Emerging Technology Program

#1087: Hydronic Heat Transfer Enhancement Additive

Public Project Report

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Full Report

The following executive summary is made publicly available by Nicor Gas as part of their Emerging Technology Program (ETP). The detailed Nicor Gas ETP report is available to qualified state and utility run energy efficiency programs upon request. Please contact the Nicor Gas ETP administrator at NicorGasETP@gastechnology.org to find out how to access the full report.

Executive Summary

Introduction

The Nicor Gas 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 ETP is part of the ongoing Nicor Gas energySMART energy efficiency program and is delivered by Gas Technology Institute (GTI). This report summarizes the findings to evaluate a hot water boiler additive and its potential to provide energy efficiency savings to Nicor Gas residential, commercial, and industrial customers.

Background

The additive manufacturer submitted an application to the Nicor Gas Emerging Technology Program (ETP) for its chemical additive that claims to save up to 15% on boiler gas use in existing hydronic space heating systems. Such additives for heat transfer enhancement in hydronic systems appear to be relatively new offerings and are not established among any of the major chemical treatment providers for boiler based systems, either domestically or overseas. The manufacturer indicates their chemical additive yields various improvements in the properties of water that increase heat exchange effectiveness throughout the hydronic system and results in a decrease in gas use by the boiler.

Although the specific nature of these claimed performance enhancements seemed to have evolved over time, the company currently asserts that the additive changes the surface tension of water, which allows the fluid to access even minute cracks within the radiator and thus enhances the heat transfer efficiency.

Documentation provided by the manufacturer suggested independent testing under controlled conditions have confirmed that systems dosed with their additive require one less complete heating cycle over a 7-hour period, putting less strain on the boiler and a reduction in energy consumption of up to 15% when compared with water only systems.

This product is a relatively low cost additive with a usable life of six years. A 500ml bottle will typically be applied to a hydronic system with 12 radiators. The manufacturer states the additive is safe and a homeowner or building operator can apply the additive themselves.

Manufacturer-supported laboratory and field work to date on use of their additive with operating boilers show promising results but lacks sufficient, substantiating detail on which to normalize and evaluate the claims of energy savings. Field testing of this product presents the difficulty of normalizing variables, which would require a longer timeframe for statistically dampening out such effects. As a more time and cost efficient alternative, the Nicor Gas ETP conducted a targeted laboratory evaluation to quantify a before and after performance comparison of a hot water boiler coupled with a radiator/convector in a temperature controlled chamber. This testing aimed to establish any heat transfer improvements with the addition of the chemical additive product in the hot water loop.

Potential Savings from Tested Chemical Additive

Potential savings for the system comes multiple places:

1. Improved heat transfer of radiators and heat exchangers

   Per manufacturer claims, the additive changes the surface tension of water by breaking down hydrogen bonds so water can access micro-cracks within a hydronic system (radiator, boiler tube or heat exchanger) increasing thermal contact and improving heat transfer.

2. Lower return temperature to boiler

   Lower return temperature will cause the boiler to fire at higher loads for longer periods, reducing the number of firing cycles and associated cyclic losses, resulting in more efficient boiler operation. Lower return temperatures will allow condensing boilers to recover more latent heat.

3. Reduce boiler cycling and cycling losses

   The manufacturer reports that independent testing under controlled conditions showed reduced boiler cycling over a 7-hour period, which saves energy use by reducing cycling losses.

Test Results

The Nicor Gas ETP developed a test plan for the laboratory evaluation of the heat transfer enhancement additive to experimentally measure any increase in heat transfer or savings in energy use. The test setup simulated a residential boiler installation, including one hydronic radiator installed in a large environmentally-controlled test chamber. The heating load on the chamber was initially adjusted to maintain a 70°F average space temperature, then held constant for the duration of tests. The hydronic loop was instrumented to monitor flow rate and temperatures. Natural gas consumption of the boiler was also monitored.

Five test cases were conducted with both water only and additive-dosed solution at four radiator flow rates. Flow through the radiator was controlled by settings on the radiator valve, which ranged from #1 to #6. Tests were conducted at different flow rates ranging from maximum flow rate, 2.6 gpm (setting #6) to 0.6 gpm (setting #2½). Test case five measured temperature decay (zero flow rate) at the radiator, by recording the time required for the radiator temperature to decrease from 180°F to room temperature (approximately 70°F).

Tests were operated to obtain steady state conditions, i.e. temperatures, flow rates, and boiler firing rates were consistent for 15 minutes. Then a real-time data acquisition system recorded natural gas pressure flow rates, water flow rates, and water temperatures every five seconds during eight hours of steady state testing.

Test results did not indicate any measurable increase in the heat transfer at the hydronic radiator (Figure 1). Based on this data, the variability within each test case was greater than any difference in heat transfer between water only and the additive-dosed solution. However, the difference in all test cases was within the measurement accuracy. Measurement accuracy was deemed to be acceptable for energy savings greater than 4.3%. Also, no significant difference was found in measuring the temperature decay at the radiator inlet and outlet, at zero flow (Figure 2).

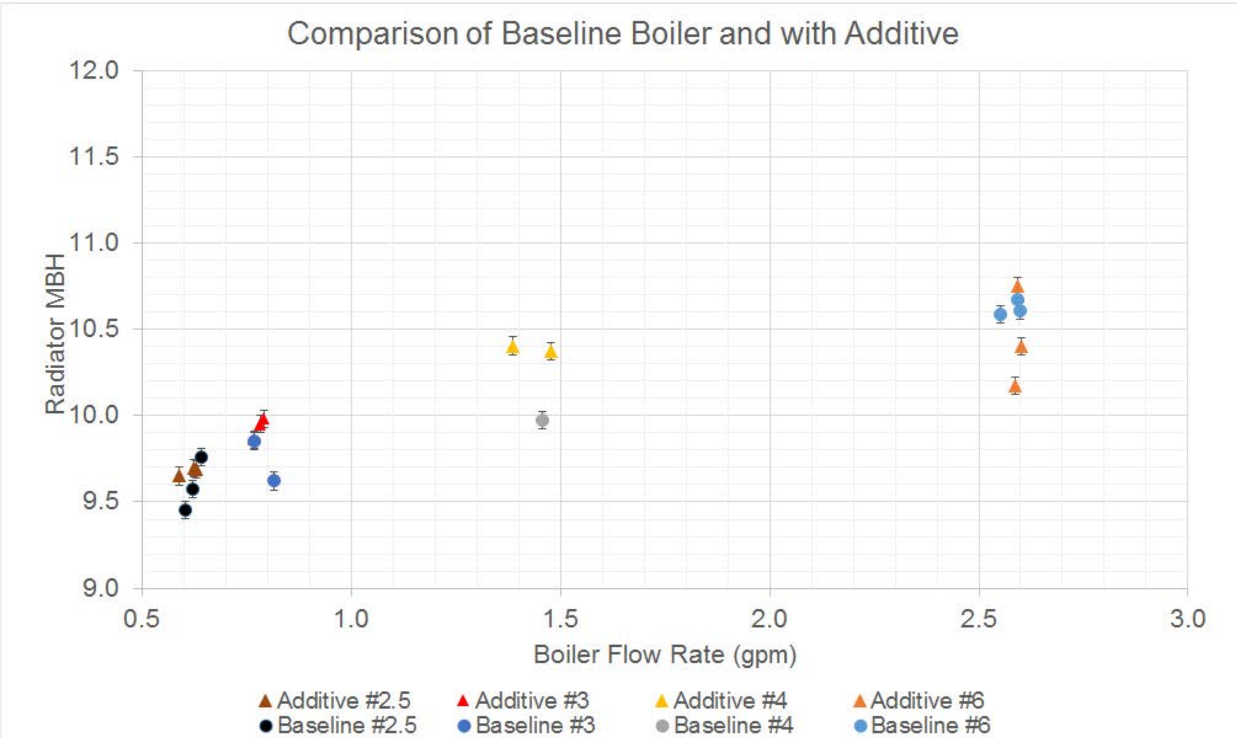


Figure 1: Radiator Output (MBH) Measured for All Test Cases

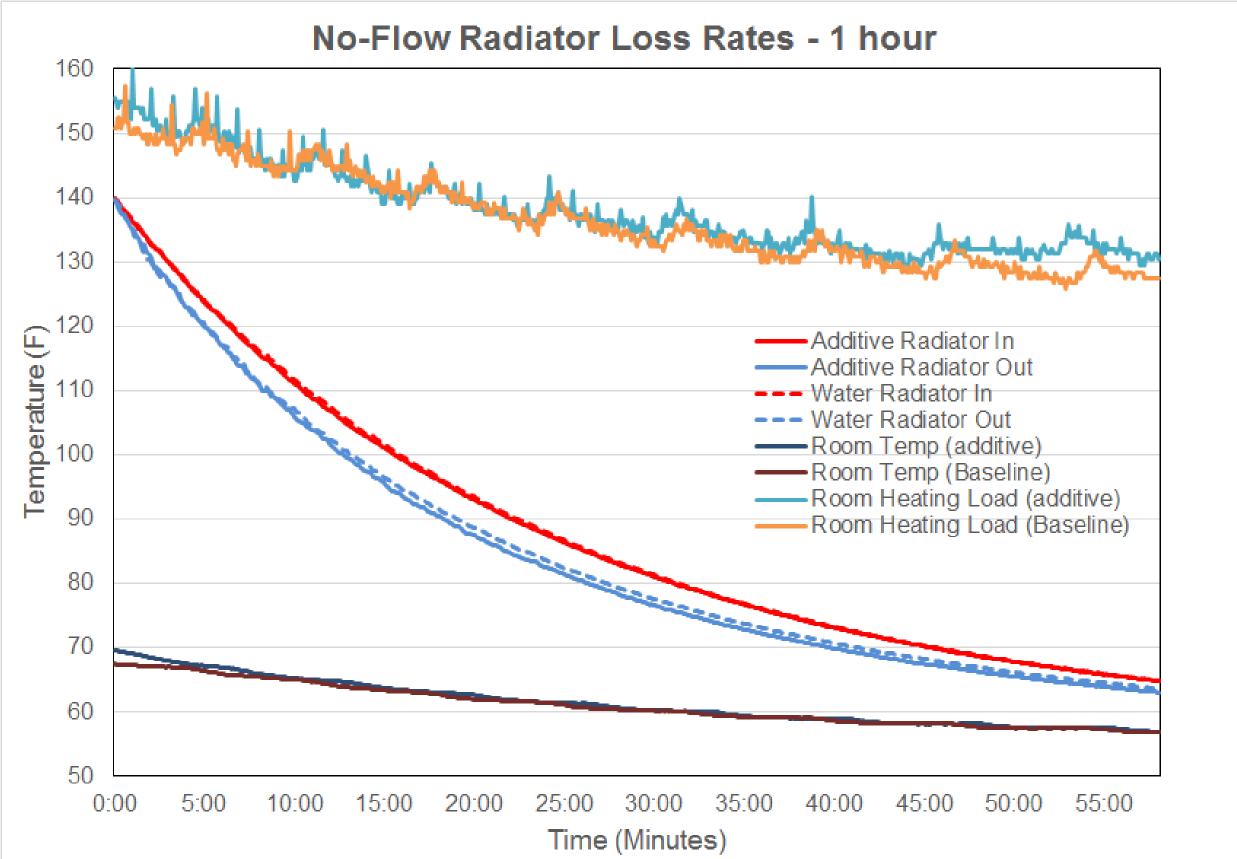


Figure 2: Temperature Decay with Additive Compared to Water at Zero Flow Rate

Table 1 shows that the boiler total efficiency increased by 3.2%, which is within the measurement accuracy range. Trial #4 with the additive at 1.4 GPM as shown in Figure 1 was omitted because of repeatability issues with keeping the radiator load constant.

Table 1: Boiler Efficiency Improvement

Max Radiator Setting (#6)	Baseline Average	Additive Average	Percentage Change
Boiler Total Efficiency	76%	78%	3.0%
Mid-Low Radiator Setting (#3)			
Boiler Total Efficiency	74%	76%	3.2%
Low Radiator Setting (#2.5)			
Boiler Total Efficiency	74%	75%	1.3%

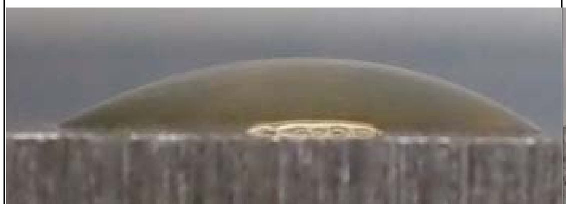
Table 2: Simple Payback for Additive based on Hypothetical Savings Scenarios

Climate Zone	Cost	Payback (years)			
		2.5% Energy Savings	5.0% Energy Savings	10.0% Energy Savings	15.0% Energy Savings
Rockford	$50	1.6	0.8	0.4	0.25
Chicago	$50	1.65	0.85	0.8	0.3

Analytical Methods

The Nicor Gas ETP compared measurements of the contact angle of the additive-dosed solution to tap water to further investigate the potential basis for heat transfer enhancement claims associated with a chemical additive to reduce surface tension, i.e., greater "wetting" potential. The goal of this test was to measure the magnitude of the change in contact angle so as to indicate a change in surface tension resulting from the use of the chemical additive. It was clear that the drops containing the additive sat lower with lower contact angles compared to tap water (Table 3). For cold steel the average contact angle with tap water was 52^{o}, while the contact angle was only 19^{o} for the drop containing the additive-dosed solution. Similar results were obtained with cast iron; the tap water had a contact angle of 43^{o} while the drop containing the additive-dosed solution had a contact angle of only 22^{o}.

Table 3. Contact Angle Test Results

Tap Water on Cast Iron	**1% Additive- in Tap Water on Cast Iron**
Contact Angle: 43 degrees ± 7	Contact Angle: 22 degrees ± 3
	

Discussion

From these test results, the improvement in boiler efficiency was within the margin of error based on the conditions of the test setup. There were no measurable improvements in heat transfer at the radiator under these conditions.

Heat transfer improvements may be less than the measurement accuracy or scattered in repeating test conditions. Several factors can influence boiler efficiency, including part-load and cycling. According to the manufacturer, reductions in cycling is one of the key mechanisms for this product to reduce gas use.

Due to the constraints of the laboratory test setup, this boiler operated at 20-30% its rated capacity of (159 MBH). In addition, there were multiple test conditions which influenced boiler operation, such as the heat exchanger flow rate, coolant temperature, etc.

As a result, improvements in boiler cycling and efficiency may not apply directly to a typical boiler installation, but may indicate potential gas savings with the additive to warrant further investigation.

As another consideration, a mechanical aerator was used in the hydronic test loop as is standard practice in hydronic system design. During preliminary testing, as much air as possible was removed from the hydronic system. This may have impacted the effectiveness for the additive.

Implications for Nicor Gas Energy Efficiency Programs

If gas savings from use of this additive in boilers could be confirmed, this product offers a potential low cost and simple measure to implement in an energy efficiency program, as a direct install measure and/or point of sale rebate. This new measure could also compliment the installation of a high AFUE hot water boiler used for space heating. The additive can be applied to residential markets as well as small commercial markets, which is an underserved sector from an energy efficiency program standpoint. Since this is a simple retrofit technology, there is significant potential in the existing building inventory with hydronic heating systems.

Recommendations for Further Study

The Nicor Gas ETP recommends a limited field testing effort to further explore the potential energy savings of this additive. The lack of conclusive results in our laboratory tests may be due to singularities of the test setup, low part-load boiler operation, or the impact of a mechanical air separator. The growing number of case studies, ease of implementation, potential cost effectiveness, and suitability for retrofit applications may warrant further investigation in actual installations.