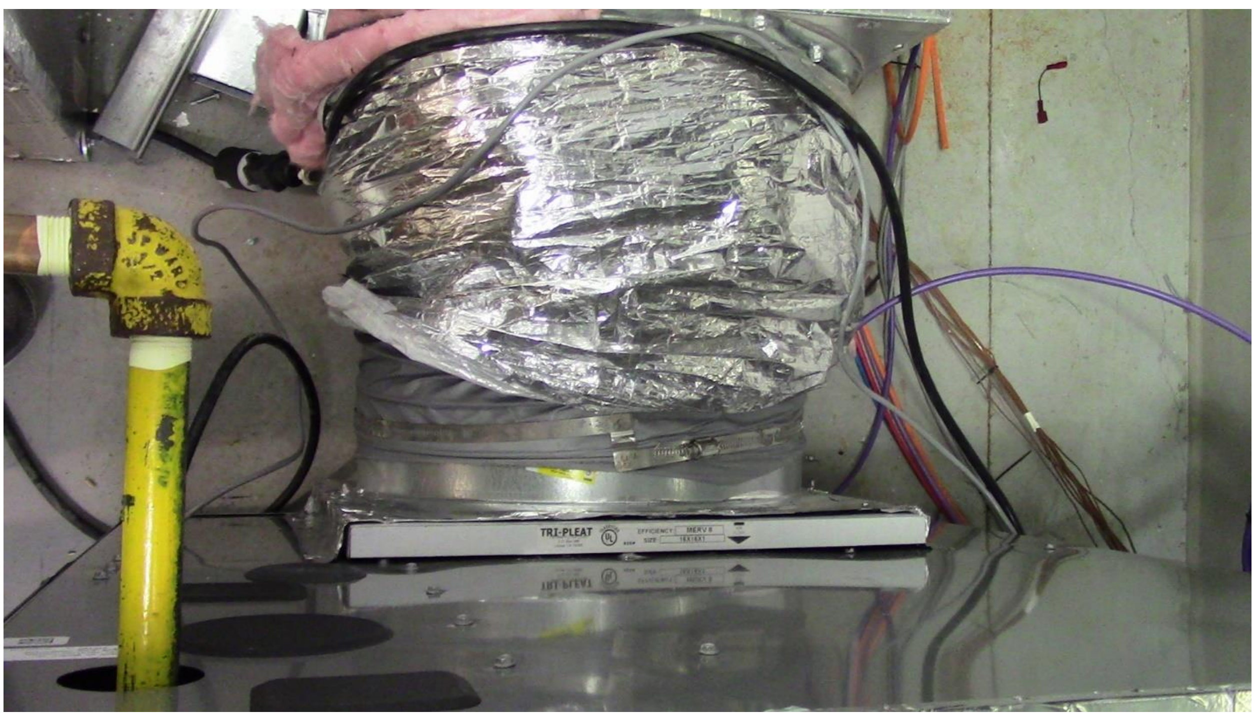

Figure 6 - Air filter location

In the following sections, the test results are presented and discussed.

Test Equipment

Figure 7 identifies the equipment and instruments included in the test setup, delineates the system components and subsystems, and identifies the input and output energy streams for each of the systems tested. The instruments used in the test setup identified in Figure 7 are listed in Appendix A. Data acquisition and calculation methods associated with the instrument measurement points are defined in Appendix B.

Room air and furnace leaving air temperatures were measured using a nine-point horizontal thermocouple array.

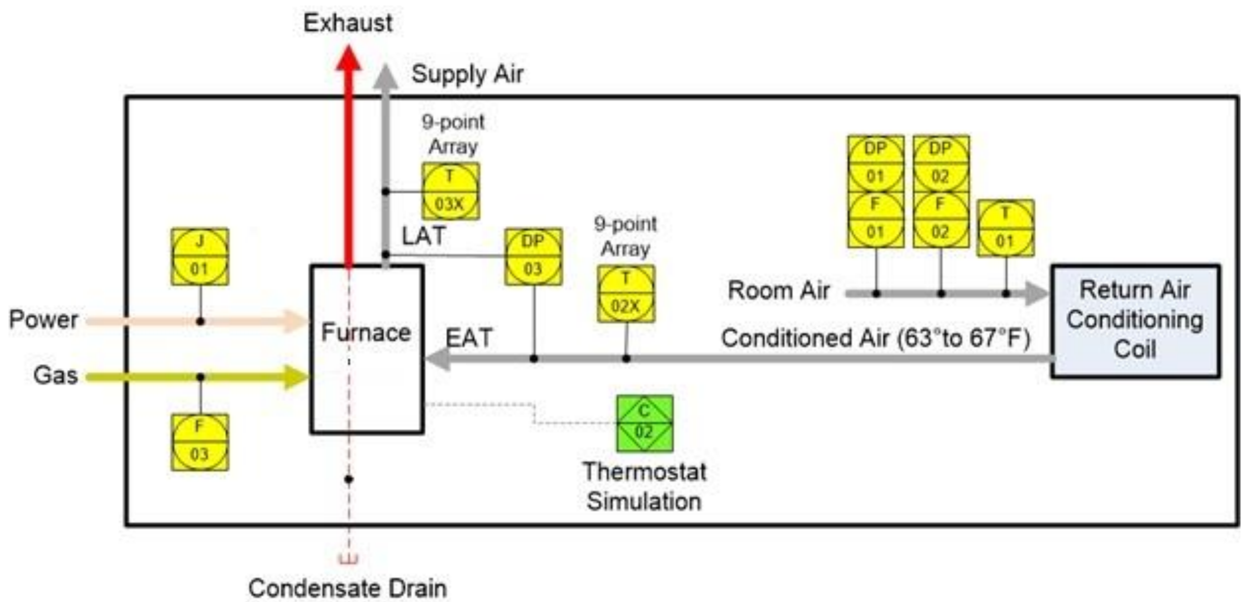

Figure 7 - Instrumentation Diagram

Results and Discussion

Table 2 shows the test matrix. First, the furnace performance is evaluated without an air filter and with a clean air filter to generate a baseline for the operation characteristics of the furnace. After establishing the baseline, three set of tests are performed with air filters with furnace filter alarm whistles. The first set of tests (Test C) clean air filters are used. The second set of tests (Test D) are performed on filters moderately contaminated artificially. For the last set of tests (Test E) the air filter is heavily contaminated and clogged. Each test is continued for 1 hour and the data is considered for the calculations after steady state conditions are reached. Figure 8 through Figure 10 show the tested air filters for each case.

Table 2 - Test matrix

	Whistle Whistling	Test A - No Filter	Test B - Filter (MERV8)	Test C - Filter (MERV8) + Whistle	Test D - Filter (MERV8) + Whistle + Moderately Clogged	Test E - Filter (MERV8) + Whistle + Heavily Clogged	Low Limit Air Flow Condition (Furnace Shuts Down)
Baseline testing - No filter		•					
Baseline testing - With filter			•				
Blue Whistle	•			•			
Blue Whistle	•				•		
Blue Whistle	•					•	
Green Whistle				•			
Green Whistle					•		
Green Whistle						•	•
Red Whistle				•			
Red Whistle					•		
Red Whistle						•	•

Figure 8 - Blue whistle test C, test D, test E (from left to right)

Figure 9 - Green whistle test C, test D, test E (from left to right)

Figure 10 - Red whistle test C, test D, test E (from left to right)

As mentioned earlier, the initial goal of the investigation is to check if the furnace filter alarm whistles perform as claimed. Among 3 tested furnace filter alarm whistles, one unit made intermittent whistle noises for all cases regardless of the amount of contamination put on the air filter. However, the other two units did not make any noise.

Table 3 shows furnace performance indicators for each set of tests. As it is shown, when dirtier air filter is used in the system, the supply air flow rate declines. For example, the blue furnace filter alarm whistle experiences up to 5% supply air flow loss when the air filter is heavily contaminated (i.e. from test C to test E). Reduced air flow across the heater results in hotter supply air temperature. As the air flow drops too low, the furnace temperature reaches the high-limit setting and the limit switch shuts off the burner. That is the reason causing intermittent operation of the furnace during test E for green and red furnace filter alarm whistles. Considering the steady state tests, the furnace efficiency fluctuates with an interval of 1.5% for different amounts of contamination on the air filter, which is within the uncertainty limitations of the test. To sum up, the effect of a clogged air filter on the performance of a gas furnace is negligible unless it reaches to a point the operation of the furnace becomes intermittent.

Table 3 - Performance indicators for each test

Test	Thermal Efficiency [%]	Air Flow [CFM]	Notes
Baseline testing - No filter	88.6	957	
Baseline testing - With filter	86.2	781	
Blue Whistle (test C)	86.3	794	
Blue Whistle (test D)	87.8	783	
Blue Whistle (test E)	86.4	752	
Green Whistle (test C)	86.9	781	
Green Whistle (test D)	85.3	709	
Green Whistle (test E)	84.2	-	Intermittent operation
Red Whistle (test C)	87.4	790	
Red Whistle (test D)	86.4	779	
Red Whistle (test E)	84.1	-	Intermittent operation

Appendix A – Instrumentation

Instrumentation is listed in Table 4.

Table 4 - Instrumentation

ID	Parameter	Instrument	Range	Accuracy
T01	Laboratory Air Entering the Return Air Conditioning Coil	Open-Ended Direct Exposure RTD Omega P-L-A-1/8-6-0-T-3	–100 to 250°F	± 0.65°F at 130°F
T021-T029	Furnace Entering Air Temp	T-Type Insulated Thermocouples KK-T-20-36	–100 to 250°F	at >32 to 662°F ±1.8°F or 0.75%
T031-T039	Furnace/AHU Leaving Air Temp	T-Type Insulated Thermocouples KK-T-20-36	–100 to 250°F	at >32 to 662°F ±1.8°F or 0.75%
F01	Furnace/AHU Conditioned Air Flow Low	Duct-Mounted Air Flow Measurement Station Dwyer FLST-C8	100 to 10,000 FPM	± 2%
F02	Furnace Conditioned Air Flow High	Duct-Mounted Air Flow Measurement Station Dwyer FLST-C10	100 to 10,000 FPM	± 2%
DP01	Furnace Conditioned Air Flow Differential Pres Low	Low Differential Pressure Transmitter Dwyer 607-2	0” to 0.5” wc	±0.5%
DP02	Furnace Conditioned Air Flow Differential Pres Hi	Low Differential Pressure Transmitter Dwyer 607-2	0” to 0.5” wc	±0.5%
DP03	Furnace Total Static Pressure	Low Differential Pressure Transmitter Dwyer 610-01A-DDV	0” to 1” wc	±0.25%
J01	Furnace Power	WattNode Pulse WNB-3Y-208P	48 to 62Hz at -20% to +15% Voltage	± 0.5%
F03	Furnace Gas Flow	Gas Flow Diaphragm Meter Elster American Meter AC-250	0 to 656 SCFH (5 psig)	± 0.5%

Appendix B – Calculation

Measured data from all the instruments listed in Table 3 were continuously collected and recorded at 5-second intervals. All calculations were post-processed using the raw data from the data acquisition system as follows:

Energy Input

The following basic equation was used to calculate energy input to the systems in natural gas:

$$Q_{\mathrm{NG}} = HHV \cdot V_{NG}$$

Where:

Q_{NG} = Energy input from natural gas (Btu/day or Btu/hr)

HHV = Higher heating value (HHV) of natural gas (Btu/ft^3)

V_{NG} = Volumetric flow rate of natural gas (ft^3/day or ft^3/hr)

Fuel gas was sampled daily for major component analyses, and higher and lower heating value calculations. The gas meter used to measure volumetric flow was temperature compensated. Gas pressure was recorded before each test, and the flow rate was corrected for the actual pressure.

Furnace Energy Output

Heat supplied by the furnace was determined by measuring the air flow rate and supply and return air temperatures at the furnace inlet/outlet as follows:

$$Q_{\mathrm{sup}} = \sum_{time} C \cdot V_l \cdot \rho \cdot c_p \cdot |\Delta T| \cdot \Delta time$$

Where:

Q_{sup} = Summation of supplied heat by the furnace for each time step (Btu/time step)

V_l = Volumetric flow rate of air (ft^3/min) calculated by:

$$V_l = 3.1415926 \cdot \left(\frac{D}{12}\right)^2 \cdot \frac{1}{4} \cdot \left(1096.7 \cdot \frac{P}{0.07368}\right)^{1/2}$$

Where:

P = Velocity Pressure at each recorded interval

D = Duct diameter for the flow measurement station.

$|\Delta T|$ = the difference between average supply and return temperatures at each recorded interval (°F).

C_p = Specific heat of air at the average temperature between the supply and return air, (Btu/lb-°F)

ρ = Density of air based on air temperature at the flow meter for each recorded interval, (lb/ft^3)

C = Unit conversion factor

$\Delta time$ = time interval used in the data collection program (i.e., 5 seconds)

Furnace Thermal Efficiency

Furnace thermal efficiency (η_f) was calculated as the ratio of the heat supplied by the furnace to the sum of the energy carried by the natural gas and the electrical energy input at the same time interval (i.e., hourly efficiency), as shown in the following:

$$\eta_f = \frac{Q_{sup}}{Q_{NG} + Q_e}$$

Where:

η_f = Furnace efficiency (%)

Q_{sup} = Total energy supplied by the furnace (Btu)

Q_{NG} = Total natural gas energy input (Btu)

Q_e = Total electrical energy input (Btu)