Food Service
Technology Center

Greenheck Energy Recovery Filter Test Report

FSTC Report # 501311263-R0

Application of a Customized
Non-Standard Test Method

October 2016

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Food Service Technology Center Background

The information in this report is based on data generated at the Pacific Gas and Electric Company (PG&E) Food Service Technology Center (FSTC). Dedicated to the advancement of the foodservice industry, The FSTC has focused on the development of standard test methods for commercial foodservice equipment since 1987. The primary component of the FSTC is a 10,000 square-foot laboratory equipped with energy monitoring and data acquisition hardware, 60 linear feet of canopy exhaust hoods integrated with utility distribution systems, equipment setup and storage areas, and a state-of-the-art demonstration and training facility.

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Revision History

Revision num.	Date	Description	Author(s)
0	Oct 2016	Initial_Release	R. Swierczyna

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The Greenheck Energy Recovery Filter was tested to determine the amount of energy recovered from an exhaust airstream of a heavy-duty commercial cooking appliance. The standard heat exchanger effectiveness was also determined. The heat recovery filter was a second generation design that included improvements to the original model by adding heat transfer fins to the copper heat exchanger tubing. Three 19.5-inch by 19.5-inch filters were installed in a 5-foot canopy hood over a 3-foot gas underfired broiler or gas range. The appliances operated with inputs of 105,721 Btu/h, 66,295 Btu/h, 66,261 Btu/h, 66,260 Btu/h, and 34,045 Btu/h. The water flow through the heat recovery system varied from 1.0 gpm, 3.1 gpm, 3.9 gpm, 3.7 gpm, 3.8 gpm and 3.9 gpm. The average air flow rate through the hood was 1,441 cfm.

The evaluation found the standard heat exchanger effectiveness at the low water flow condition of 1.0 gpm to be 0.45. The standard heat exchanger effectiveness at the average water flow of 3.6 gpm was 0.20. The range of heat exchanger effectiveness varied from 0.18 to 0.45. The filter and test set up are shown in Figures 1 through 3.

Figure 1: Front and Rear View of Energy Recovery Filter

Figure 2: Detail View of Energy Recovery Filter

Figure 3: Test Set Up

The water temperatures were taken with submerged sensors at the inlet and outlet of each filter. The energy recovered in the filter water stream was calculated using Equation (1) below.

$$q = 8.3\ (1.0)(60)(Q)(\Delta T) \quad (1)$$

Where: q is heat recovered in the water stream in Btu/h
8.3 is the density of water in pounds per gallon
1.0 is the specific heat of water in Btu per pound per °F
60 is the conversion from minutes to hour
Q is the flow rate of water in gallons per minute
ΔT is the temperature differential of the water between the inlet and outlet of the filter

The standard heat exchanger effectiveness was calculated using Equation (2) below.

$$\varepsilon = \frac{C_w\left(T_{w,out} - T_{w,in}\right)}{C_{min}\left(T_{a,in} - T_{w,in}\right)} \quad (2)$$

Where: $C_w = \dot{m}_w C_{pw}$

m_w is the mass flow rate of the water
c_{pw} is the specific heat of water
$T_{w,out}$ is the temperature of the water out of the filter
$T_{w,in}$ is the temperature of the water into the filter
$T_{a,in}$ is the temperature of the air into the filter
$T_{w,in}$ is the temperature of the water into the filter
C_{min} is the smaller of the $\dot{m}_w C_{pw}$ and $\dot{m}_a C_{pa}$ magnitudes.

C_{min} is smaller on the water side with the water flow rate of 1.0 gpm and smaller on the air side with the water flow rate of 3.1 gpm and above.

The results of the testing are summarized in the Table 1.

Table 1: Energy Recovery Data Summary for One Appliance under a 5-foot Hood with Three Heat Recovery Filters

Appliance Input Rate [Btu/h]	Energy Rate to Filter Water Stream Overall [Btu/h]	HX Effectiveness	Water Flow Rate [GPM]	Water Inlet Temperature [°F]	Water Temperature Rise Overall [°F]	Airflow Rate [CFM]	Exhaust Temperature [°F]	Average Energy Rate to Filter Water Stream Per Filter [Btu/h]
66,295	8,636	0.45	1.0	71.1	16.7	1,428	105.4	2,879
66,261	12,523	0.21	3.1	69.6	8.2	1,420	103.1	4,174
66,260	13,225	0.22	3.9	69.0	6.8	1,428	102.5	4,408
34,045	6,902	0.18	3.7	68.8	3.7	1,464	88.6	2,301
105,712	17,735	0.19	3.8	68.4	9.5	1,463	117.8	5,912

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The range of heat exchanger effectiveness varied from 0.18 to 0.45. The standard heat exchanger effectiveness at the low water flow condition of 1.0 gpm was 0.45. The standard heat exchanger effectiveness at the average water flow 3.6 gpm was 0.20. The energy rate recovered as a fraction of the appliance input varied with flow rates and appliance input rates and ranged from 13% to 20% with an average of 18%.

For comparable water flow rates and appliance input rates, the second generation design performed at a 39% higher recovery rate and a 58% higher heat exchanger effectiveness than the original filter at 1.0 gpm and a 62% higher recovery rate and a 91% higher heat exchanger effectiveness than the original filter at 3.0 gpm [Ref: FSTC Report #501311121-R0].

To predict the impact that this heat recovery system could have on the water heating load in a commercial operating facility, a full service restaurant (FSR) using 2,500 gal per day was modeled using the test data and the following assumptions. The filter heat recovery system was installed in a kitchen hood with a heavy-duty appliance line consisting of three 3-foot gas underfired broilers. The input rating of each broiler was 96,000 Btu/h. The diversity of the appliance was taken to be 75%. The energy consumption (i.e., 72,000 Btu/h) would not vary during idle and cooking conditions. The operating hours were 12 hours per day, 363 days per year.

The model also assumed that a preheat tank was incorporated into the design of the water heating system and that a circulation pump flowed water through the heat exchanger at 3.0 gpm. This simplified model also assumed that the water in the preheat tank would be maintained at 94°F (i.e., an 8°F temperature rise for one broiler per Table 1, or a 24°F temperature rise for three broilers). Based on field monitoring experience, the water heating system efficiency of 65% for the FSR was selected.

The annual heat recovery from the filter system of was calculated to be 2,400 therms. The model predicted an annual water heater consumption of 8,700 therms. The 2,400 therms recovered by the filter system represents a 30% offset in the water heater natural gas consumption. With a 2,400 therm offset, the remaining gas load on the water heater was to be 6,300 therms. The natural gas savings for the water heater by the heat recovery filter system was estimated at 2,400 therms annually.

Manufacturer Specifications Sheet

Energy Recovery Filter

The energy recovery filter is designed for medium duty grease applications.

How it works:

- A portion of your incoming cold water is directed through a control panel which directs 2-3.5 gpm of water to the hood and the remaining water to your hot water heater.
- The water enters the hood and travels through the energy recovery filters which have heat exchangers built into them.
- As the hot exhaust air passes over the heat exchanger's coils, the water captures the waste heat from the airstream
- The pre-heated water exits the hood and is sent to the hot water heater.

U.S. Patent 8,728,189,82

Saves Energy

- As the water travels through the hood, it will be pre-heated by the exhaust airstream achieving a 25-40°F temperature rise.
- The preheated water is sent to the hot water heater where it requires less natural gas to heat the water up to the required operating temperature.
- Less natural gas required to heat incoming water equals lower monthly utility bills.

Saves Money

- The cooling temperatures at the filters condense more of the grease vapor.
- More grease removed by the filters reduces the grease accumulation in the duct and plenum which means fewer duct cleanings and expenses.

The energy recovery filter removes 88% of the grease particles at 8 microns

- UL 1046 Listed
- NSF Certified