The Ravina Project

Boiler Modification

Decreasing Carbon Footprint

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2021/10/10

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The Ravina Project - Goals

The Ravina Project consists of several projects all proceeding concurrently. If we were to rename our project today we probably would name it, “The Ravina Projects”.

Our project goals page allows our readers to understand the scope and depth of the various areas of inquiry focused totally on the household.

See the Project Goals page on our WEB site at:

www.theravinaproject.org/project_goals.htm

Boiler Modification

Abstract

A gas fired boiler system provides our domestic hot water (DHW) and home heating functions. When a hot water tap is opened anywhere in the house, the boiler fires up and provides hot water to the user. We noticed an anomaly in the boiler control logic. We modified it with an external device and found we dramatically decreased the amount of natural gas used for domestic hot water production. We present our data and conclude with a software modification suggestion to manufacturers which would, according to our data, reduce their product's carbon footprint.

Introduction

Our house uses a boiler system to produce hot water for the radiators in the wintertime and domestic hot water all year long. It functions as both a tankless hot water on demand system and furnace. In the non-heating part of the year when the home heating part of the boiler is not active, natural gas usage is limited to: cooking, clothes drying and domestic hot water (DHW) production. Cooking in the summer time is limited because our diet changes to hot weather fare and we use the microwave more frequently. We use the clothes dryer less and the clothes line more. Our DHW usage is slightly less than wintertime because our showers are cooler and shorter.

Over the years of usage we became quite familiar with the boiler's operational sequence logic from tap opening to the boiler shutdown. We noticed that there were instances where the boiler consumed natural gas for no reason; the gas is wasted.

This paper describes our external modification to the boiler's control logic.

We also present the data showing the change in our natural gas usage after the modification.

Boiler Control logic

Like most houses in urban areas our potable water comes piped in from our water utility. The water flow is split in three with one pipe connecting to all the cold water taps, the other connected to the cold side of the mixing valve and the third running through the tankless water heater's heat exchanger. The mixing valve mixes the cold and very hot water from the heat exchanger so that the resulting hot water from the taps will not scald users. When hot water is requested the heat exchanger heats the water flowing through it.

The boiler knows when hot water is required because a hot water tap is opened. A water flow sensor in the hot water pipe sends a signal to the boiler. The boiler goes through its start-up routine, firing up the heat exchanger until the heat exchanger reaches a preset temperature then it shuts down. Every time a hot water tap is opened the heat exchanger is warmed up to that temperature. This is a feature because the goal of a tankless hot water system is to provide hot water to the user as fast as a tanked system. Subsequent openings of a hot water tap will pull water through an already hot heat exchanger mimicking a tanked system. One can think of a busy family's morning routine with many hot water tap openings for basins, showers and baths. Only the first tap opening will result in a delay in the arrival of hot water.

The advantage of a tankless system centers upon the fact there is no energy used to keep a tank of hot water in a proper temperature range. A hot water on demand system reduces this extra gas usage to zero.

We modified the boiler control logic with the goal of further reduction in the boiler's already small carbon footprint.

As indicated above the boiler responds to a hot water tap opening by heating its heat exchanger to a preset temperature and then shutting down. It performs this operation at all times without exception. It is this operation we modified to reduce our carbon footprint.

We posed the question, “What happens when we open the hot water tap with no desire to use hot water but to just get water?” We kept track of the number to times, through habit, we opened a hot water tap. We found we did this many times during the day. But as noted above each time we opened a tap, gas was consumed to heat the heat exchanger in anticipation of another tap opening. We wanted to attack this excessive gas usage.

To sum up the control logic:

If a tap is opened and closed the heat exchanger will be energized until it reaches its cut off temperature.

If during this heat-up time another tap is opened the heat exchanger will continue to be energized until that tap is closed and the heat exchanger reaches its cut off temperature.

There are no other logical pathways available to the boiler.

Our modification to the control logic focuses on the occasional opening of a hot water tap that is not a demand for hot water yet the boiler powers the heat exchanger until cut off.

Control Logic Fix

It is important to note that gas boilers are complex computer controlled machines that burn natural gas at high temperatures. It is not recommended to modify their internal hardware, software or connections to both natural gas and water.

Our modification is external to the boiler. There is a water flow sensor which senses the water flow through the hot water piping when a hot water tap is opened. The sensor has two wires that connect it to the boiler’s main computer control. The computer monitors these wires for any change in the electrical resistance. When there is no flow the resistance is high. When there is flow the resistance drops in value. When the water flow terminates, the resistance of the wires becomes high again. The computer knows when there is demand for DHW and goes through the routines described above.

So far so good …

What modification did we make?

We placed a single pole switch in series with one of the flow sensor wires that connects to the boiler’s control computer.

When the switch is open the impedance of the wire will be high at all times resulting in the boiler not being aware of any hot water tap opening.

When the switch is closed, the boiler will be able to sense whether a tap is opened or closed and act accordingly.

The test setup is as follows. The switch is operated (opened and closed) using off-the-shelf hardware and an IPHONE application.

Think of the modification as an 'arming' switch. In the military many weapons have a separate arming switch that needs to be activated before the weapon can be fired using a different 'trigger' switch. This helps prevent accidental weapon firing. In our case we want to prevent accidental boiler fire up.

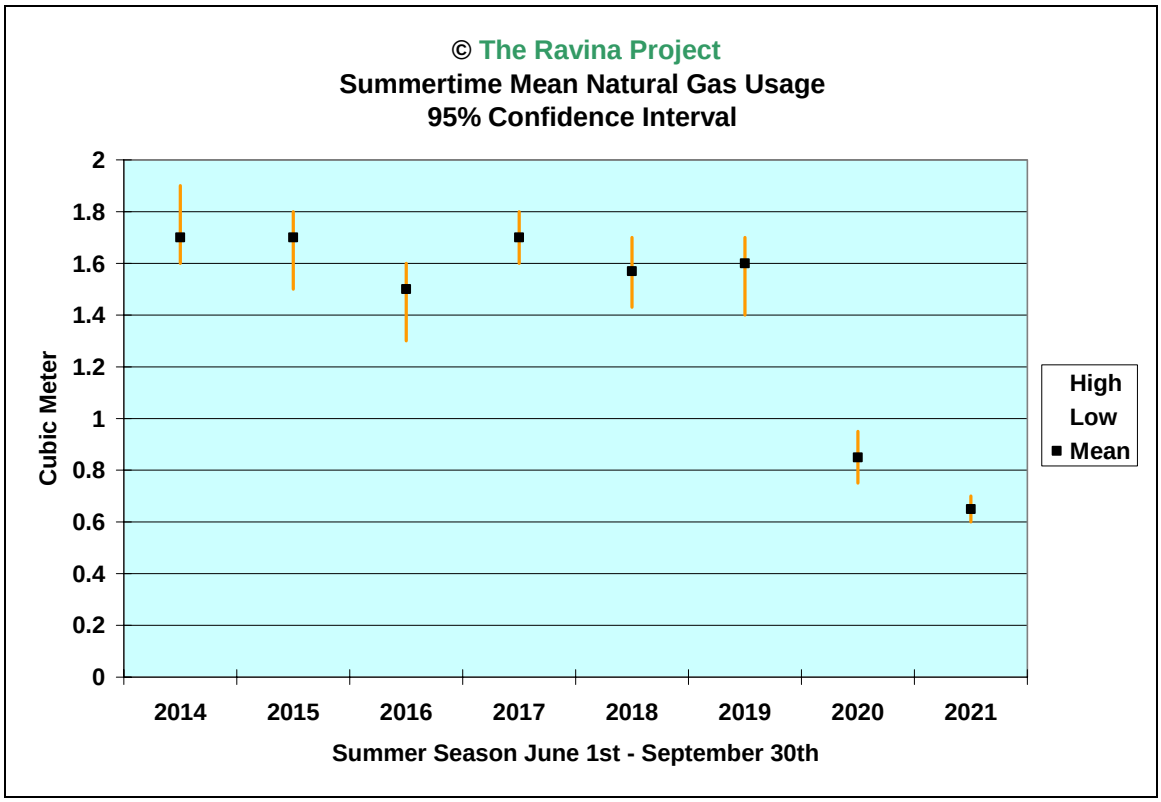
This modification has significantly changed the amount of natural gas used over the course of two summers as presented below.

Data Presentation

We have been recording our daily natural gas usage since January 1st, 2007. We have a robust high fidelity description of our natural gas usage over the course of many Summers. We use this data to demonstrate the changed gas usage when our modification is in place.

The cooling season starts here in Toronto on the 1st of June and ends on the 30th of September.

Consider the following chart:



The data represents Mean daily natural gas usage for the last eight Summers and the 95% confidence interval for each value. We have employed our modification for the past two Summer seasons. Note the last two seasons are outliers.

Conclusions and Manufacturer Recommendations

This modification to the operation of our boiler shows promise.

We believe that this modification could be incorporated into tankless water heaters to decrease their carbon footprint even if the tankless system is electrically powered. The carbon savings calculation would adopt the CO2e value of the energy supply. Here in Ontario we release about 40 gm of CO2 per kWh of energy used. However this value does not include the carbon-dioxide equivalent release of fugitive Methane from the natural gas distribution system.

Since I come from a software R&D background I gave a thought as to how such a modification could be implemented in software without any hardware modification. I assume that all boilers that provide DHW have a water flow sensor and software that reads it. In a hot water on demand system this is the most important and most scanned sensor. The boiler initializes into its monitoring state at power on.

The software routine that handles this sensor input may be changed to do the following:

1. When a tap is opened a software timer initializes but the boiler does not fire up the heat exchanger. The tap can be closed at any random time no matter the state of the timer. No energy is used. The timer reaches zero, resets and the boiler reverts to its monitoring state.

2. If a tap is opened starting the timer and the tap is closed but the timer has not completed its count down the boiler waits for one of two things to happen. (XOR)

    - The timer reaches the end of its count down and the boiler reverts to its monitoring state.
    - A second tap opening occurs while the timer is still in a countdown. The boiler fires up the heat exchanger and provides hot water until the tap is closed AND the heat exchanger reaches its shutdown temperature. The timer is reset as the boiler goes into its monitoring state.

So to boil it down (pun intended), two tap openings when the timer is actively counting down is the only condition that will provide hot water.

Our data shows that savings in DHW carbon footprint is possible by adopting this modification.

This is a marketable feature as the Public becomes more aware of the necessity to cut down our natural gas usage especially when fugitive Methane from the distribution system is considered.

Regarding the calculation of the amount of fugitive Methane from our natural gas distribution system see the paper, “*Howarth 2020”*.

New machines with new software could be shipped with this modification … part of a new ultra-efficient product line or enhancement.

"If we knew what we were doing, it would not be called research."
- A. Einstein

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Friends of the Ravina Project

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Designer of our sun altitude compensating, solar array structure